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figg. 4 - tabb. 3

A method for the identification and assessment of significance of geomorphosites in Vorarlberg (Austria), supported by Geographical Information Systems

Un metodo supportato dal GIS per l'identificazione e la valutazione del significato dei geomorfositi nel Vorarlberg (Austria)

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ABSTRACT – Using 1:10,000 full-area covering analogue geomorphological maps as the basis for our geoconservation work in the State of Vorarlberg (Austria), we define geomorphosites as the smallest coherent landforms which can be delineated, weighted and ranked, based on these maps. In our approach the term 'geomorphosite' is not restricted to unique or spectacular geomorphological objects or a group of objects, but it also includes 'common' sites in which people, animals and plants live. Therefore, the total landscape is valued on the basis of detailed geomorphological information. This means that not only individual landforms, but also associations or groups of landforms are assessed. A method has been developed for assessing the degree of significance ('value') of geomorphosites, with the objective of identifying potential geoconservation sites, within a frame of reference of choice. In a first step landform boundaries are identified, digitized in polygons and color-coded in a Geographical Information System (GIS) using a morphogenetic classification scheme. The degree of significance of the units is rated in a second step with a set of weighting and ranking criteria which include scientific relevance, frequency of occurrence, intactness and vulnerability. The assessment of significance combines expert knowledge and GIS-analyses which results in three ranks of significance of geomorphosites: low, moderate and high. The descriptive factors land use, scenery, status of protection, and additional criteria capture additional information in a third step, which may influence the final ranking for the degree of significance of the geomorphosites. In a fourth step, the ranking leads to the selection of potential geoconservation sites. The results are presented in a GIS and are hyperlinked to additional information, such as site descriptions, landscape photos and other thematic information. The method is illustrated in two case studies.

KEY WORDS: Geoconservation, Geomorphosites, Geomorphological mapping, Austria, GIS.

RIASSUNTO – Utilizzando le carte geomorfologiche digitali a scala 1:10.000 come base per il lavoro di geoconservazione nello stato del Vorarlberg (Austria), i geomorfositi sono stati definiti come le più piccole forme del rilievo coerenti, che possono essere individuate, pesate e classificate, basandosi su queste carte. Secondo questo approccio di lavoro il termine 'geomorfosito' non è utilizzato in modo restrittivo per indicare oggetti geomorfologici unici o spettacolari o gruppi di oggetti, ma include anche siti 'comuni' nei quali persone, animali e piante vivono. Quindi, il paesaggio nel suo complesso viene valutato sulla base di dettagliate informazioni geomorfologiche. Questo significa che non solo forme singole, ma anche associazioni o gruppi di forme possono essere valutate. È stato sviluppato un metodo per valutare il valore dei geomorfositi, con l'obbiettivo di individuare siti potenziali per la geoconservazione. Nella prima fase vengono definiti i limiti delle forme del rilievo e vengono digitalizzati i poligoni, utilizzando colori codificati in un sistema GIS per indicare la morfogenesi. Il grado di importanza delle unità è valutato in una seconda fase utilizzando un insieme di criteri che includono l'importanza scientifica, l'abbondanza, il grado di conservazione e la vulnerabilità. La valutazione del significato (valore) del geomorfosito combina la conoscenza dell'esperto e l'analisi GIS ed è stata classificata come bassa, moderata e alta. Elementi descrittivi come l'uso del suolo, la spettacolarità, lo stato di protezione e valori aggiunti aggiungono informazioni addizionali nella terza fase, che può influenzare il risultato finale del valore del geomorfosito. In una quarta fase, i valori ottenuti guidano nella selezione di siti potenziali per la geoconservazione. I risultati vengono presentati in ambiente GIS e sono collegati ad informazioni aggiuntive, come la descrizione dei siti, fotografie ed altre informazioni. Il metodo sviluppato viene illustrato in due casi studio.

PAROLE CHIAVE: Geoconservazione, Geomorfositi, Cartografia geomorfologica, Austria, GIS.

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1. – INTRODUCTION

Governments, inhabitants and visitors of mountain regions nowadays realize that mountain landscapes have vital functions and that overexploitation should be avoided to ensure sustainable landscape management. As a result of the interference by man, original mountain landscapes become fragmented or may even disappear.

Therefore, the conservation of such landscapes is of prime importance, now and in the future. Geodiversity plays a crucial role and is defined by GRAY (2004) as 'the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, processes) and soil features. It includes assemblages, relationships, properties, interpretations and systems'. Slightly different definitions have been proposed by EBERHARD (1997) and SHARPLES (2002). In central Europe the term 'geotope' is often used, e.g. by STÜRM (2005) who refers to "distinct components of the landscape with an outstanding geological, geomorphological or geoecological value. They are relics of, or give good insight into the Earth history, the evolution of life, climate or landscape". According to the IAG Working Group on Geomorphological Sites (2005), geomorphological sites (or geomorphosites) are portions of the geosphere that present a particular importance in the comprehension of the Earth history.

In our approach, the term 'geomorphosite' is not restricted to unique or spectacular geomorphological objects or groups of objects, but also includes 'common' sites in which people, animals and plants live. Such sites can be identified as being worth conservation (protection) on the basis of a set of objective weighting and ranking criteria, applied within and depending on a frame of reference of choice (cf. EMBLETON, 1984). Once a geomorphosite has been officially elevated by the authorities to the status of being protected, it is called a geoconservation site. Our method has been developed within the context of plans to make a complete inventory of potential geomorphosites in the State of Vorarlberg at a level of detail which is required for planning purposes, based on a full-area-covering evaluation of all landforms. This is different from the methods developed in some other countries, where the assessment often focuses on direct validation of individual geomorphosites (compare e.g. STÜRM, 1994; SHARPLES, 2002; GRAY, 2004; PRALONG 2005; GONGGRIJP, 2005). The method presented here seeks to a) define geomorphosites boundaries in a consistent manner using geomorphological information and b) assess the degree of significance and ranking of geomorphosites using well-defined weighting and ranking criteria in GIS as presented in table 1.

Tab. 1 – *Scheme outlining the method of identifying geomorphosites and assessing their significance in selecting geoconservation sites in Vorarlberg.*
– Schema che illustra il metodo di identificazione e valutazione dei geomorfositi nel processo di selezione dei siti per la geoconservazione nel territorio di Vorarlberg.

Steps	Input	Action	Output	
			Landforms	**Geomorphosites**
1	Geomorphological maps (1:10.000) and morphogenetic classification scheme (table 2)	Identification of homogeneous units	Landform boundaries	Geomorphosite boundaries
		Digitizing of unit boundaries	Digital Landform boundaries	Digital Geomorphosite boundaries
		Coding and coloring of polygons	Digital geomorphological maps	Digital geomorphosite maps
2	Weighting and ranking scheme	Quantitative weighting and ranking of primary criteria	Degree of significance for geomorphosites (low, moderate, high)	
		Quantitative weighting and ranking of secondary criteria		
3	Additional assessment criteria	Qualitative weighting and ranking of additional criteria	Final degree of significance for geomorphosites (low, moderate, high) = ranked geomorphosites	
4	Ranked geomorphosites	Selection of potential geoconservation sites	Potential geoconservation sites	
5	Potential geoconservation sites	Application of legislation by authorities	Geoconservation sites	

2. – A FRAMEWORK FOR GEOCONSERVATION IN VORARLBERG

The first inventory of potential geoconservation sites in Vorarlberg was initiated by the nature museum in the city of Dornbirn (formerly called 'Vorarlberger Naturschau', now 'inatura'), in co-operation with the University of Amsterdam (UvA). It resulted in a first description of "valuable" geomorphosites (at the time called geotopes) for Vorarlberg, based on geomorphological information. It is electronically published on the internet (De Graaff *et alii*, 1988). The objective of the inventory was to provide geoconservation information to be considered in local planning. The set of evaluation criteria used in that study forms the building stones for the new ranking method.

At present, 35 field-based full-area covering geomorphological maps at scale 1:10,000 are available in the public domain, which cover approximately 750 km^2 of Vorarlberg (De Graaff *et alii*, 1987; Seijmonsbergen, 1992; Van Noord, 1996). More maps are available in manuscript format. These maps inform on the distribution of and relations between landforms of a certain appearance, size, origin, and age; they also include morphographic, morphometric, morphogenetic and morphochronological data (Klimaszewski, 1982; Seijmonsbergen, 1992). They form the basis for identifying, delineating, digitizing, coding and coloring of digital map units, i.e. the geomorphosites of our approach of assessing geoconservation potential. A digital geomorphosite map unit can be assessed for its significance on the basis of a set of objective criteria, which guarantees the reproducibility of results. After ranking as a potential geoconservation site it can be officially elevated by the authorities to the status of being protected, and be integrated in geoconservation. The necessary legislation for this step is available in the State of Vorarlberg.

GIS processing is an essential tool for the method of weighting, ranking and visualization of geomorphosites and potential geoconservation sites. It is anticipated that the GIS-based ranking maps will be integrated into the GIS of the State of Vorarlberg (VOGIS), which can be consulted through a web-based interface via the internet.

3. – A METHOD FOR IDENTIFICATION AND RANKING OF GEOMORPHOSITES IN VORARLBERG

Based on the legend of the detailed geomorphological maps at 1:10,000 scale available in Vorarlberg, a morphogenetic classification scheme was designed (tab. 2). The scheme is used to identify, delineate, and code basic digital geomorphosites from the geomorphological maps. Eight main geomorphological classes are recognized in the scheme (Glacial, Fluvial, Mass Movement, Periglacial, Organic, Karst, Aeolian, and Anthropogenic), to which 'Water' is added as a separate class. Twenty-four 'Landforms and Deposits' classes are defined at the most detailed level, each with a distinctive color and GIS code.

A protocol for weighting and ranking geomorphosites in Vorarlberg, consisting of a quantitative and a qualitative part, has been developed (tab. 1;

Tab. 2 – *Morphogenetic classification scheme of 'Processes' and 'Landforms and Deposits'.*
– Schema di classificazione morfogenetica per "processi" e "forme e depositi".

Processes	**Glacial** (1000)							**Fluvial** (2000)					**Mass Movement** (3000)				**Periglacial** (4000)		**Organic** (5000)	**Karst** (6000)		**Aeolian** (7000)	**Human** (8000)	**Water** (9000)
	Erosion (1100)		Accumulation (1200)					Erosion (2100)	Accumulation (2200)				Degradation (3100)		Accumulation (3200)		Disintegration (4100)	Accumulation (4200)	5100	Karst in carbonates (6100)	Karst in sulphates (6200)	Accumulation (7100)		9100
	(1110)		Subglacial (1210)	Ice marginal (1220)				(2110)	(2210)				(3110)		(3210)		(4110)	(4210)	(5110)	(6110)	(6210)	(7110)	(8110)	(9110)
Landforms and deposits	Glacially eroded bedrock	Glacially eroded Quaternary deposits	Landforms underlain by subglacial till s.l.	Landforms underlain by ablation till s.l.	Erosional landform	Landform underlain by fluvial deposits	Landform underlain by lake fill deposit	Incision: slope subject to fluvial erosion	Recent streambed	Fluvial terrace	Alluvial fan, debris fan	Landform underlain by lake fill deposits	Slope with deep seated mass movement	Slope with shallow mass movement	Landforms underlain by fall deposits	Landforms underlain by flow and/or slide deposits	Terrain subject to disintegration	Rock glacier	Landform underlain by peat deposits	Slope surface strongly affected by karst	Slope surface strongly affected by karst	Landform underlain by aeolian deposits	Graded or leveled land; pits, quarries etc.	Lake
GIS code	1111	1112	1211	1221	1222	1223	1224	2111	2211	2212	2213	2214	3111	3112	3211	3212	4111	4211	5111	6111	6211	7111	8111	9111

tab. 3A-C). The frame of reference for the assessment is the State of Vorarlberg, rather than the world, Europe, a country or a certain region within Vorarlberg (cf. EMBLETON, 1984). Each digital geomorphosite unit is assessed for its degree of significance according to primary and secondary evaluation criteria, which have been quantified in the attribute table using a weighting and ranking scheme. The weighting and ranking forms the basis for the selection of potential geoconservation sites. The assessment is best done by an experienced earth scientist who either has been working in the region or has access to sufficiently detailed geological and geomorphological maps and literature.

Worthwhile to refer to in this context are the following studies. CORATZA & GIUSTI (2005) proposed to assess scientific quality as a major factor, by weighting the expert knowledge factors, area, rareness, degree of conservation, exposure and added value. Some of these factors or qualities are difficult to 'measure', something which was also stressed by BRUSCHI & CENDRERO (2005). They proposed to use indicators that can be expressed on a continuous scale. The weighting system designed by SERRANO & GONZÁLEZ-TRUEBA (2005) is strongly based on geomorphological mapping and the use of three assessment scoring criteria: scientific value, cultural value and use value. Geomorphosite description cards are used to assess the importance of landform and processes. PRALONG (2005) used criteria and scoring tables that focused on scenic, scientific, cultural and economic values with the aim to assess tourist potential and other use of geomorphological sites.

We use four factors in the quantitative part of the weighting and ranking protocol: scientific relevance, frequency of occurrence, intactness and vulnerability. Various criteria are applied to weight the scientific relevance. A landform or deposit can be a 'textbook example' of a certain geomorphological process or of a group of processes and as such be scientifically relevant. A certain landform or deposit may bear value in the reconstruction of landscape history. The frequency of occurrence is a measure for the uniqueness of a landform or deposit. The more frequent a landform or deposit occurs, the less unique it is. It is context-dependent, i.e. it depends on the size of the study area.

A landform may be unique in a certain community, but not in the State of Vorarlberg. Scientific relevance and frequency of occurrence of digital geomorphosite units are the primary quantitative parameters in the weighting and ranking protocol (tab. 1; tab. 3A), of which the former is considered the most important. Scientific relevance is rated from no (0), low (1), some (3), high (5) to very high relevance (7). The frequency of occurrence can be rated as: high (1), normal (2) or low frequency (3). Combination of scientific relevance and frequency of occurrence results in a matrix (tab. 3A), of which the cells are ranked into 'low rank', 'medium rank' and 'high rank', according to the combined scores in the table.

Intactness and vulnerability are secondary weighting and ranking parameters. Intactness refers to the degree in which a landform or deposit has already been destroyed by human activity. It does not refer to an 'ideal' or 'textbook' condition of a landform or deposit. Vulnerability refers to the effect human activity will have on a landform or deposit. Questions to be answered are: is human activity likely to adversely affect a potential geomorphosite? Will it be partly or completely destroyed even at low levels of human activity? The adverse effect of human activity on geomorphosites varies, certain ones are likely to be completely destroyed by small-scale human activity (i.e. high vulnerability), whereas other ones will still preserve their essential nature at larger scale activity (i.e. low vulnerability). The scores for intactness (undisturbed, score = 5; <10% disturbed, score = 3; 10-30% disturbed, score = 1; >30% disturbed, score = 0) and vulnerability (low, score = 1; medium, score = 3; high, score = 5) are combined in a matrix and are ranked in three classes (tab. 3B). The geomorphosites which are classified as 'low rank' in the combination of scientific relevance and frequency of occurrence (tab. 3B) are not included in the weighting and ranking of the secondary factors, for the sake of efficiency.

The matrices of table 3A and table 3B are then combined into a new matrix. The geomorphosites with scores from 7 through 10 have a 'low degree of significance' and do not deserve specific attention. The geomorphosites with scores from 11 through 15 are considered as having a 'moderately degree of significance' and deserve attention. A score of 16 and higher indicates a 'high degree of significance' and deserve prime attention in terms of becoming a potential geoconservation site. The weighting and ranking of primary and secondary factors has been automated in GIS.

Decision-making usually requires further characterization and assessment of significance of valuable geomorphosites identified in the forementioned protocol. Additional descriptive factors provide additional characterization. These are *status of protection*, *scenery*, *land use*, and *additional criteria*. The status of protection is indicated when an area already has a specific status of protection. This information can be obtained from local or regional authorities. Scenery refers to visual appreciation of a landform – which is rather subjective. An additional complication is that a certain appreciation is usually for a group of landforms, in combination with other fragmented parameters, such as vegetation and pasture. Nevertheless, it is considered useful to include information on the scenic value of individual geomorphosites in the attribute table. The scenic value is differentiated in low (1), medium (2) and high value (3). The land use classes differentiated in Vorarlberg are: deciduous forest, coniferous forest, mixed forest, grassland, bare land, urban land and agricultural land. Additional criteria, such as hydrological features and soil development, can be entered as text in the attribute table.

The additional descriptive criteria capture information which may lead to a revision of the degree of significance of a given geomorphosite as determined in the quantitative part of the weighting and ranking protocol. In most cases the revision will be an upgrade of the geomorphosite to a higher rank of significance. If so, the new ranking will be entered in the attribute table as the final ranking. This is illustrated in the example of the Lech area below. Once the weighting and ranking is completed, a selection of geomorphosites can be made to become potential geoconservation sites.

The GIS geo-database contains files to which hyperlinks can be made from the various maps or tables (compare CARTON *et alii,* 2005). A clickable

Tab. 3 – *Weighting and ranking scheme used for assigning the degree of significance to geomorphosites.*
– Schema dei pesi utilizzati per assegnare un valore ai geomorfositi.

A: Primary factor weighting and ranking			**Scientific relevance**				
			no	**low**	**some**	**high**	**very high**
			0	1	3	5	7
Frequency	**high**	1	1	2	4	6	8
	normal	2	2	3	5	7	9
	low	3	3	4	6	8	10

	1-4 low rank		6-7 medium rank		8-10 high rank

B: Secondary factor weighting and ranking			**Intactness**			
			>30%	**10-30%**	**<10%**	**Intact**
			0	1	3	5
Vulnerability	**low**	1	1	2	4	6
	medium	3	3	4	6	8
	high	5	5	6	8	10

	1-4 low rank		6-7 medium rank		8-10 high rank

C: Final weighting and ranking		**Medium and high primary factors**				
		6	7	8	9	10
Secondary factors	1	7	8	9	10	11
	2	8	9	10	11	12
	3	9	10	11	12	13
	4	10	11	12	13	14
	5	11	12	13	14	15
	6	12	13	14	15	16
	8	14	15	16	17	18
	10	16	17	18	19	20

	7-10 low degree of significance		11-15 moderate degree of significance		16-20 high degree of significance

point file may bring up a photo, whereas a hyperlinked text document may be opened upon clicking the geomorphosite polygon. This technique also allows the capturing of special geomorphological features, such as small exposures, which are 'overlooked' in the polygon-based evaluation. GIS presentation and visualization of geomorphosites allows easy interactive access for the non-scientific public in a web based environment.

In the next sections the application of the method is illustrated by two case studies.

4. – EXAMPLES

4.1. – The Bürserberg area

The first area is situated near the village of Bürserberg (fig. 1) and is composed of landforms and deposits which reflect the deglaciation phases of the Würm glaciation. The interactions that existed between the trunk Ill glacier and the tributary Brandner glacier have been locally preserved in ice-marginal fluvial and deltaic terraces and moraine ridges which indicate invasion of the larger Ill glacier into the lower reaches of the smaller Brandner Valley. Limestone and marl of the East Alpine Lechtal nappe (Muschelkalk, Arlbergschichten and Partnachschiefer Formations, Oberhauser, 1998) underlie the Quaternary deposits and are locally exposed as glacially eroded ridges. Postglacial denudation and erosion have degraded the glacial s.l. landscape to some extent. Apart from agriculture and forestry, human influence is restricted to an abandoned gravel pit (excavation of sand and gravel from ice-marginal deposits) and to some hamlets and roads on the level parts of the ice-marginal terrace remnants. Refer to Simons (1985), Keller (1988), De Graaff & Seijmonsbergen (1993) and Van Noord (1996) for more details on the geomorphological history of these surroundings. The area has no current protection status. Due to local population pressure, especially recreation, the Late Glacial landscape elements are exposed to further disturbances.

The method described in the previous sections has been applied and the results are depicted in figure 2. Spatial information is presented in 6 layers. The basic layer is formed by the digital geomorphological map, whereas the spatial distribution of the primary (scientific relevance and frequency of occurrence) and secondary (intactness and vulnerability) weighting and ranking factors is displayed as overlays. The final step of assessment, i.e. degree of significance, is the combination of the four factors. It can be displayed separately or in combination with other layers. The photos are from the GIS database and show scenery (A), a local karst depression (B) and a small, but informative roadside exposure in ice-marginal deposits (C).

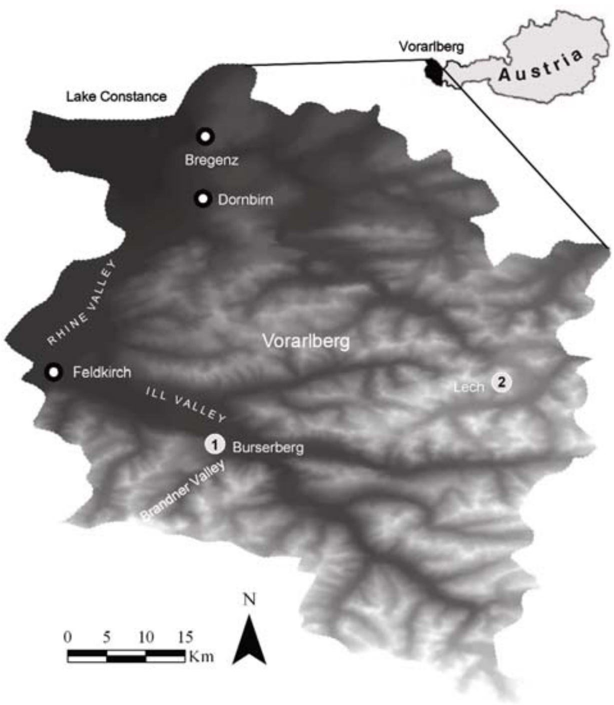

Fig. 1 – Location of the two example areas in Vorarlberg, western Austria.
– *Inquadramento geografico delle due aree campione in Vorarlberg, Austria occidentale.*

4.2. – The Lech area

The second area is located between the villages of Schröcken and Lech in the Lechquellen Mountains of eastern Vorarlberg, on the divide between the catchments of the rivers Bregenzerach and Lech, at altitudes above 1500 m (fig. 1). Bedrock is formed by the formations of the East Alpine 'Kalkalpen' of the Allgäu and Lechtal nappes (Oberhauser, 1998). Geologically speaking, the area is significant because of the occurrence of tectonic klippes and a tectonic half-window, and because of outcrops of the Upper Cretaceous Branderfleck Formation, which are rare in Vorarlberg (Von Eynatten, 1996). From a geomorphological point of view, the area is remarkable because of its rather 'open' topography in a high-alpine setting. Situated between the peaks of the Juppenspitze-Mohnenfluh and Auenfelder Horn-Karhorn, the area is characterized by a wide valley floor and a plateau-like high with a field of glacially moulded humps, which are underlain by the Branderfleck Formation. Such morphology usually occurs at lower altitudes. In figure 3 an overview of the Lech area is seen. An inventory of the geomorphology of the area was made in 2002 (De Graaff *et alii*, 2003). Using the criteria of De Graaff *et alii* (1988), landforms with significant geoconservation value were then identified at three levels: individual landforms; groups of landforms; and the area as a whole.

A part of the original study area has been selected to show how a first ranking of significance based on the quantitative weighting and ranking criteria is modified by including one qualitative parameter (i.e. bedrock geology). For the sake of simplicity only scientific relevance and frequency of occurrence have been used for the quantitative ranking. The method is visualized in a series of 6 maps (fig. 4).

The map of figure 4A shows the digital geomorphological map with geomorphosite boundaries and the original analogue geomorphological field map as a backdrop image. Refer to De Graaff *et alii* (1987) for the legend of the geomorphological field map. A simple geological map (modified from De Graaff *et alii*, 2003) is shown

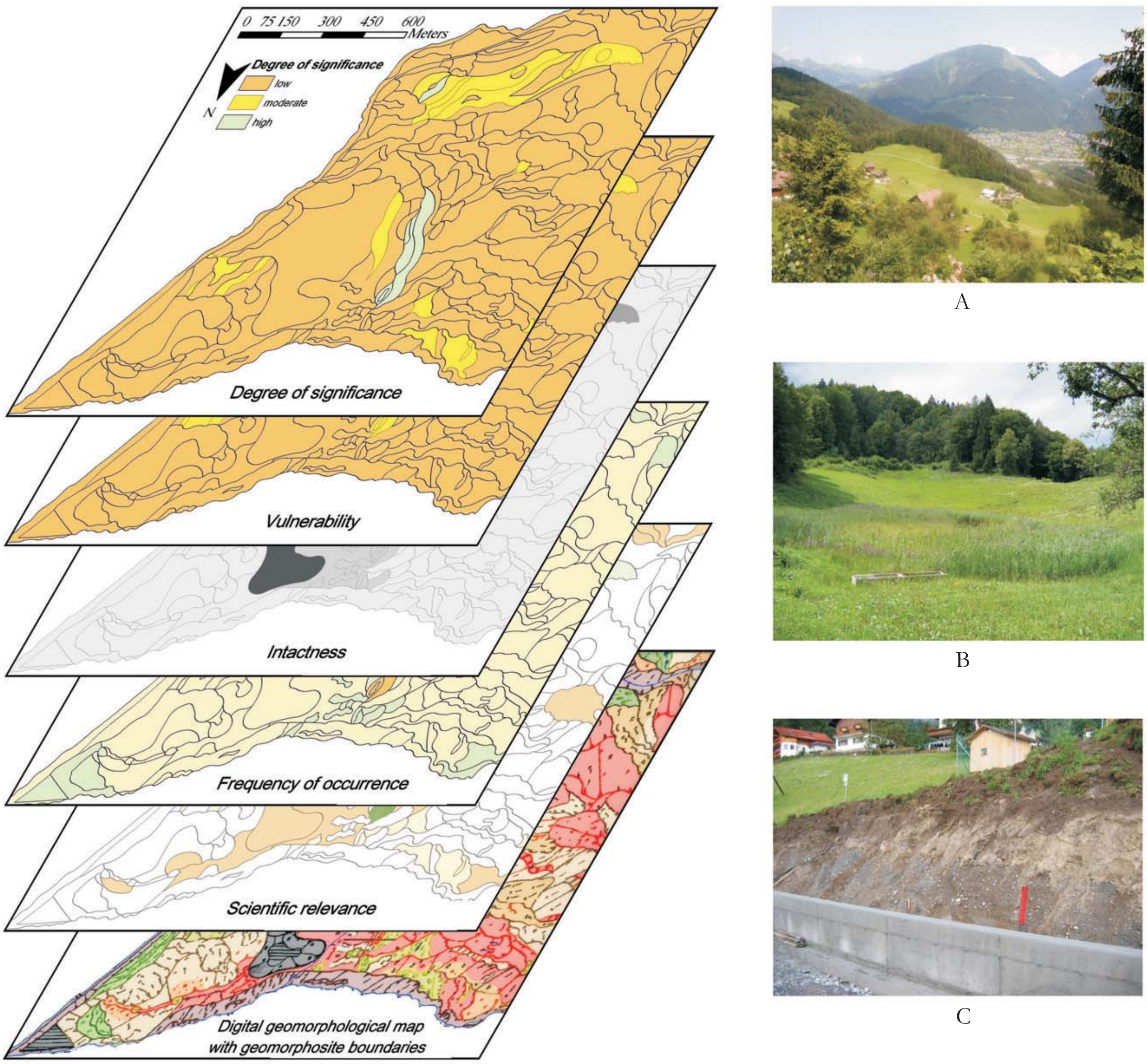

Fig. 2 — Representation of GIS layers depicting the spatial distribution of landforms with geomorphosite boundaries, the weighting and ranking factors and the final degree of significance for the Bürserberg area. Three examples of terrain situations are shown: A. Scenic view of the Bürserberg area (centre of photo), B. Karst depression and C. Exposure in ice-marginal deposits.

– *Rappresentazione dei livelli informativi della distribuzione spaziale delle forme con indicazione dei confini dei geomorfositi, dei criteri utilizzati per la valutazione e del valore finale per l'area di Bürserberg. Vengono illustrati tre esempi differenti: A. Vista panoramica dell'area di Bürserberg (al centro nella fotografia), B. depressione carsica e C. Affioramento di deposti glaciali marginali.*

Fig. 3 – View to the north of the area near Lech. The area of figure 4 is in the centre-foreground and centre-left of the photo. – *Panoramica dell'area vicino a Lech. L'area illustrata in figura 4 corrisponde alla zona in primo piano al centro e a sinistra rappresentata in fotografia.*

in figure 4B. Scientific relevance and frequency of occurrence are shown in figures 4C and 4D, respectively. Figure 4E shows the results of the quantitative weighting and ranking, i.e. degree of significance. As mentioned before, the Branderfleck Formation (see figure 4B) is rare in Vorarlberg. Landforms underlain by this formation, therefore, gain significance. This has been implemented by upgrading the relevant geomorphosites one rank, i.e. the geomorphosites of 'low degree of significance' are included in the 'medium degree of significance', those of 'medium degree of significance' are included in the 'high degree of significance', and the 'high degree of significance' geomorphosites remain 'high degree of significance' (fig. 4F).

Grouping of geomorphosites is also illustrated in figure 4. A group of adjoining geomorphosites has been hatched in figure 4F. Together they represent a highly diverse geomorphological association in a very small area. The grouping has been done by the expert; tests are ongoing to automate the grouping procedure in GIS. The geomorphosites within the group are all upgraded to the rank of the highest-ranking individual geomorphosite of the association. This is, however, not shown in figure 4F, for the sake of clarity.

5. – DISCUSSION AND CONCLUSIONS

The method here presented for the identification and assessment of geomorphosites has been developed for Vorarlberg. Evaluation at a degree of detail necessary for small-scale planning purposes is possible due to the availability of geomorphological maps at scale 1:10,000. It is concluded that this method is also applicable at larger scales by making groups or associations of geomorphosites.

Grouping of geomorphosites may also be required for reasons of efficiency. Applying the method at scale 1:10,000 to large areas is, for obvious reasons, time-consuming. The method as presented here is considered robust; further work focuses, among other things, on improving efficiency. Experiences with the selection of boundaries indicate that some generalizations can already be made during the process of digitization: adjoining landforms and deposits of similar nature can be grouped. Tests are being done to see if the weighting and ranking of factors such as frequency of occurrence and intactness can be automated in GIS, e.g. by using buffering techniques and by using geodiversity indicators. It is considered logical that expert knowledge will always remain a necessary input for the selection of boundaries and for assessing the scientific relevance of geomorphosites.

The morphogenetic classification scheme of landforms and deposits (tab. 2) is a 'box of bricks'. New geomorphologic features can be added. It may contribute to fill the 'lack of classification systems for landforms' already noted by Gray (2004).

Text descriptions and photos of terrain situations have been hyperlinked in the GIS to the digital maps. A further point of interest is to link the geoconservation geodatabase to external sources of digital information or hyperlinked documents.

We believe that the here presented method is applicable to other mountainous areas. We also believe that in areas without detailed geomorpholog-

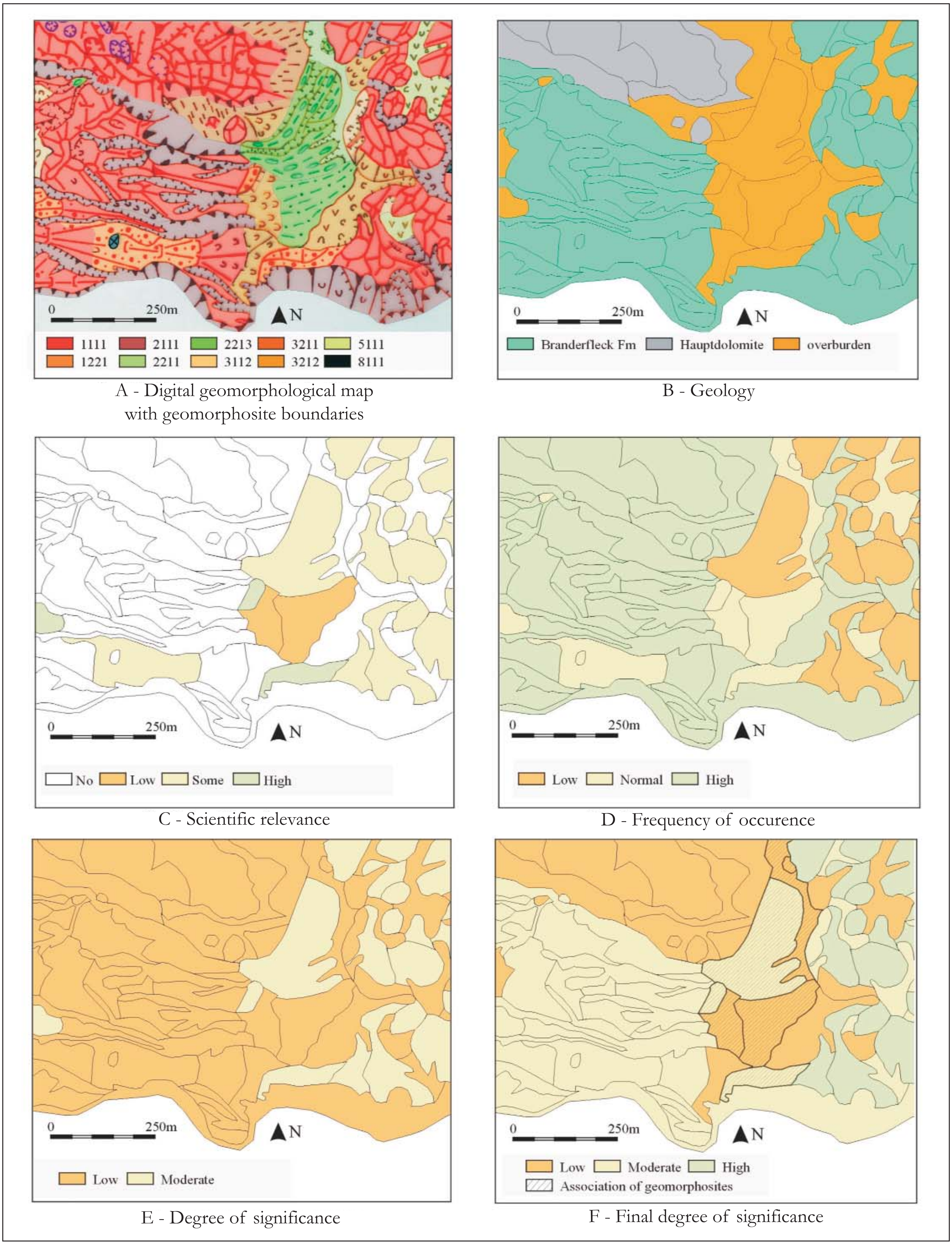

Fig. 4 – Representation of GIS layers depicting the sequence from identification of geomorphosite boundaries to the assessment of their final degree of significance. See text for further explanation.

– *Rappresentazione dei livelli tematici che illustrano la sequenza dall'identificazione dei limiti del geomorfosito fino alla valutazione del suo valore. Confronta il testo per ulteriori spiegazioni.*

ical maps expert knowledge can be applied to extract the relevant information from other (scale) available maps, such as geological maps, soil maps or geomorphological overview maps and additional information such as excursion guides.

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