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Vegetation outlines of two active rock glaciers with contrasting lithology

D. Tampucci[1], G. Boffa[1], F. Mangili[1], M. Gobbi[2], M. Caccianiga[1]
[1]*Department of Biosciences, University of Milano, Via Celoria 26, I-20133 Milano, Italy.*
[2]*Department of Invertebrate Zoology and Hydrobiology, MUSE - Museo delle Scienze, Corso del Lavoro e della Scienza 3, I-38123 Trento, Italy.*

Abstract
Rock glaciers are periglacial landforms consisting of coarse debris with interstitial ice or ice core, characterized by creeping due to ice deformation. These landforms are drawing the attention of plant ecologist as harsh habitats and potential refugia in the global change context. Our aim was to describe the vegetation outlines of two active rock glaciers of the Ortles-Cevedale Massif (Central Italian Alps) on different substrates (silicate and carbonate) and compare them with the neighboring stable slopes and scree slopes. Two hypotheses were tested: 1) rock glaciers differ from the surrounding landforms for the presence of cold-adapted plant communities; 2) rock glacier plant communities indicate similar microclimatic conditions in spite of the contrasting lithology. Data were collected by phytosociological method performing 80 relevés of 25 m². Plant communities were compared by a cluster analysis based on the presence/absence species matrix and species relative frequencies for each landform were calculated. The cluster analysis separated first for all the two sites; afterwards, the landforms were differently discerned each other depending on the site. Despite the remarkable floristic differences due to the substrate, the vegetation of both rock glaciers suggest a general adjustment to cold-moist microclimate and long-lasting snow cover, differentiating more or less evidently from the adjacent scree slopes and enhancing the survival of nival entities at the elevation of alpine grasslands.

Key words: alpine flora, alpine vegetation, climate change, periglacial, permafrost, refugia, scree slope.

Introduction

Rock glaciers are periglacial landforms consisting of coarse debris with interstitial ice or ice core, characterized by creeping due to ice deformation (Barsch, 1996; Janke *et al*., 2013). These landforms are one of the most evident expressions of permafrost in mountain regions. They are theoretically located between the lower permafrost limit and the equilibrium line of the glaciers, an altitudinal belt well expressed in cold and dry climates that tends to shrink in response to temperature and precipitations increase (Barsch, 1996; Haeberli, 1985). Consequently, rock glaciers gravitate towards continental ranges like the inner Alps, even though the relative contribution of debris and snow at topoclimatic scale seems to have a major role in driving their distribution rather than regional climate itself (Humlum, 1998). Ice deformation gives rock glaciers a creep movement similar to that of glaciers but slower (generally less than 1 m/y). There are three types of rock glaciers depending on dynamic and ice presence: active (with ice and creeping, located in contexts compatible with permafrost); inactive (with ice, but static for climatic or geomorphological reasons); relict (iceless and static, found in conditions no more compatible with permafrost and linked to past climate conditions) (Barsch, 1996; Haeberli, 1985).

In the last decade, rock glaciers have drawn the attention of ecologists and botanists. Indeed, these landforms host communities adapted to harsh ecological conditions and are supposed to assume a biogeographical role in relation with climatic variations. In the matter of that, rock glaciers were proposed as potential refugia for high alpine plants and animals during the warm stages of the Holocene, as consequence of their microclimate and thermal inertia (Gentili *et al*., 2015; Gobbi *et al*., 2014; Millar & Westfall, 2010; Millar *et al*., 2013), a role similar to that already hypothesized for debris-covered glaciers (Caccianiga *et al*., 2011; Gentili *et al*., 2015; Gobbi *et al*., 2011).

Previous knowledge about the vegetation of alpine rock glaciers come from the studies of Cannone & Gerdol (2003) in the area of Livigno-Bormiese (Central Italian Alps) and Burga *et al*. (2004) in the area of Piz Corvatsch (Switzerland). These authors reported pioneer communities generally attributable to the order *Androsacetalia alpinae* (associations *Sieversio-Oxyrietum digynae* and *Androsacetum alpinae* following Burga *et al*., 2004), with plants adapted to mechanical disturbance also recurring on scree slopes, glacier forelands and recent moraines. Vegetation cover and floristic composition depend mainly on substrate particle-size and movement intensity. Active rock glaciers are almost unvegetated, with sporadic glareicolous plants concentrated overall in the peripheral zones, where the surface movement is slower

Corresponding author: Duccio Tampucci. *Department of Biosciences, University of Milano, Via Celoria 26, I-20133 Milano, Italy*; *e-mail: duccio.tampucci@unimi.it*

and fine-grained material is available. Instead, inactive and relict rock glaciers tend to be colonized by the typical species of alpine grasslands and snow-patches communities, or even by subalpine shrubs and trees at lower elevations. Rieg *et al.* (2012), analyzing four active rock glaciers in Stubai and Ötztal Alps (Tyrol, Austria), found a threshold of 1,5 m/y for surface velocity: below this value plants cover depends on fine-grain availability, while over that limit the vegetation is heavily affected by ground instability. Coherently, Gobbi *et al.* (2014) identify grain-size as main driver of species distribution, highlighting the correlation with organic matter availability. In the same paper, the thermal regime of rock glacier was analyzed and evaluated as further limiting factor in plant colonization.

However, the vegetation features of alpine rock glaciers deserve further researches, since the few available studies concern only silicate substrates and the comparison with other high alpine landforms were not always in-depth analyzed. Our aim was to describe the vegetation of two active rock glaciers on different substrates (silicate and carbonate) and compare them with the neighboring stable slopes and scree slopes. Two hypothesis were tested: 1) rock glaciers differ from the surrounding landforms for the presence of cold-adapted plant communities; 2) rock glacier plant communities indicate similar microclimatic conditions in spite of the contrasting lithology.

Study area

The analyzed rock glaciers are located in two valleys belonging to the Ortles-Cevedale Massif (II/C-28.I-A in Marazzi, 2005), within the area of Stelvio National Park (Italy): Val d'Ultimo and Valle del Braulio. The sites are less than 32 km apart and no geographical barriers occurs between them, so they can be considered part of the same floristic context (Northeastern Alps subsection in Blasi *et al.*, 2015).

Val d'Ultimo (South Tyrol) is a NE-SW oriented valley extended from the basin of Merano to the Giogo Nero pass. The examined rock glacier ("Lago Lungo"; 46° 27.435' N, 10° 48.985' E) (fig. 1a) is located in the Group of Gioveretto-Sternai (II/C-28.I-A.3.c in Marazzi, 2005). It is a multilobe tongue-shaped rock glacier fed by acid silicate debris (micaschist and ortogneiss of "Unità di Pejo") that leans against a NW-facing slope between 2350 and 2550 m a.s.l. The surrounding areas are characterized by widespread and well-expressed periglacial landforms, while the glacial masses are few and small. (Artoni, 1992; Martin *et al.*, 2009; Seppi *et al.*, 2005).

Valle del Braulio (Lombardy) is a SW-NE oriented valley extended from the basin of Bormio to the Stelvio Pass. The examined rock glacier ("Vedrettino"; 46° 30.025' N, 10° 24.050' E) (fig. 1b) is located in the Group of Cristallo (II/C-28.I-A.1.a in Marazzi, 2005). It is a multilobe tongue-shaped rock glacier fed by carbonate debris (dolomite limestones of "Dolomia Principale") that lies in a NW-facing glacial cirque, between 2500 and 2650 m a.s.l. The site is surrounded by imposing talus and until the first decades of 20th century was occupied by the namesake glacier, now reduced to a little mass of dead-ice completely debris-covered (Artoni, 1992; Bonardi *et al.*, 2012; Montrasio *et al.*, 2012).

Since the examined landforms stand at comparable elevation with similar values of aspect and slope, the main ecological difference between them lies in the bedrock. Temperatures and precipitations within the period 1983-2012 were analyzed using the records provided by Meteo Service of the Province of Bolzano for Val d'Ultimo (station of Fontana Bianca, 1900 m a.s.l.) (fig. 2a) and ARPA Lombardia for Valle del Braulio (station of Bormio, 1225 m a.s.l.) (fig. 2b). Calculating the Rivas-Martinez Index of thermal continentality (Rivas-Martínez & Rivas-Saenz, 1996-2009) and the Gams Index of hygric continentality (Ozenda, 1985), both areas results characterized by the typical continental climate of the inner Alps (respectively: 27,37 and 60,96° for Val d'Ultimo and 25,41 and 58,00° for Valle del Braulio).

Methods

Data were collected between July and August 2014. 80 vegetation relevés were performed by phytosociological method with the Braun-Blanquet scale as modified by Pignatti (1952) on three landforms for each area: stable slope (soil without ice), scree slope (debris without ice) and rock glacier (debris with ice). All the relevés were performed on 25 m^2 surfaces. Such value allows a homogeneous and representative sampling of the main object of our research, glareicolous vegetation of rock glaciers and scree slopes. On alpine grasslands, the micro-topographic pattern causes floristic variability at small (few centimeters) scale. Such variability, intrinsic of these communities, could be overlooked by our sampling strategy: for this reason, we performed a high-rank phytosociological outline of these communities. Relevés were compared by a cluster analysis based on the presence/absence species matrix, using the UPGMA method with Jaccard dissimilarity index. The conventional dissimilarity value of 0,75 was assumed as lower threshold for the admission of an association, according to Mueller-Dombois & Ellenberg (1974). Species relative frequencies for each landform, regardless the clustering, were calculated and gathered in 5 frequency classes with resolution of 20%. We also compared our data with that collected in the previous studies (Burga *et al.*, 2004; Cannone & Gerdol, 2003; Gobbi *et al.*, 2014; Rieg *et al.*, 2012).

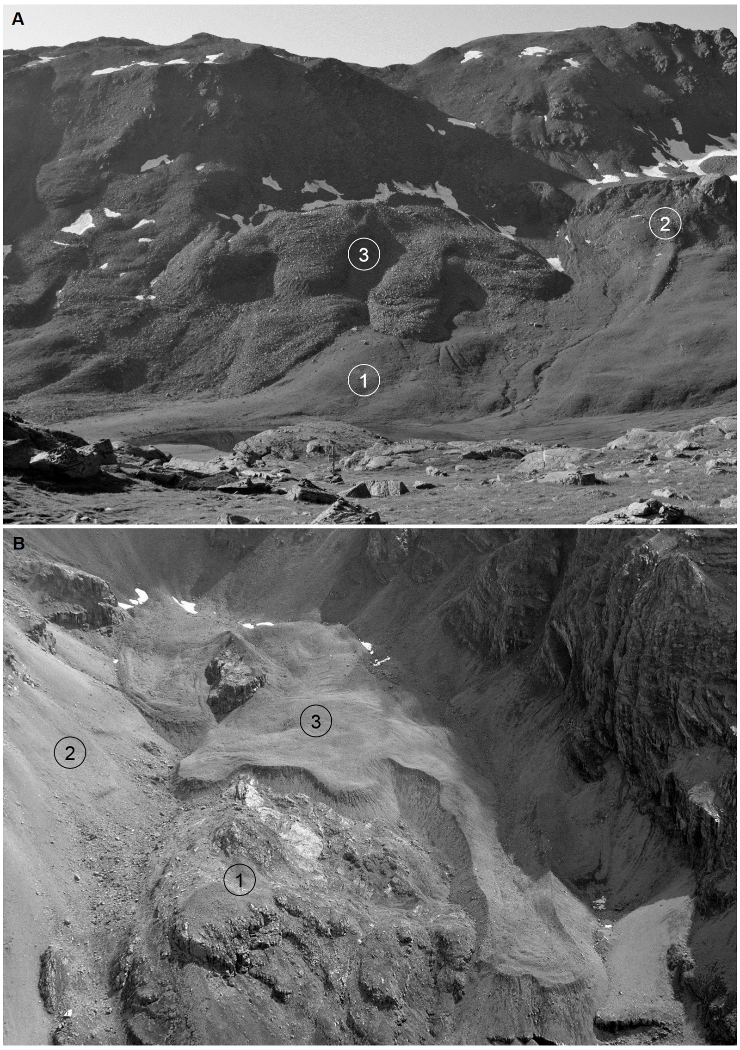

Fig. 1 - Rock glaciers “Lago Lungo” in Val d’Ultimo (A) and “Vedrettino” in Valle del Braulio (B). The landforms are indicated as follows: 1) stable slope, 2) scree slope, 3) rock glacier.

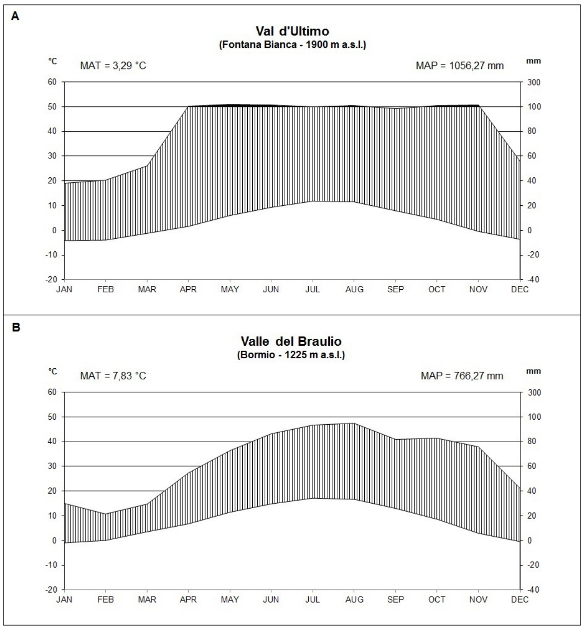

Fig. 2 - Climograms of Fontana Bianca for Val d’Ultimo (A) and Bormio for Valle del Braulio (B).

The nomenclature follows Landolt *et al*. (2010) for species and Grabherr & Mucina (1993) for syntaxa. The phytosociological interpretation generally agrees with Grabherr & Mucina (1993) and Oberdorfer (1977), adjusted for some local peculiarities following Giacomini & Pignatti (1955).

Results

We identified 118 vascular plant species in total. 71 plant species were found both in Val d’Ultimo and Valle del Braulio (47 mutually exclusive and 24 shared). It was possible to describe five clusters with dissimilarity index > 0,75 (fig. 3). The main dichotomy detected by cluster analysis was the one between the two investigated sites, afterwards the landforms were differently discerned each other depending on the site. Concerning Val d’Ultimo, the dendrogram separated at first the stable slope from the remaining landforms, but inside the latter group another partition between rock glacier and scree slope was well recognizable. Concerning Valle del Braulio, the cluster analysis distinguished only stable slopes, without a clear split between rock glacier

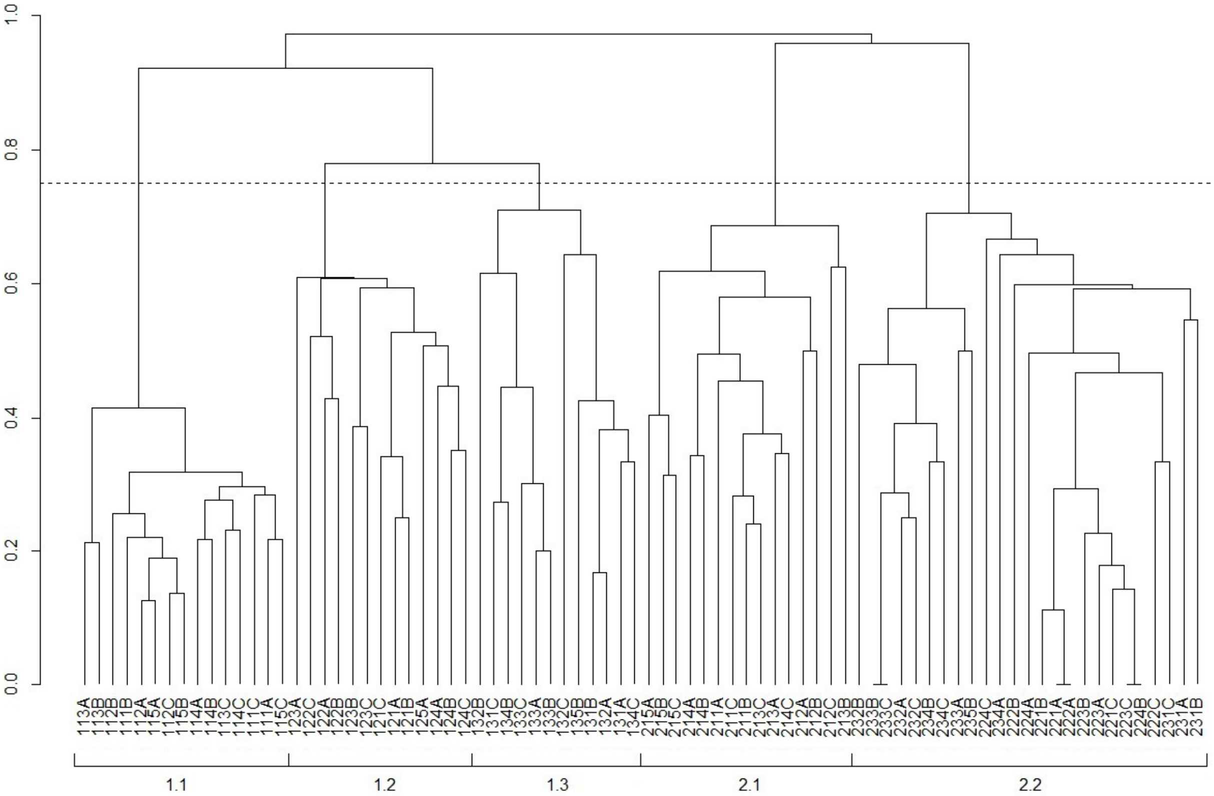

Fig. 3 - Dendrogram resulting from the cluster analysis of relevés. The dotted line indicates the dissimilarity value of 0,75.

and scree slope. Data are reported in the analytic table (tab. 1) and the synoptic table (tab. 2).

Cluster 1.1: stable slope on silicate substrate

The stable slope of Val d'Ultimo (fig. 4) is a seamless patchwork of humps and hollows covered by a continuous alpine grassland. *Carex curvula* and A*nthoxanthum alpinum* dominate the community, with a scarce shrubby layer of *Loiseleuria procumbens*, *Vaccinium gaultherioides* and *Rhododendron ferrugineum*. Locally, canopy overlapping may be quite high and species like *Potentilla aurea*, *Leontodon helveticus*, *Ligusticum mutellina*, *Homogyne alpina* and *Soldanella alpicola* can reach remarkable cover values. The micro-topographic pattern at centimeter scale allows the coexistence of hummock species (e.g. *Loiseleuria procumbens* and *Vaccinium gaultherioides*) and snowbed elements (e.g. *Primula glutinosa* and *Gnaphalium supinum*). Such situation made difficult a phytosociological outline at the association level, but the community could be ascribed to the alliance *Caricion curvulae* Br.-Bl. in Br.-Bl. et Jenny 1926.

Fig. 4 - *Caricion curvulae* on the stable slope of Val d'Ultimo (cluster 1.1).

Cluster 1.2: scree slope on silicate substrate

The scree slope of Val d'Ultimo (fig. 5) includes a wide range of particle size and hosts a scattered glareicolous vegetation rather rich in species. Among the preferential elements, *Geum reptans*, *Oxyria digyna*, *Saxifraga seguieri*, *Saxifraga oppositifolia*, *Silene acaulis* and *Pritzelago brevicaulis* are the most frequent. *Luzula alpino-pilosa*, *Poa laxa*, *Saxifraga bryoides* and *Cerastium uniflorum* are likewise widespread and abundant, but all shared with the cluster 1.3. Species assemblage is ascribable to the association *Sieversio-Oxyrietum digynae* Friedel 1956 em. Englisch *et al*. 1993 for the dominance and constancy of *Geum reptans* and *Oxyria dygina*. Some element of

Fig. 5 - *Sieversio-Oxyrietum digynae* with *Geum reptans* and *Oxyria digyna* on the scree slope of Val d'Ultimo (cluster 1.2).

Salicetea herbaceae Br.-Bl. in Br.-Bl. et Jenny 1926 like *Soldanella alpicola*, *Sedum alpestre* and *Veronica alpina* are also present where fine-grained material is available.

Cluster 1.3: rock glacier on silicate substrate

On the rock glacier of Val d'Ultimo (fig. 6) vegetation changes notably depending on geomorphological situation, with few species occurring with high frequency: *Luzula alpino-pilosa*, *Poa laxa*, *Saxifraga bryoides*, *Cerastium uniflorum* and *Doronicum clusii*. Plant cover on the surface is mainly represented by sporadic individuals growing among coarse boulders, or patches of herbaceous vegetation on pockets of fine-grained substrate (relevés 131A, 131B, 131C, 132A, 132C, 134B, 134C, 135B). On the slopes and the edges, the vegetation is more rich and dense, probably in response to higher stability and presence of fine-grained material. In these zones, the above mentioned assemblage includes some typical element of the stable environments, as *Carex curvula*, *Agrostis rupestris*, *Festuca halleri*, *Campanula scheuchzeri*, *Senecio carniolicus* and *Erigeron uniflorus*, locally accompanied by *Rhododendron ferrugineum* and *Salix serpyllifolia* (relevés 132B, 133A, 133B, 133C). The community is roughly attributable to the alliance *Androsacion alpinae* Br.-Bl. in Br.-Bl. et Jenny 1926, with low frequency of species belonging to *Caricetea curvulae* Br.-Bl. 1948 and *Salicetea herbaceae* Br.-Bl. in Br.-Bl. et Jenny 1926, while the characteristic elements of *Sieversio-Oxyrietum digynae* are totally absent.

Fig. 6 - Community with *Luzula-alpino pilosa* and *Doronicum clusii* on the rock glacier of Val d'Ultimo (cluster 1.3).

Cluster 2.1: stable slope on carbonate substrate

The stable slope of Valle del Braulio (fig. 7) is colonized by a fragmented alpine grassland alternated with outcrops and debris, locally interrupted by ample hollows. The community is dominated by *Carex firma*, *Sesleria caerulea* and *Dryas octopetala*, with a conspicuous group of low-covering exclusive species: *Saxifraga caesia*, *Agrostis alpina*, *Carex ornithopoda*, *Minuartia verna*, *Helianthemum alpestre*, *Anthyllis vulneraria*, *Draba aizoides*, *Sedum atratum*, *Polygonum viviparum*, *Aster bellidiastrum*, *Bartsia alpina*, ecc. Such plant assemblage is ascribable to the alliance *Caricion firmae* Gams 1936 (relevés 211A, 211B, 212A, 212B, 212C, 213A, 213B, 213C). In the depressions, the above mentioned species sharply decrease and are replaced by high cover of *Silene acaulis*, *Ranunculus alpestris* and *Soldanella alpina*, with *Gnaphalium hoppeanum* and other sporadic species of *Arabidion caeruleae* Br.-Bl. in Br.-Bl. et Jenny 1926 (relevés 214A, 214B, 215A, 215B, 215C and to a lesser extent 211C, 214C).

Fig. 7 - *Caricion firmae* on the stable slope of Valle del Braulio (cluster 2.1).

Cluster 2.2: scree slope and rock glacier on carbonate substrate

On the unstable substrates of Valle del Braulio, plant cover is scarce or absent, with isolated individuals even where fine-grained material is available. Even though two clusters are recognizable, their dissimilarity index is < 0,75 and the lack of a clear distinction between scree slope and rock glacier brings us to attribute the whole community to the same association: *Papaveretum rhaetici* Wikus 1959. The two landform are joined by the constant presence of *Poa minor*, *Arabis alpina* and *Arabis pumila*, but the relative frequency of other species shows some difference. The scree slope (fig. 8) is colonized by a well-expressed *Papaveretum rhaetici*, where *Papaver aurantiacum*, *Saxifraga aphylla*, *Pritzelago alpina* and *Moehringia ciliata* are widespread (relevés 221A, 221B, 221C, 222A, 222B, 222C, 223A, 223B, 223C, 224A, 224B, 224C). The rock glacier (fig. 9) shows a lower frequency and abundance of these elements and is better characterized by the exclusive coexistence of *Arabis caerulea* and *Saxifraga oppositifolia*, both rare on stable slope and scree slope respectively (relevés 232A, 232B, 232C, 233A, 233B, 233C, 234B, 234C, 235B). Species richness reaches the highest values on the peripheral zones of the rock glacier, where the elements of both aspects equally coexist (relevés 231A, 231B, 231C and to a lesser extent 234A).

Fig. 8 - *Papaveretum rhaetici* with *Papaver aurantiacum* and *Saxifraga aphylla* on the scree slope of Valle del Braulio (cluster 2.2).

Fig. 9 - *Papaveretum rhaetici* with *Arabis caerulea* and *Saxifraga oppositifolia* on the rock glacier of Valle del Braulio (cluster 2.2).

Discussion

The nature of the bedrock appears to be the main factor influencing floristic composition of the studied landforms. Cluster analysis clearly grouped relevés as a function of the study site rather than of the different landforms. Being our study sites very close to each other, without geographical barrier between them and located at similar elevation, aspect and slope, the different floristic composition can be attributed to the different substrate. The landforms could be discriminated only within each site, with stable slopes always clearly different from scree slopes and rock glaciers.

Particularly interesting is the comparison between scree slopes and rock glaciers, environments similar to each other but except for the occurrence of ice. In Val d'Ultimo the difference between these two landforms emerges at the community level, with *Sieversio-Oxyrietum digynae* on the scree slope and an *Androsacion alpinae* community on the rock glacier. The latter looks like a transition toward the association *Luzuletum spadiceae* Rübel 1911 (class *Salicetea herbaceae*) for the dominance of *Luzula alpino-pilosa* and the elective presence of *Doronicum clusii*, even though the scarcity of characteristic species of the class make this collocation uncertain. *Luzuletum spadiceae* is strictly linked to silicate coarse substrates at high elevation, and is considered as an indicator of low temperatures during the whole year and snow permanence up to 8-9 months (Giacomini & Pignatti, 1955; Grabherr & Mucina, 1993; Oberdorfer, 1977). In summary, the community detected on the rock glacier could be interpreted either as an *Androsacion alpinae* conditioned by cold-moist microclimate and long-lasting snow cover or as a species-poor aspect of *Luzuletum spadiceae* where the elements of *Salicetea herbaceae* are limited by the unavailability of fine-grained substrate. However, both cases implicate the crucial role of microclimate in determining this plant assemblage. This result contrasts with the previous studies on silicate rock glaciers (Burga *et al*., 2004; Cannone & Gerdol, 2003; Gobbi *et al*., 2014; Rieg *et al*., 2012), where the high frequencies of *Oxyria digyna* and *Geum reptans* and the lack of *Luzula alpino-pilosa* and *Doronicum clusii* allow the attribution of the vegetation cover to *Oxyrietum digynae*. A better knowledge of the whole vegetation contest of these rock glaciers, including the surrounding landforms, is necessary for an ecological interpretation of such difference.

Concerning Valle del Braulio, the communities of scree slope and rock glacier are very similar and both attributable to *Papaveretum rhaetici*, but some floristic difference emerges analyzing the distribution of single species. Particularly interesting is the exclusive coexistence of *Arabis caerulea* and *Saxifraga oppositifolia* on the rock glacier, a plant assemblage to our

Tab. 2 - Synoptic table of mean relevés values and species frequency classes for each landform (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%).

Val d'Ultimo	**Stable slope**	**Scree slope**	**Rock glacier**	**Valle del Braulio**	**Stable slope**	**Scree slope**	**Rock glacier**
Shrubs cover (%)	**11**	**0**	**3**	**Shrubs cover (%)**	**1**	**0**	**0**
Herbaceous cover (%)	**70**	**15**	**15**	**Herbaceous cover (%)**	**65**	**5**	**2**
Bryophytes and lichens cover (%)	**12**	**4**	**4**	**Bryophytes and lichens cover (%)**	**6**	**0**	**0**
Outcrop cover (%)	**16**	**4**	**0**	**Outcrop cover (%)**	**7**	**4**	**0**
Debris cover (%)	**0**	**77**	**76**	**Debris cover (%)**	**18**	**91**	**98**
Soil cover (%)	**0**	**0**	**2**	**Soil cover (%)**	**7**	**0**	**0**
Species richness	**23**	**17**	**10**	**Species richness**	**23**	**7**	**8**
Loiseleuria procumbens	**V**			***Agrostis alpina***	**V**		
Potentilla aurea	**V**			***Carex firma***	**V**		
Primula glutinosa	**V**			***Dryas octopetala***	**V**		
Vaccinium gaultherioides	**V**			***Polygonum viviparum***	**V**		
Helictotrichon versicolor	**IV**			***Sedum atratum***	**V**		
Geum montanum	**II**			***Bartsia alpina***	**IV**		
Hieracium glanduliferum	**II**			***Minuartia verna***	**IV**		
Huperzia selago	**II**			***Sesleria caerulea***	**IV**		
Nardus stricta	**II**			***Anthyllis vulneraria***	**III**		
Alchemilla vulgaris aggr.	**I**			***Carex ornithopoda***	**III**		
Bartsia alpina	**I**			***Draba aizoides***	**III**		
Calluna vulgaris	**I**			***Helianthemum alpestre***	**III**		
Cirsium spinosissimum	**I**			***Carex parviflora***	**II**		
Diphasiastrum alpinum	**I**			***Gentiana verna***	**II**		
Juniperus nana	**I**			***Leontodon helveticus***	**II**		
Larix decidua	**I**			***Myosotis alpestris***	**II**		
Luzula lutea	**I**			***Pinguicula alpina***	**II**		
Pinguicula leptoceras	**I**			***Salix herbacea***	**II**		
Selaginella selaginoides	**I**			***Salix reticulata***	**II**		
Sibbaldia procumbens	**I**			***Selaginella selaginoides***	**II**		
Pedicularis kerneri	**I**	**II**		***Silene acaulis***	**II**		
Gnaphalium supinum	**IV**	**II**		***Valeriana saxatilis***	**II**		
Poa alpina	**V**	**II**		***Arenaria biflora***	**I**		
Polygonum viviparum	**V**	**II**		***Crepis kerneri***	**I**		
Ligusticum mutellina	**V**	**I**		***Cystopteris fragilis***	**I**		
Oreochloa disticha	**I**	**I**		***Daphne striata***	**I**		
Silene exscapa	**I**	**V**		***Euphrasia minima***	**I**		
Geum reptans		**V**		***Gentiana bavarica***	**I**		
Oxyria digyna		**V**		***Gentiana engadinensis***	**I**		
Saxifraga oppositifolia		**IV**		***Globularia cordifolia***	**I**		
Saxifraga seguieri		**IV**		***Hieracium bifidum***	**I**		
Pritzelago brevicaulis		**III**		***Hieracium villosum***	**I**		
Arabis alpina		**II**		***Juniperus nana***	**I**		
Artemisia genipi		**II**		***Larix decidua***	**I**		
Ranunculus glacialis		**II**		***Ligusticum mutellina***	**I**		
Taraxacum alpinum s. l.		**II**		***Poa alpina***	**I**		
Androsace alpina		**I**		***Potentilla brauneana***	**I**		
Cryptogramma crispa		**I**		***Saxifraga hostii***	**I**		
Linaria alpina		**I**		***Vaccinium gaultherioides***	**I**		
Saxifraga androsacea		**I**		***Veronica aphylla***	**I**		
Saxifraga paniculata		**I**		***Asplenium viride***	**III**	**I**	
Saxifraga bryoides		**V**	**V**	***Homogyne alpina***	**III**	**I**	
Cerastium uniflorum		**V**	**IV**	***Aster bellidiastrum***	**IV**	**I**	
Poa laxa		**IV**	**V**	***Cerastium latifolium***		**I**	
Doronicum clusii		**II**	**V**	***Festuca quadriflora***		**I**	
Saxifraga exarata		**II**	**II**	***Salix retusa***		**I**	
Myosotis alpestris		**II**	**I**	***Saxifraga aizoides***		**I**	
Cystopteris fragilis		**II**	**I**	***Cerastium uniflorum***		**III**	**II**
Lloydia serotina		**I**	**I**	***Saxifraga aphylla***		**V**	**I**
Sempervivum montanum		**I**	**I**	***Papaver aurantiacum***		**V**	**II**
Senecio carniolicus		**I**	**III**	***Arabis alpina***		**V**	**V**
Erigeron uniflorus			**II**	***Saxifraga oppositifolia***		**II**	**V**
Gentiana verna			**I**	***Leucanthemopsis alpina***			**I**
Anthoxanthum alpinum	**V**		**I**	***Linaria alpina***			**I**
Carex curvula	**V**		**I**	***Carex rupestris***	**I**		**I**
Leontodon helveticus	**V**		**I**	***Pinus mugo***	**I**		**I**
Euphrasia minima	**V**		**I**	***Veronica alpina***	**I**		**I**
Phyteuma hemisphaericum	**IV**		**I**	***Arabis caerulea***	**II**		**IV**
Campanula scheuchzeri	**I**		**II**	***Gnaphalium hoppeanum***	**II**		**I**
Agrostis rupestris	**V**	**III**	**III**	***Erigeron uniflorus***	**III**		**I**
Cardamine resedifolia	**I**	**III**	**III**	***Soldanella alpina***	**III**		**I**
Festuca halleri	**I**	**I**	**III**	***Ranunculus alpestris***	**V**		**I**
Homogyne alpina	**V**	**I**	**I**	***Salix serpillifolia***	**V**		**II**
Leucanthemopsis alpina	**IV**	**I**	**III**	***Achillea atrata***	**IV**	**I**	**I**
Luzula alpinopilosa	**II**	**V**	**V**	***Arabis pumila***	**II**	**V**	**IV**
Rhododendron ferrugineum	**V**	**I**	**I**	***Campanula cochleariifolia***	**III**	**I**	**I**
Salix herbacea	**V**	**II**	**I**	***Moehringia ciliata***	**I**	**III**	**II**
Salix serpillifolia	**I**	**I**	**I**	***Poa minor***	**I**	**V**	**V**
Sedum alpestre	**I**	**IV**	**II**	***Pritzelago alpina***	**I**	**V**	**II**
Soldanella alpicola	**V**	**IV**	**I**	***Saxifraga caesia***	**V**	**I**	**II**
Veronica alpina	**I**	**IV**	**I**	***Taraxacum alpinum s. l.***	**II**	**I**	**II**
Total species richness	**45**	**43**	**30**	**Total species richness**	**60**	**20**	**24**

knowledge never evaluated before within *Thlaspietalia rotundifolii*. *Arabis caerulea* is the characteristic species of *Arabidetum caeruleae* Br.-Bl. 1918, typical of snowbeds on carbonate substrates (Giacomini & Pignatti, 1955; Grabherr & Mucina, 1993; Oberdorfer, 1977). *Saxifraga oppositifolia* is a glareicolous plant widespread on many different substrates, provided the suitable elevation (Aeschimann *et al*., 2004; Landolt *et al*., 2010; Pignatti, 1982; Webb & Gornall, 1989). Although the syntaxonomical interpretation of these species could be unclear, their ecological information appears evident, since both find their optimum in cold and moist habitats typical of the nival belt. In our case the presence of *Arabis caerulea* and *Saxifraga oppositifolia* was not sufficient to discriminate a well-defined community, but collecting data from further carbonate sites, it would be probably possible to formalize a new variant of the association *Papaveretum rhaetici* Wikus 1959 differentiated by these species as plausible indicators of cold and moist microclimates.

Therefore, in spite of the remarkable floristic differences due to the substrate, the vegetation of both rock glaciers suggest a general adjustment to cold-moist microclimate and long-lasting snow cover, differentiating more or less evidently from the adjacent scree slopes and enhancing the survival of nival entities at the elevation of alpine grasslands. The role of microclimatic heterogeneity in matter of refugia is more and more acknowledged (Ashcroft *et al*., 2012; Birks & Willis, 2008; Dobrowski 2011; Rull, 2009; Stewart *et al*., 2010). Active rock glaciers seem to increase the environmental variability between alpine and nival belts at the landscape level, providing potential warm-stage refugia for cold-adapted species. Our observations may thus establish a basis for further researches about rock glaciers plant communities, focused on the ecological and biogeographical significance of these landforms in the global change context.

Syntaxonomic scheme

THLASPIETEA ROTUNDIFOLII Br.-Bl. 1948
THLASPIETALIA ROTUNDIFOLII Br.-Bl. in Br.-Bl. et Jenny 1926
Thlaspion rotundifolii Jenny-Lips 1930
Papaveretum rhaetici Wikus 1959
ARABIDETALIA CAERULEAE Rübel ex Br.-Bl. 1948
Arabidion caeruleae Br.-Bl. in Br.-Bl. et Jenny 1926
ANDROSACETALIA ALPINAE Br.-Bl. in Br.-Bl. et Jenny 1926
Androsacion alpinae Br.-Bl. in Br.-Bl. et Jenny 1926
Sieversio-Oxyrietum digynae Friedel 1956 em. Englisch *et al*. 1993

CARICETEA CURVULAE Br.-Bl. 1948
CARICETALIA CURVULAE Br.-Bl. in Br.-Bl. et Jenny 1926
Caricion curvulae Br.-Bl. in Br.-Bl. et Jenny 1926

SALICETEA HERBACEAE Br.-Bl. 1948
SALICETALIA HERBACEAE Br.-Bl. in Br.-Bl. et Jenny 1926
Salicion herbaceae Br.-Bl. in Br.-Bl. et Jenny 1926
Salicetum herbaceae Rübel 1911
Luzuletum spadiceae Rübel 1911

SESLERIETEA ALBICANTIS Oberd. 1978 corr. Oberd. 1990
SESLERIETALIA COERULEAE Br.-Bl. in Br.-Bl. et Jenny 1926
Caricion firmae Gams 1936

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Tab. 1 - Analytic table of relevés.

Cluster	1.1															1.2													1.3												2.1															2.2																								
Code	113A	113B	112B	111B	112A	115A	112C	115B	114A	114B	113C	114C	111C	111A	115C	123A	122C	122A	122B	123B	123C	121C	121A	121B	125A	124A	124B	124C	132B	131C	134B	133C	133A	133B	132C	135B	131B	132A	131A	134C	215A	215B	215C	214A	214B	211A	211C	211B	213C	213A	214C	212A	212B	212C	213B	232B	233B	233C	232A	232C	234B	234C	233A	235B	224C	234A	222B	224A	221B	221A	222A	223B	223A	221C	223C	224B	222C	231C	231A	231B
Date	07.08.2014	07.08.2014	07.08.2014	06.08.2014	07.08.2014	21.08.2014	07.08.2014	21.08.2014	21.08.2014	21.08.2014	07.08.2014	21.08.2014	06.08.2014	06.08.2014	21.08.2014	07.08.2014	06.08.2014	06.08.2014	06.08.2014	07.08.2014	07.08.2014	06.08.2014	06.08.2014	06.08.2014	07.08.2014	07.08.2014	07.08.2014	07.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	06.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	05.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	04.08.2014	22.08.2014	22.08.2014	04.08.2014	04.08.2014	04.08.2014	22.08.2014	05.08.2014	04.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	05.08.2014	04.08.2014	05.08.2014	04.08.2014	04.08.2014	04.08.2014
Coordinates	N46 27.567 E10 48.805	N46 27.572 E10 48.808	N46 27.541 E10 48.821	N46 27.522 E10 48.848	N46 27.545 E10 48.827	N46 27.582 E10 48.863	N46 27.533 E10 48.823	N46 27.587 E10 48.870	N46 27.625 E10 48.830	N46 27.628 E10 48.842	N46 27.578 E10 48.813	N46 27.632 E10 48.851	N46 27.521 E10 48.841	N46 27.517 E10 48.846	N46 27.595 E10 48.875	N46 27.334 E10 48.749	N46 27.329 E10 48.696	N46 27.321 E10 48.679	N46 27.325 E10 48.687	N46 27.329 E10 48.747	N46 27.325 E10 48.754	N46 27.336 E10 48.642	N46 27.326 E10 48.657	N46 27.330 E10 48.651	N46 27.369 E10 48.827	N46 27.328 E10 48.789	N46 27.330 E10 48.797	N46 27.334 E10 48.808	N46 27.555 E10 48.879	N46 27.469 E10 48.890	N46 27.513 E10 48.963	N46 27.507 E10 48.950	N46 27.528 E10 48.935	N46 27.522 E10 48.935	N46 27.551 E10 48.887	N46 27.490 E10 48.994	N46 27.481 E10 48.893	N46 27.553 E10 48.868	N46 27.485 E10 48.882	N46 27.520 E10 48.985	N46 30.215 E10 23.994	N46 30.219 E10 23.989	N46 30.227 E10 23.988	N46 30.186 E10 24.053	N46 30.190 E10 24.051	N46 30.173 E10 24.013	N46 30.157 E10 24.021	N46 30.179 E10 24.013	N46 30.253 E10 24.001	N46 30.247 E10 24.001	N46 30.202 E10 24.054	N46 30.202 E10 24.038	N46 30.209 E10 24.039	N46 30.210 E10 24.030	N46 30.247 E10 24.007	N46 30.019 E10 24.072	N46 30.004 E10 24.189	N46 30.004 E10 24.177	N46 30.023 E10 24.077	N46 30.015 E10 24.068	N46 29.951 E10 24.205	N46 29.968 E10 24.195	N46 30.005 E10 24.195	N46 29.965 E10 24.234	N46 30.058 E10 24.291	N46 29.934 E10 24.210	N46 30.204 E10 24.292	N46 30.066 E10 24.294	N46 30.279 E10 24.174	N46 30.274 E10 24.172	N46 30.200 E10 24.287	N46 30.130 E10 24.290	N46 30.136 E10 24.298	N46 30.272 E10 24.178	N46 30.128 E10 24.283	N46 30.066 E10 24.300	N46 30.210 E10 24.294	N46 30.079 E10 24.016	N46 30.075 E10 24.035	N46 30.076 E10 24.031
Area	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Ultimo	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio	Braulio
Landform	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Stable slope	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Rock glacier	Scree slope	Rock glacier	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Scree slope	Rock glacier	Rock glacier	Rock glacier
Elevation (m a.s.l.)	2380	2380	2390	2415	2390	2380	2395	2380	2365	2365	2380	2360	2415	2415	2375	2520	2490	2490	2490	2525	2530	2470	2475	2470	2485	2530	2525	2530	2420	2470	2480	2470	2445	2450	2420	2500	2465	2415	2460	2480	2470	2470	2465	2450	2450	2485	2485	2485	2440	2440	2445	2470	2465	2460	2440	2545	2575	2575	2540	2545	2610	2605	2575	2590	2610	2620	2555	2620	2445	2445	2555	2595	2595	2450	2590	2610	2555	2520	2525	2525
Aspect (°)	280	290	305	330	305	315	310	330	320	320	315	340	315	340	340	325	315	315	315	340	340	310	310	310	355	350	345	330	350	340	310	235	265	250	20	320	335	330	330	315	15	30	45	330	320	270	155	70	85	310	275	290	300	290	15	345	330	315	355	350	345	355	0	325	295	350	300	285	310	310	300	285	285	310	285	295	290	340	75	340
Slope (°)	20	25	15	20	15	10	20	10	20	20	25	20	20	15	20	35	35	35	35	40	40	15	30	20	35	40	40	30	25	25	30	45	45	40	20	35	35	5	30	35	10	10	15	15	10	20	10	20	15	15	20	20	15	25	15	0	10	25	5	0	15	10	0	15	35	25	35	35	30	30	35	35	35	30	35	35	35	10	5	15
Shrubs cover (%)	10	5	<5	5	5	10	5	10	5	15	35	25	15	10	5	0	0	0	0	0	5	<5	0	0	0	0	0	0	15	0	0	0	15	5	0	0	0	0	0	0	5	<5	<5	<5	5	0	5	<5	<5	<5	<5	<5	<5	<5	0	<5	0	0	0	<5	0	0	0	0	0	0	0	0	0	0	0	0	0	<5	0	0	0	0	0	<5
Herbaceous cover (%)	70	70	85	75	75	70	75	65	85	65	50	55	70	70	70	10	20	15	10	20	20	15	15	15	10	10	20	20	30	10	5	45	35	50	<5	<5	<5	5	5	<5	35	45	25	85	75	70	70	65	80	85	70	75	55	80	60	<5	5	<5	5	<5	<5	<5	<5	<5	<5	<5	10	5	10	5	5	5	<5	5	5	<5	5	5	5	5
Bryophytes and lichens cover (%)	10	10	15	5	10	10	10	10	20	20	30	10	5	5	10	0	5	0	5	5	5	5	5	5	0	5	5	5	15	5	0	5	5	10	0	0	0	5	0	0	15	5	10	5	5	5	10	5	5	5	5	5	5	0	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Outcrop cover (%)	15	25	15	15	20	20	20	20	10	20	5	10	10	15	20	0	0	0	0	0	25	0	0	0	0	0	10	15	0	0	0	0	0	0	0	0	0	0	0	0	0	10	5	0	0	20	0	25	10	5	0	5	15	5	5	0	0	0	0	0	0	0	0	0	0	0	15	10	0	0	0	0	0	0	0	0	25	0	0	0
Debris cover (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	75	85	85	75	50	80	80	80	90	85	65	60	40	85	95	40	35	35	100	100	100	90	95	100	5	15	40	10	10	10	25	10	10	10	20	25	30	15	35	100	95	100	95	100	100	100	100	100	100	100	70	85	90	95	95	95	100	95	95	100	70	95	95	95
Soil cover (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	40	25	20	10	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Species richness	27	33	19	23	22	23	20	21	21	21	24	22	20	22	20	8	18	20	13	22	22	19	16	20	13	13	17	16	19	9	10	16	20	16	3	3	5	6	5	5	20	25	30	36	34	20	27	25	22	23	27	21	15	13	9	9	5	5	7	7	5	5	3	3	3	5	8	10	11	8	8	5	7	8	6	6	9	11	16	17
Differential of stable slope on silicate substrate																																																																																	
Anthoxanthum alpinum	1	1	2	1	2	1	2	1	1	1	1	1	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geum montanum	+	+	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nardus stricta	.	.	1	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa alpina	1	1	+	1	+	1	+	+	1	+	1	.	+	+	+	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron ferrugineum	1	+	+	+	+	+	+	+	.	+	+	+	+	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caricion curvulae																																																																																
Carex curvula	1	2	1	2	2	1	3	1	2	2	2	2	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca halleri	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	+	.	+	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gnaphalium supinum	+	+	+	+	1	+	+	+	.	.	+	.	+	+	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium glanduliferum	.	.	.	.	+	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ligusticum mutellina	1	1	1	1	1	1	1	+	+	1	+	+	1	1	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Loiseleuria procumbens	1	+	+	+	1	1	+	+	1	1	2	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oreochloa disticha	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedicularis kerneri	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Primula glutinosa	+	+	+	+	1	+	+	+	+	+	+	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio carniolicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene exscapa	1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	1	+	+	+	+	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium gaultherioides	+	+	.	+	+	1	1	1	+	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caricetea curvulae e Caricetalia curvulae																																																																																
Agrostis rupestris	1	1	+	+	+	1	+	1	1	+	1	1	+	+	1	.	.	.	.	+	+	+	+	+	.	.	+	+	+	+	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphrasia minima	+	+	+	+	+	+	+	+	+	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helictotrichon versicolor	1	1	+	.	.	+	.	+	1	1	1	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Huperzia selago	.	+	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon helveticus	1	1	+	+	1	+	1	+	+	+	1	+	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leucanthemopsis alpina	+	+	+	+	+	+	+	+	+	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	+	+	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Luzula lutea	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phyteuma hemisphaericum	+	+	.	.	+	+	+	+	+	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla aurea	1	1	1	+	+	+	+	+	1	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sieversio-Oxyrietum digynae																																																																																
Geum reptans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	1	+	+	1	+	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxyria digyna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	1	1	1	1	1	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Androsacetalia alpinae and Androsacion alpinae																																																																																
Androsace alpina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artemisia genipi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cardamine resedifolia	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	+	+	.	.	+	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa laxa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	+	+	+	+	1	+	+	+	1	1	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pritzelago brevicaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus glacialis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga bryoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	1	+	.	+	+	+	.	+	+	+	1	+	+	1	1	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga exarata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga seguieri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	1	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzuletum spadiceae																																																																																
Doronicum clusii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	1	1	+	1	1	1	.	.	+	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula alpinopilosa	.	+	.	+	+	+	.	.	+	.	.	.	.	.	.	+	1	1	1	1	1	+	+	1	1	+	1	+	1	1	+	2	1	1	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salicetea herbaceae, Salicetalia herbaceae and Salicion herbaceae																																																																																
Salix herbacea	.	+	+	1	1	+	+	+	+	+	+	+	+	1	+	.	.	.	.	+	.	+	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum alpestre	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	.	+	+	+	+	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Soldanella alpicola	1	1	1	1	1	1	1	1	1	1	+	1	+	1	1	.	.	1	.	.	.	1	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Veronica alpina	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	+	+	+	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Differential of stable slope on carbonate substrate																																																																																
Asplenium viride	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	+	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Erigeron uniflorus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.	.	.	+	.	.	.	.	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
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Thlaspietalia rotundifolii and Thlaspion rotundifolii																																																																																
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Campanula cochleariifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+
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Arabidetalia caeruleae and Arabidion caeruleae																																																																																
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Gnaphalium hoppeanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
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Juniperus nana	.	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Lloydia serotina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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