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figg. 17

Enhancement of glacial and periglacial Geomorphosites based on geomorphological and dendrochronological research. An example from the Trafoi Valley (Ortles - Cevedale Group)

La valorizzazione dei geomorfositi glaciali e periglaciali sulla base delle ricerche geomorfologiche e dendrocronologiche. Un esempio dalla Val Trafoi (Gruppo Ortles - Cevedale)

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ABSTRACT – Many studies on geomorphology, glacial geology and glaciology have been carried out for years on the Alps with the goal of reconstructing the glacier history of the upper Holocene and the Little Ice Age. However, the results of this research are typically almost exclusively used by specialised researchers and their dissemination is lacking for people not working in these fields. At the same time, people enjoying the alpine environment are becoming more interested in learning about biotic and abiotic natural topics. These needs can be satisfied by creating naturalistic itineraries suitable for the communication of the scientific results in an easy and correct language. The scientific support can be given by naturalistic guides, illustrated panels or simply by brochures. The goal of this work is to demonstrate how both geomorphological and vegetational aspects concur in the reconstruction of Holocene glacier history. Moreover, this kind of integration allows to understand the sequence of the glacial processes. Finally, these naturalistic aspects can be easily observable along high mountain trails. The proposed work is an example showing how to apply these concepts along a thematic itinerary where geomorphology and dendrochronology are the two main subjects. In particular, the results about Quaternary geology, geomorphology and dendrogeomorphology recently carried out in upper Val Venosta (Trafoi Valley-Alto Adige), with the goal of reconstructing the glacier history of the Madaccio Glacier, are reported. Apart from proposing an itinerary, this work suggests how to prepare a "geotouristic" guided trail, able to easily transfer to a wide public the results of the basic research. Beyond logistic information, an explanation of the geomorphological evolution of the territory, using description, illustrations and drawings has been included.

KEY WORDS: Madaccio Glacier, Glacier History, Dendrochronology, Geomorphosite.

RIASSUNTO – Da anni sulle Alpi sono in corso studi di geomorfologia, geologia glaciale e glaciologia, finalizzati alla ricostruzione della storia glaciale nell'Olocene superiore e nella Piccola Età Glaciale. I risultati di queste ricerche vengono utilizzati quasi esclusivamente dagli "addetti ai lavori" e manca un'opportuna divulgazione verso chi non opera in questi specifici settori. Parallelamente si assiste ad un crescente interesse verso la conoscenza degli aspetti naturalistici biotici ed abiotici. Queste esigenze possono essere soddisfatte attraverso la realizzazione di itinerari naturalistici che trasmettono in modo comprensibile ma scientificamente rigoroso i risultati delle ricerche di base. Il supporto scientifico agli itinerari può essere fornito da guide naturalistiche, note illustrative, carte geoturistiche o semplici brochure. Obiettivo del presente lavoro è dimostrare come aspetti geomorfologici e vegetazionali si integrino per la ricostruzione della storia glaciale olocenica, come essi siano stati utilizzati per la ricostruzione di determinate situazioni ambientali e come siano oggetti di interesse naturalistico facilmente osservabili lungo gli itinerari d'alta montagna. Si propone un esempio che ben si presta per applicare questi concetti lungo un percorso tematico che vede come protagonista la geomorfolo-

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gia e la dendrocronologia. In particolare vengono illustrati alcuni aspetti derivanti da ricerche di geologia del Quaternario, di geomorfologia e di dendrogeomorfologia in atto da alcuni anni, nell'alta Val Venosta (Valle di Trafoi – Alto Adige) in prossimità del Ghiacciaio del Madaccio, finalizzate alla ricostruzione della storia glaciale degli ultimi secoli. Il presente lavoro, oltre a dimostrare come i risultati della ricerca di base possano essere facilmente divulgati/trasferiti ad un ampio pubblico, si configura come proposta di itinerario e suggerisce le modalità di allestimento di un percorso geoturistico guidato. Oltre alle informazioni di tipo logistico sono state inserite esemplificazioni dell'evoluzione geomorfologica del territorio, trasmesse attraverso immagini, disegni, foto e schemi.

PAROLE CHIAVE: Ghiacciaio del Madaccio, Storia glaciale, Dendrocronologia, Geomorfosito.

1. – INTRODUCTION

Many studies on geomorphology, glacial geology and glaciology have been carried out for years on the Alps with the goal of reconstructing the glacier history of the upper Holocene and the Little Ice Age (DENTON & KARLEN, 1977; OROMBELLI & PORTER, 1982; GROVE, 1988; PELFINI, 1988, 1992, 1999 A-B; PELFINI & SMIRAGLIA, 1992; BARONI & CARTON, 1996; DELINE & OROMBELLI, 2005). However, the results of this research are typically almost exclusively used by specialised researchers and their dissemination is lacking for people not working in these fields. For a better use and management of the territory, people enjoying the mountain (such as mountaineers, hikers and tourists) or people working on the mountains should know well the past natural history and possible future evolution of the environments they frequent.

At the same time, people enjoying the Alpine environment are becoming more interested in learning about biotic and abiotic natural topics. These needs can be satisfied by creating naturalistic itineraries suitable for the communication of the scientific results in an easy and correct language.

In many tourist areas, several traditional trails have been recently transformed into thematic paths. For example, the S. Vito - Forcella Grande - Foresta di Somadida naturalistic trail (CARTON, 1991), the Vittorio Sella glaciological path close to the Ventina Glacier (Servizio Glaciologico Lombardo, 1992), the Luigi Marson glaciological path close to the Fellaria Occidentale Glacier (realized by Servizio Glaciologico Lombardo), the glaciological trail close to Forni Glacier (SMIRAGLIA, 1995), the Antelao naturalistic-glaciological path (SCORTEGAGNA, 2001), the Dos Capèl geological path (DELL'ANTONIO & ROGHI 2001). The scientific support can be given by naturalistic guides (fig.1), illustrated panels or simply by brochures. Besides transmitting naturalistic information, these solutions can be also a way of passing on the results of the basic research.

Informing also not-specialised people through different approaches about scientific topics is one of the goals of the national research project, financed in 2004 by the Italian Ministry of Education, University and Research (MIUR), "The geomorphological heritage as resource for sustainable tourism" (national coordinator M. Panizza). Another aim of this project is how to transfer the scientific knowledge to the possible users and the local communities. Within this project, many researchers have organized guided itinerary as a tool to give information about different

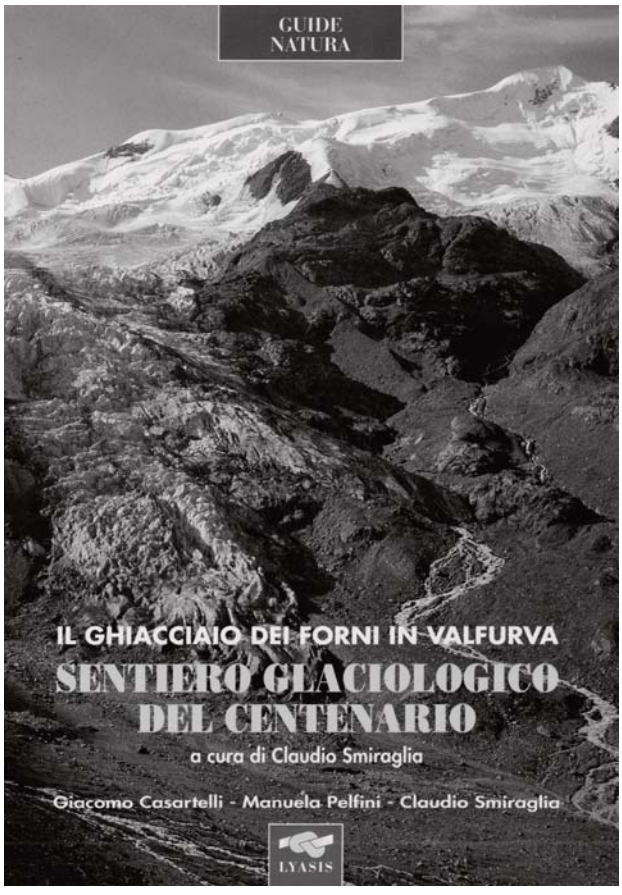

Fig. 1 – Cover of the volume illustrating the Centenary glaciological trail at the Forni Glacier, prepared to celebrate the 100 years since the institution of the "Comitato Glaciologico Italiano". In this popular-scientific guide readers will find much information about the recent glacier history and about the landscape forms recognisable along the path. The trail crosses also the glacier's tongue. It is possible to observe from different perspectives the Forni Glacier and its glacial landforms.
– Copertina del volume che descrive il sentiero glaciologico del centenario nel Ghiacciaio dei Forni, realizzato per celebrare il centenario dell'istituzione del Comitato Glaciologico Italiano. In questa popolare guida scientifica i lettori possono trovare informazioni sulla storia recente del ghiacciaio e sulle forme dl rilievo osservabili lungo il percorso. Il sentiero attraversa anche la lingua del ghiacciaio. È possibile osservare da diverse prospettive il Ghiacciaio dei Forni e le forme glaciali caratteristiche.

scientific results in geomorphology, geology, glaciology, botany, ecology, zoology, etc.

In upper Val Venosta (Trafoi Valley-Alto Adige), close to the Madaccio Glacier, many different researches had been performed for years with the goal of reconstructing the glacier history of the last centuries through studies in Quaternary geology (BINI *et alii*, 1996), in geomorphology (MARTINOLI, 2005) and in dendrogeomorphology (PELFINI, 1999 a-b). The goal of this work is to demonstrate how geomorphological and vegetational aspects both concur in the reconstruction of Holocene glacier history. Moreover, this kind of integration allows to understand the sequence of the glacial processes. Finally, these naturalistic aspects can be easily observable along high-mountain trails. The proposed work is an example showing how to apply these concepts along a thematic itinerary where geomorphology and dendrochronology are the two main subjects.

2. – STUDY AREA

The upper Trafoi Valley is located inside the Stelvio National Park, in the Alto Adige side of the Ortles-Cevedale Group (fig. 2).

This valley is highly attractive for tourists and it is frequented by thousands of people going to the Passo dello Stelvio, visiting the surroundings and walking along the numerous tourist paths towards the mountain tops and huts.

The idea to propose a naturalistic thematic path in the upper Trafoi Valley comes also from the recent requirement to widen the tourist offer during summer months. This is done as an alternative to the summer ski activities, which in the recent years have seen a progressive reduction in the available period because of the contraction of the glacial surfaces on which ski runs are open (DIOLAIUTI *et alii*, 2006).

In Trafoi Valley six glaciers are currently present: Vedretta della Tabaretta, Vedretta Alta dell'Ortles, Vedretta Bassa dell'Ortles, Vedretta di Trafoi, Vedretta del Madaccio and Vedretta Piana.

Each of them has left erosion landforms and deposits which clearly describe the historical fluctuations. Madaccio glacier (fig. 3) and its proglacial area present some clear, easily accessible geomorphologic aspects and dendrochronological data made available from the past, given the continuous interactions between the glacier advances and tree vegetation.

3. – TREE GROWTH AND GLACIER FLUCTUATIONS

The numerous remains of conifers found in living and uprooted positions (fig. 4) offer an opportunity to understand how they contribute to the chronological reconstruction of the different glacial events.

During the advancing phases, glaciers can impact forested areas, sweeping up and burying trees which are sometimes found re-emerging from the debris,

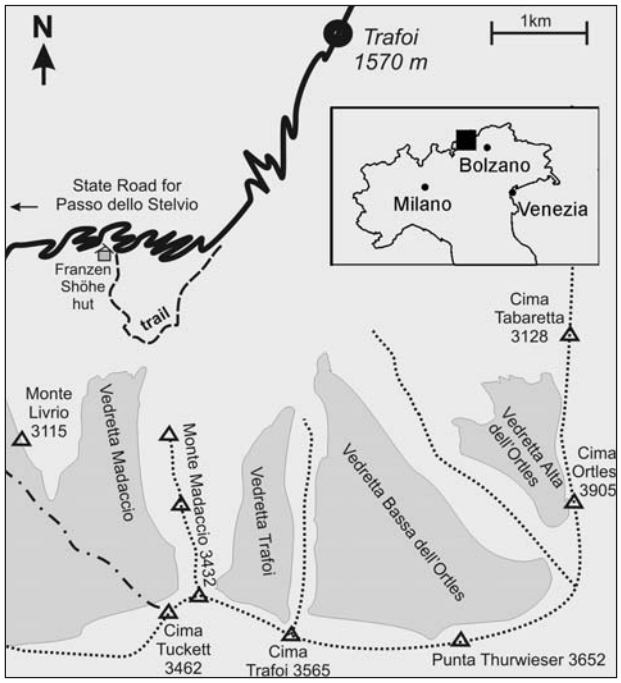

Fig. 2 – Location map of the study area. The proposed trail (broken line) starts from the road for Passo dello Stelvio and stop near a hut (see details of the trail in figure 6).
– *Inquadramento geografico dell'area di studio. Il sentiero proposto (linea tratteggiata) inizia dalla strada per il Passo dello Stelvio e termina vicino al rifugio (cfr. dettagli del sentiero in figura 6).*

Fig. 3 – Panoramic view of Madaccio Glacier and its proglacial area (photo by Bozzoni, summer 2005).
– *Vista panoramica del Ghiacciao del Madaccio e dell'area proglaciale (fotografia di Bozzoni, estate 2005).*

Fig. 4 – Typical half-buried trunk in the proglacial area (photo by Pelfini, 2004).
– *Tipico tronco parzialmente sepolto nell'area proglaciale (fotografia di Pelfini, 2004).*

4. – GLACIAL AND PERIGLACIAL LANDFORMS AS GEOMORPHOSITES

The combination of attributes and values of the "Madaccio" site in general and in its details, allow the area to be defined as a possible geomorphosite, as proposed by PANIZZA (2005); PANIZZA & PIACENTE, (2003), PELFINI & SMIRAGLIA (2003), CARTON *et alii* (2005), PRALONG & REYNARD (2005), REYNARD, (2005).

Concerning the scientific attribute, the area in which the Madaccio Glacier is located represents a *didactic example*, a model of *geomorphological evolution* and a *paleoenvironmental evidence*. The didactic example is given by a series of very well preserved erosion and accumulation landforms, typical of a glacial landscape, allowing observation and understanding of the abrasion processes (roches moutonnées, striae, crescentic gouges, glacial valley "rieghel" etc.), and of deposition ones (accretion moraines, superposition moraines, proglacial fans, etc.). The *geomorphological evolution* model comes from the interactions of the glacial, slope and fluvial forms describing the complex vicissitudes alternating over time, during repeated glacier advance, stasis and retreat phases. The *paleoenvironmental evidence* is documented by a series of morainic ridges, mainly dated, allowing the reconstruction of relative or absolute chronology. It is possible to add also the *ecological support* given by

and sometimes damaging the trees beside the tongue or those at the limit of the area, in the frontal position, reached by the glacier terminus (fig. 5).

Generally, trees at the margins of the advancing tongue, record the same climatic events recorded by the trees growing at a larger distance from the glacier. The situation when the glacial ice reaches the stem or the roots is quite different. In this case the tree suffers and forms particularly narrow rings (SCHWEINGRUBER, 1996). In both cases trees allow precise reconstruction of the glacier history. In fact the date of tree death obtained from stems still *in situ* allows precise determination of the year in which the glacier reached a certain position. If this position is coincident with a frontal moraine, it is possible to date the moraine deposition phase. Similarly, damage or disturbances found on living trees, such as scars and compression wood, allow to date the glacier impact (fig. 5). On the contrary, logs buried in the lateral moraines can only indicate the thickness of the glacier tongue at the moment of the insertion into the moraine itself. In fact, their death could have happened also years before and also can be due to different causes (SCHWEINGRUBER, 1988; PELFINI, 2003; 2006).

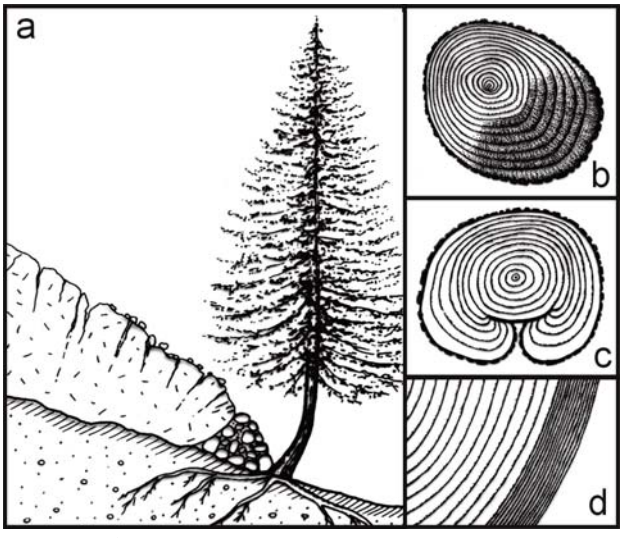

Fig. 5 – The different reactions of a tree to glacial ice pressure (a). Trees can form compression wood, typical reaction wood which conifers produce also making eccentric rings to recover the vertical position (b). Trees can be directly damaged and the scars can be used to date the year in which the contact happened (c). Trees can form narrow rings until the glacier retreats (d) (from PELFINI, 2006).
– *Differenti reazioni di un albero alla pressione esercitata dal ghiacciaio (a). Gli alberi possono formare legno di compressione, tipico legno di reazione che le conifere producono anche attraverso anelli eccentrici per riprendere la posizione verticale (b). Gli alberi possono essere danneggiati direttamente e, successivamente, le cicatrici possono essere usate per datare l'anno in quale il contatto con il ghiacciaio è avvenuto (c). Gli alberi possono formare stretti anelli fino al ritiro del ghiacciaio (d) (da PELFINI, 2006).*

the dendrochronological documentation to these attributes. The presence of easily visible buried trunks and the numerous trees damaged and deformed by the geomorphological processes and by atmospheric events, provide added value to the geomorphosite, not only concerning the dating of glacial deposits, but also with regard to the paleoenvironmental reconstruction of the site.

The morphological and vegetational elements can be observed either walking along a trail within the proglacial area (fig. 2) or along a panoramic one (trail no. 20, connecting the Garibaldi hut, near Passo dello Stelvio and the end of the "Forcola" chair lift) on the opposite side of the valley.

The possibility of exploring the same subject firstly in detail and then in its entirety, also plays an educational role because it shows to the tourists the scientific approach, resolving a naturalistic problem starting from the analysis of the single aspects which are later jointly interpreted, leading to a synthetic vision. The reading of past history using the data supplied by the glaciological and dendrochronological studies, gives also to the tourists an example of an integrated approach for reading the landscape, equally involving both biological and geological disciplines.

5. – THE TRAIL

The proposed trail (figures 2 and 6) starts as a cart-road from the State Road leading to the Passo dello Stelvio, just above the Weißer Knott hotel (1923 m), it then follows the path indicated by the trail no. 13 and 14, and ends close to the Franzen Shöhe hut (2180 m) on the same road.

Both the departure and arrival points can be reached by bus or car during the summer season. The itinerary descends along the slope until it reaches the Trafoi River. Next, it goes along the proglacial area. The trail crosses frontal moraines of the Little Ice Age and continues in a complex of glacial and debris flows deposits inside the proglacial area, reaching the sharp east lateral moraine (fig. 7).

The moraine ridge can be walked both along the edge (exposed path) and outside it (path no 14). Once the upper portion of the moraine is reached, it is possible to go down along its inner slope (fig. 7) and then to cross some roches moutonnées, below the glacier terminus, and join the trails on the slope leading to the Franzen Shöhe hut.

The development of the trail and its altimetrical characteristics are summarised in a profile (fig. 8)

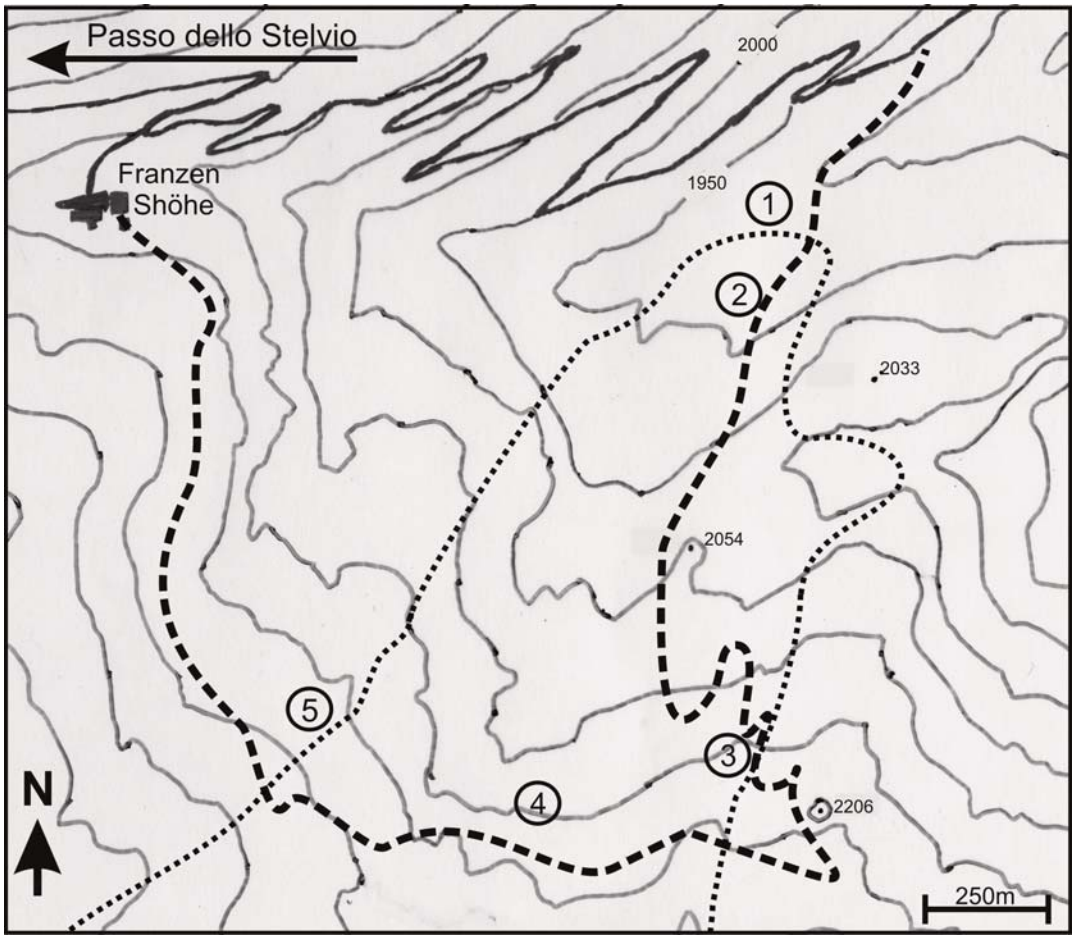

Fig. 6 – Simplified map showing the position of the proposed naturalistic trail (broken line) with the stops (numbered circles) suggested for the geomorphological and dendrochronological observations. The dotted line corresponds to the maximum advance during the LIA peak reached by the Madaccio Glacier.
– Carta semplificata che mostra la posizione del sentiero naturalistico proposto (linea tratteggiata) con l'indicazione degli stop (cerchi numerati) suggeriti per effettuare le osservazioni geomorfologiche e dendrocronologiche. La linea a punti corrisponde alla massima avanzata del Ghiacciaio del Madaccio durante la Piccola-Età Glaciale.

equipped with useful information for the hiker (e.g., width and morphology of the footpath, type of substrate etc.) (BOZZONI & PELFINI, 2007).

The itinerary we would like to create will be structured into stops allowing detailed observations, and sometimes panoramic views, of the landforms that characterises a proglacial area. Depending on the illustrative support, the itinerary will be provided with panels, guides, geotouristic map, etc.; the single situations will be described in detail with the aid of drawings and commented photos, referring, when necessary, to basic concepts useful to explain the phenomena.

6. – LANDFORMS AND TYPICAL SITUATIONS ALONG THE TRAIL

Using the results of scientific researches, some particularly meaningful points along the itinerary will be shown as an example of how we want to illustrate the entire path.

The Madaccio is the largest glacier of the Trafoi Valley and occupies a wide and irregular valley extending, north-south for 4.5 Km, between the three rocky peaks of the Madaccio mountain, on the east side, and the wide glacialized ridge that reaches the Passo dello Stelvio (2758 m) from Punta degli Spiriti (3465 m). This glacier is a typical alpine type, constituted by a wide accumulation area which originates one tongue reaching 2650 m. Its moraines deposed during the Little Ice Age and following advance and retreat phases are well represented almost everywhere (fig. 9).

The outmost frontal moraines, located at 1930 m, document the maximum Holocene advance corresponding to the LIA peak, which can be dated to 1821 (PELFINI, 1999 a-b) for the Madaccio Glacier (fig. 10) preceded by an advancing phase at the end of the 18th century.

The limits reached by the glacier tongue during the LIA are documented by portions of well preserved moraines, some of which are very sharp. On their inner slopes it is locally possible to ob-

Fig. 7 – The eastern lateral moraine of the Ghiacciaio del Madaccio. The pseudostratification given from the process of superposition is visible. The arrows indicate the small trail that crosses down the inner moraine slope (photo by Bozzoni, 2005).
– *Morena laterale orientale del Ghiacciaio del Madaccio. È visibile la pseudo stratificazione dovuta ai processi di sovrapposizione. Le frecce indicano lo stretto sentiero che attraversa il versante interno della morena (fotografia di Bozzoni, 2005).*

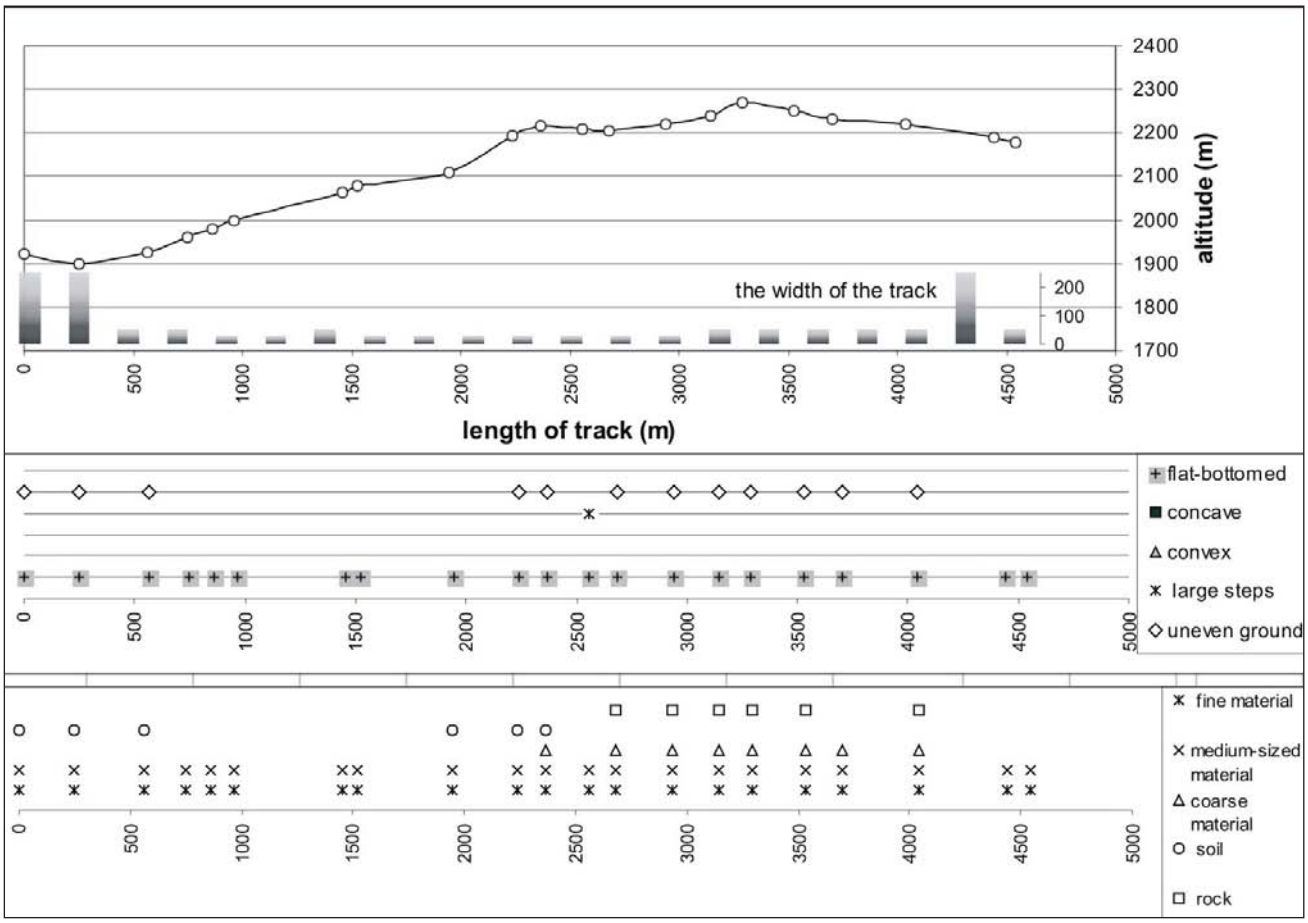

Fig. 8 – Profile of the Madaccio-Franzen Shöhe hut trail. The diagram evidences the altimetrical course referred to the real distance walked; the vertical bars in the upper diagram show how the width of the track changes along the trail; the table below supplies information about the morphological characteristics of the footpath (flat, concave, convex, irregular) and its surface (fine, medium, coarse, bedrock).
– Profilo del sentiero del rifugio del Madaccio-Franzen Shöhe. Il diagramma evidenzia l'andamento altimetrico riferito alla distanza reale percorsa; le colonne verticali nella parte superiore del diagramma mostrano come la larghezza del sentiero cambia lungo il percorso; la tabella sottostante fornisce informazioni sulle caratteristiche morfologiche del sentiero (piatto, concavo, convesso, irregolare) e sulle caratteristiche del fondo (fine, medio, grossolano, roccia).

serve the typical superposition structure. The trail segments located on the glacial deposit allow visitors to observe the sedimentological features and the moraine depositional processes in detail. The advances following the LIA maximum are widely documented by a network of low accretion and superposition moraines observable along the northwest margin (figures 9 and 11).

The Little Ice Age maximum extension of the glacier can be seen at the distal part of the moraine system (fig. 10). The trail allows to observe a stem half buried in the frontal moraine (figure 12; stop 1 in figure 6).

In this case, the buried trunk was useful to reconstruct the LIA acme phases (PELFINI, 1999 a-b): the stem could have been buried during the advancing phases already started at the end of the 17th century. The sequence of the glacier advances and retreat phases has been reconstructed by using also the ages of still living trees growing at the base of the outmost moraine and in the surrounding proglacial area. In fact, the trees located on the moraines indicate their minimum ages, while the age of those located in the proglacial area suggest when the glacier has retreated.

This is a representative case of how geomorphological and dendrochronological surveys are necessary one to the other in order to carry out paleoclimatic and paleoenvironmental reconstructions.

The proglacial area is characterised by the presence of many other tree remains deformed by the passage of the glacier and mostly uprooted (stop 2 in figure 6). In this case they can anyway supply information about the events characterising the upper Trafoi Valley in recent centuries. In fact many of the logs found in the proglacial area belong to trees buried between the end of the 17th and the second half of the 18th century. They probably testify the climatic crisis that caused the death of many trees.

The eastern margin of the glacier is delimited by a long and sharp moraine the crest of which can be walked along by a diversion of the proposed trail (fig. 7, 13).

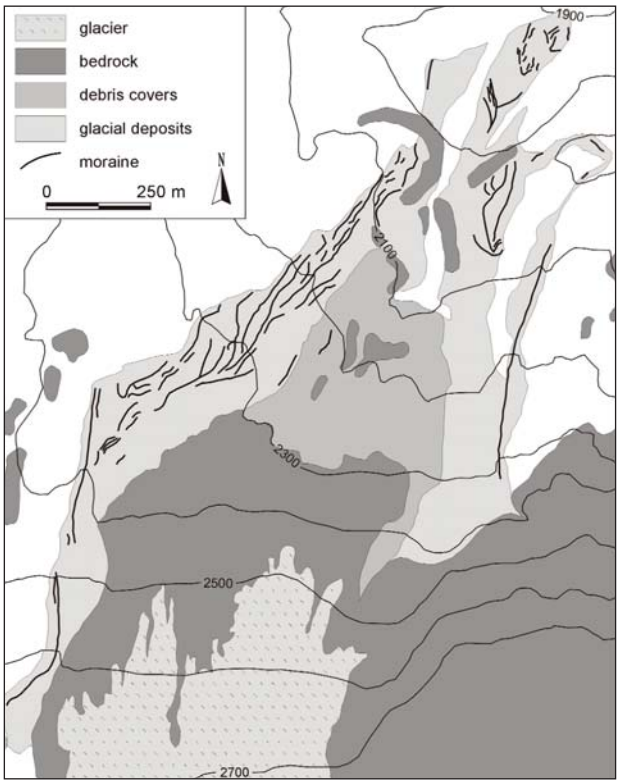

Fig. 9 – Sketch map of the proglacial area of the Madaccio Glacier. All the moraines recognised during the field survey are represented in this map. In the east side the past glacier boundary is represented by a huge moraine; in the west side minor glacier fluctuations are documented by a great number of small ridges.

– Mappa schematica dell'area proglaciale del Ghiacciaio del Madaccio. Tutte le morene individuate durante il rilevamento di campagna sono state rappresentate in carta. Nel settore orientale il limite dell'estensione passata del ghiacciaio è rappresentata da una grande morena; nel settore occidentale fluttuazioni minori del ghiacciaio sono documentate da un grande numero di piccole creste.

On the inner slope, subject to erosion, it can be seen the typical superposition structure characterising a great part of lateral moraines. Along this slope, at 2170 m and about 80 cm below the top, a fragment of larch (*Larix decidua* Mill.) emerges, being buried inside the moraine (fig. 13), while another log, placed along the glacier flow direction was found slightly further down-valley (stop 3 in figure 6). To precisely identify the species of the two buried trunks, an anatomical identification using wood sections and microscope (SCHWEINGRUBER, 1982) was done (fig. 14).

The position of the first sample in relation to the moraine in which it was recovered indicates that the construction of this lateral moraine occurred in two steps (fig. 15).

Initially, this tree probably died for other causes (e.g. mass movement) and later it has been left on an initial glacial deposit. Later, a new glacier advance has placed more till on the first moraine burying the dead tree. Successively, erosion of the inner slope of the moraine, connected with glacier shrinkage, exposed again the buried tree. Moreover, it is possible that the top part of the tree was broken by the glacier in advance and dragged a little further down-valley.

The chronostratigraphic situation indicates that at the date of death of the tree (second decade of the 19th century) the glacier was still in a growing phase, as demonstrated by the thickness of debris covering the log (figures 13 and 15).

The trail portion crossing the bedrock below the glacial tongue (2200 m of altitude), allows to observe the glacial erosion (stop 4 in figure 6). The glacier striae, lunate fractures and roches moutonnées are well preserved and common.

Along this part of the trail, and partially on its left side, traces of faded red painted marks are visible on the bedrock (fig. 16).

Many of them are difficult to decipher. They are

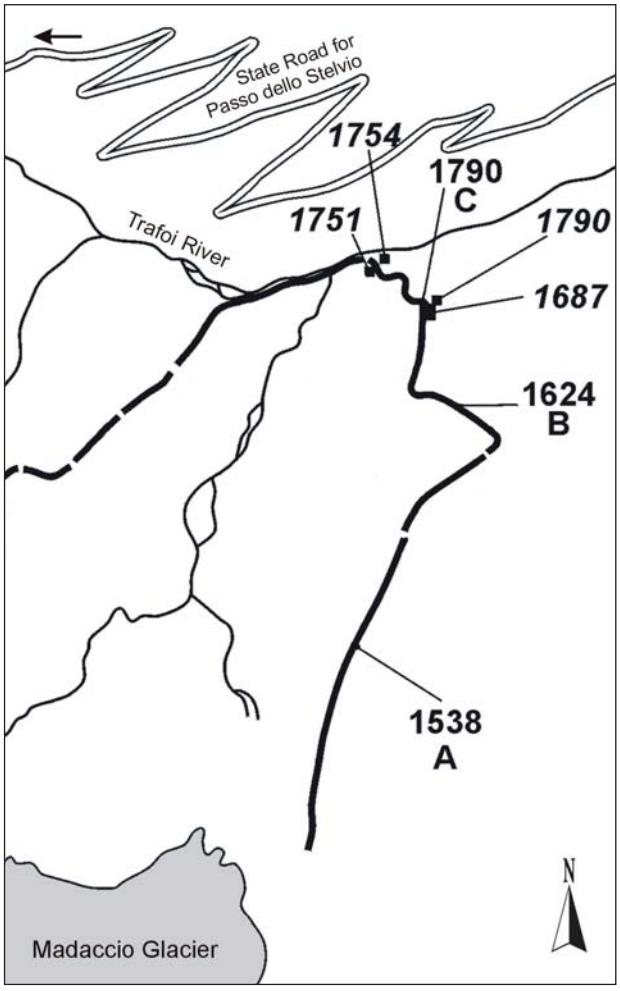

Fig. 10 – Limit of the maximum expansion of the Little Ice Age of the Ghiacciaio del Madaccio. The numbers correspond to the years of death of the trees buried in the frontal moraine. The data come from previous researches (modified from PELFINI, 1999a).

– Limite della massima espansione del Ghiacciaio del Madaccio durante la Piccola Età Glaciale. I numeri corrispondono all'età di morte degli alberi sepolti dalla morena frontale. I dati provengono da ricerche precedenti (modificato da PELFINI, 1999a).

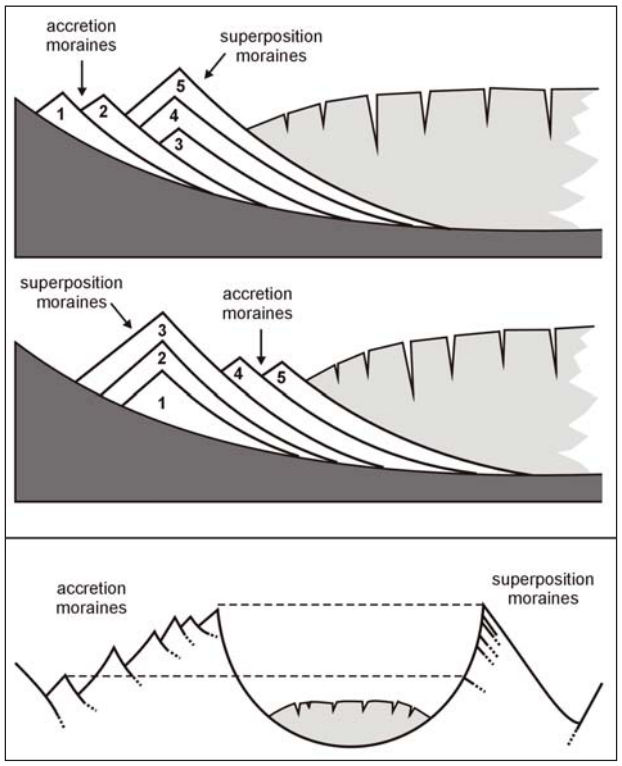

Fig. 11 – This kind of scheme, showing the formation of accretion and superposition moraines, helps visitors to better understand what they can observe in the field. This model is typical of many moraines of Madaccio Glacier and it is recognizable walking along the upper Trafoi Valley (fig. 7).
– Questo tipo di schema, che mostra la formazione delle morene per sovrapposizione e accrezione, aiuta a comprendere meglio ciò che si può osservare sul terreno. Questa struttura caratterizza molte delle morene del Ghiacciaio del Madaccio ed è facilmente riconoscibile camminando lungo la Valle del Trafoi (fig. 7).

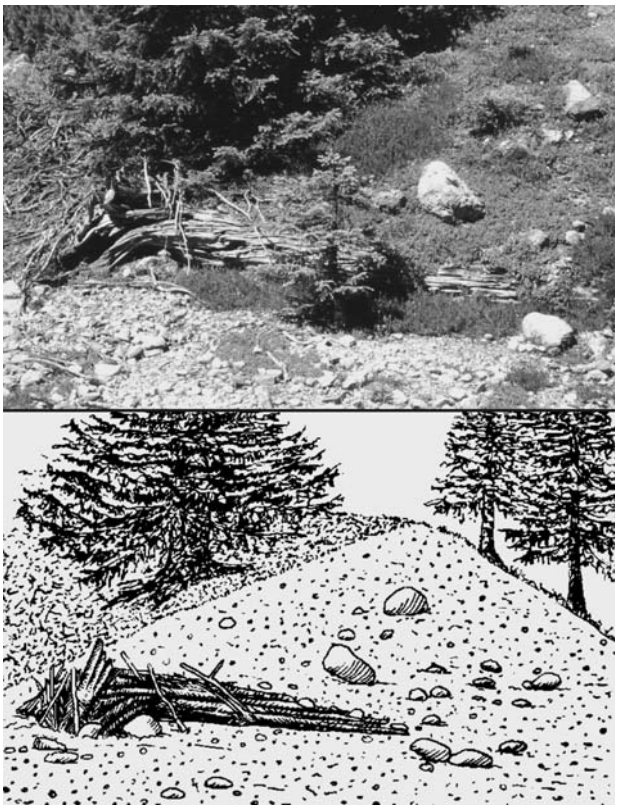

Fig. 12 – Buried trunk in the frontal moraine built by Madaccio Glacier (stop 1, figure 6) (taken from PELFINI, 1999a).
– Tronco sepolto dalla morena frontale del Ghiacciaio del Madaccio (stop 1, figura 6) (tratto da PELFINI, 1999a).

benchmarks used in the past as photographic stations, for annually reading the glacier terminus, or as references for measuring the distance from the glacier tongue. Repeated measurements over time allows to evaluate advances and retreats of the glacier tongue. Long-enough data series allow the creation of time-distance curves (fig. 17), from which glacier behaviour can be analysed (advanced, stasis, retreat).

These benchmarks are now abandoned because they are too far away from the terminus, and have been replaced by other more recent ones at higher altitude near the present glacier margin. Use of these benchmarks can be found in the reports of past glaciological surveys, but the message that they must transmit to tourists is to show the remarkable glacier retreat in the field.

On the west side of the valley, outside the Madaccio Glacier moraine system, it is possible to observe an interesting network of lateral moraines (fig. 9), from different points along the trail (stop 5 in figure 6). The moraines indicate the presence of a glacier tongue not thicker as the lateral one, but depressed as documented by the low profile assumed by the several ridges. The short adjacent

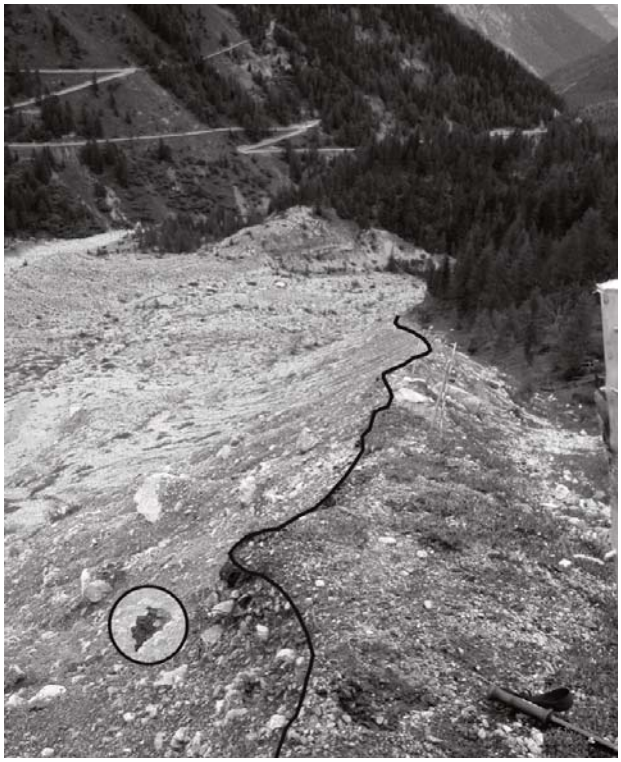

Fig. 13 – The edge of the east lateral moraine (black line) and a buried log emerging along the inner slope (in the circle) (photo by Pelfini, 2004).
– Cresta della morena laterale orientale (linea nera) e tronco sepolto che emerge lungo il versante interno (nel cerchio) (fotografia di Pelfini, 2004).

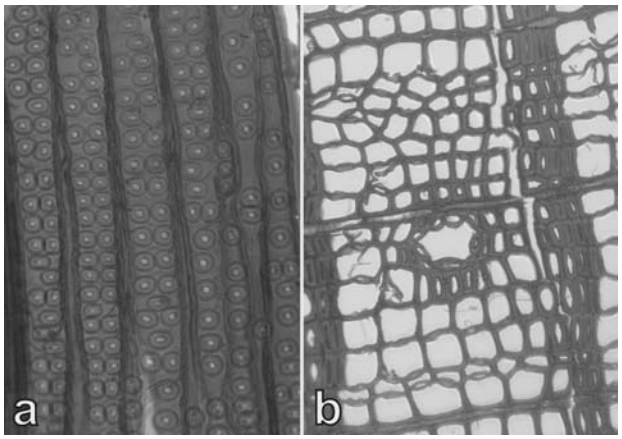

Fig. 14 – Thin section (15 µm thick, 200x) prepared for species identification. Both samples are *Larix decidua* Mill. (a) radial section, (b) transversal section (photo by Leonelli, 2005).
– Sezioni sottili (15 µm di spessore, 200×) preparata per l'identificazione delle specie. Entrambi i campioni sono Larix decidua Mill. (a) sezione radiale, (b) sezione trasversale (fotografia di Leonelli, 2005).

and locally overlapped moraines were deposited in relation to short-term climatic changes. They testify that the glacier margin remained in this position for rather a long time or that the front reached it after an advance followed by a phase of retreat. It is interesting to note that the moraine edges are sometimes close side by side, and that in other situations they emerge from the sides of larger ridges.

Focussing on the edges of single moraines, we can imagine the different shapes and extensions the glacier margin assumed here sometimes. At a certain moment in this complex succession of events, the glacier also tried to generate a small lateral tongue. This is documented by the two lobe shaped moraines departing from the previous moraine system and heading towards the small fluvioglacial plain.

7. – CONCLUSION

From the illustrated examples, we conclude that classic geomorphological research supplies the basis for understanding phenomena and processes leaving extremely detailed documentation in the field, but usually it can be recognized only by the expert eye. However it is possible to offer a correct and scientific knowledge through simplifications easily realizable using photos, schemes, drawings etc also to people without a naturalistic culture. In this way, an itinerary, where the beauty of the landscape dominates, supplies also the possibility to give a good scientific formation.

In the specific case here presented, the support of other disciplines such as dendrochronology, allows not only a detailed reconstruction of histor-

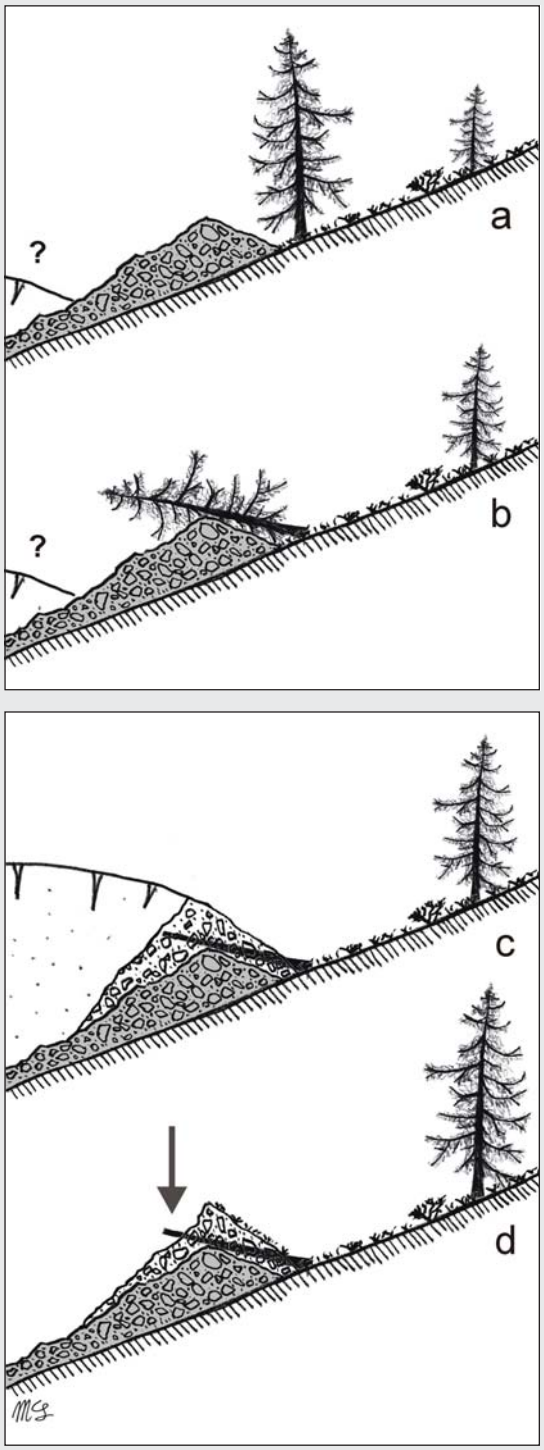

Fig. 15 – The scheme represents the hypothetical "history" of the buried tree. The tree is still living (a). The tree dies from unknown causes, but not ones due to direct glacier action, and lies down on the forming moraine (b). The glacier is still growing and continues to deposit till on the previous moraine covering the trunk (c). When the glacier retreats, the top of the trunk emerges due to erosion processes active on the inner moraine slope (d).
– Lo schema rappresenta l'ipotetica "storia" del tronco sepolto. L'albero è ancora vivo (a). L'albero muore per cause ignote, comunque non legate all'azione diretta del ghiacciaio e cade sulla morena che si sta formando (b). Il ghiacciaio continua a crescere e ad accumulare materiale sulla morena ricoprendo il tronco (c). Quando il ghiacciaio arretra la parte superiore del tronco affiora a causa dei processi erosivi attivi sul versante interno della morena (d).

Fig. 16 – Black benchmark (red in the field), now in disuse, used for measuring the frontal variations of the glacier tongue. Numbers and acronyms codify the mark and refer to the glaciological operator and to the year in which the bench mark was placed (photo by Carton, 2004).
– Caposaldo (rosso nell'immagine), ora in disuso, utilizzatio per misurare le variazioni frontali della lingua del ghiacciaio. Numeri e codici individuano il segno e si riferiscono all'operatore glaciologico e all'anno in quale il caposaldo è stato posizionato (fotografia di Carton, 2004).

ical glacier fluctuations but also the identification of events (e.g. glacier advances) whose geomorphological evidences have been cancelled by erosion processes or are now unrecognisable in the field. The help of images and schemes proposed in the various stops, permits a detailed understanding of the evolutionary phases of a natural event and offers suggestions for enquiry from other sectors of naturalistic disciplines. In this case, for example, in order to proceed with dendrochronological dating, tree species identification is necessary, and demonstrates how also the disciplines that analyse very specific details can contribute to a broad research.

Apart from proposing an itinerary, this work suggests how to prepare a geotouristic, guided trail, able to easily transmit to a wide public the results of the basic research. Moreover, beyond logistic information indicating difficulty, walking times, unevenness, etc., it wishes to emphasize the importance of including an explanation of the geomorphological evolution of the territory; in our case the trail emphatize glacier history, glacier morphology, the documentation of the geomorphological processes and the climatic signal in the tree vegetation, using description, illustrations and drawings of the phenomena at the stops. Often an image, even if just seen rapidly along a mountain trail, can explain better and in a more effective way than a written text. In any case the realization of this itinerary, like any other one realized in mountain areas, must first observe the land management laws and rules imposed by the single Countries. The path here proposed has the aim to outline and enhance the important relationships between the scientific knowledge and the educative applications.

Infact we think that all the tourist mountain paths should be associated to a scientific support in order not only to enjoy the itinerary and improve people naturalistic knowledge but also to promote the dissemination of the scientific results, also increasing the link between academic activities and educational purposes.

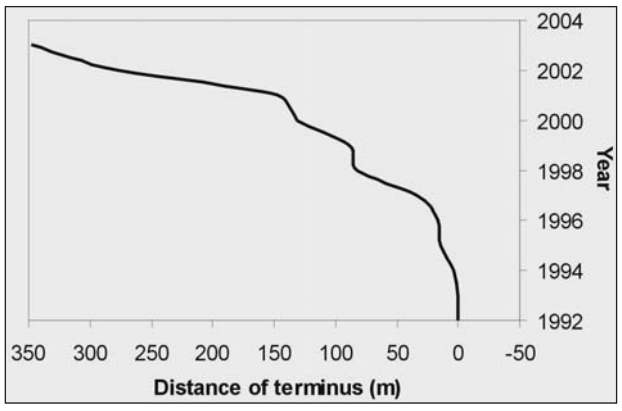

Fig. 17 – Example of a time/distance curve outlining Madaccio glacier terminus movements over time (modified from GHEZZI, 2004).
– Esempio di curva tempo/distanza che evidenzia i movimenti della fronte glaciale nel tempo (modificato da GHEZZI, 2004).

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