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TRACES OF ANCIENT GLACIATIONS IN KARST ENVIRONMENT - A CASE STUDY IN THE VENETIAN PREALPS

SLEDOVI STARIH POLEDENITEV V KRAŠKEM OKOLJU – ŠTUDIJA PRIMERA V BENEŠKIH PREDALPAH

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Abstract UDC 551.324.8:551.44(234.323.4)
Ugo Sauro: Traces of ancient glaciations in karst environment - a case study in the Venetian Prealps
To reconstruct the ancient glaciations of a mountainous area, it is necessary to consider together, in their topographic contexts, the forms of erosion and those of accumulation, aiming to model the relative glacial systems, which can be understood on the basis of the interrelationships between the various forms. In the karst areas, the forms of glacial erosion are often easily recognizable, given that the geomorphological dynamic favours their conservation. The very ancient deposition forms, on the other hand, are hardly detectable or absent given that chemical erosion contributes to the decrease in volume of the moraines until their total disappearance. As an exemplary case, the relict forms of the ancient local glacial system of Valon del Malera, developed in jurassic limestone and Main Dolomite (Dolomia Principale), partly preserved in the Lessini Mountains (Prealpi Venete, NE Italy) and partly in the nearby Carega massif (Piccole Dolomiti), are illustrated. The forms of erosion document the dismantling of a segment of a glacial valley due to accelerated erosion phenomena attributable to active tectonics along an important fault system. Other segments of the trough-shaped glacial valley are very well preserved. On the other hand, forms resulting from the "over-imprinting" of some ancient morainic ridges are detectable, due to the fact that in favourable cases the morainic cover has reduced the rate of lowering at the cover-rock interface of the underlying limestone, in comparison with the surrounding rocky surfaces not covered by till deposits, causing the formation of rocky ridges. However, the temporary aquifer hanging within the moraine has favoured the development of grike type covered Karren in the limestone, with isolated spikes or pillars of rock. Ridges mainly or totally formed by rock in place are described, which, according to all evidence, seem to be the result of the "over-imprinting" by ancient moraine ridges partly or totally eroded.
Keywords: relict glacial forms in karst areas, morainic ridges, over-imprinting, karst solution, Venetian Prealps.

Izvleček UDK 551.324.8:551.44(234.323.4)
Ugo Sauro: Sledovi starih poledenitev v kraškem okolju – študija primera v Beneških predalpah
Za rekonstrukcijo starodavnih poledenitev na gorskem območju je treba v njihovem topografskem kontekstu skupaj obravnavati oblike erozije in akumulacije, da bi lahko modelirali relativne ledeniške sisteme, ki jih je mogoče razumeti na podlagi medsebojne povezanosti med raznimi oblikami. Na kraških območjih so oblike ledeniške erozije pogosto zlahka prepoznavne, saj so se zaradi geomorfološke dinamike dobro ohranile. Ob tem pa so zelo stare oblike odlaganja komaj zaznavne ali jih sploh ni, saj se je tudi zaradi kemičnega preperevanja zmanjšala prostornina moren, pri čemer so nekatere popolnoma izginile. Kot vzorčni primer so prikazane reliktne oblike starodavnega lokalnega ledeniškega sistema Valon del Malera, razvitega v jurskem apnencu in glavnem dolomitu, ki se je delno ohranil v Lesinskih Alpah (Beneške predalpe, SV Italija), delno pa v bližnjem masivu Carega (Mali Dolomiti). Iz oblike erozije je razviden razpad segmenta ledeniške doline zaradi pospešene erozije, ki jo je mogoče pripisati aktivni tektoniki vzdolž pomembnega sistema prelomov. Drugi deli ledeniške doline, ki so v obliki korita, so zelo dobro ohranjeni. Poleg tega je mogoče zaznati oblike, ki so posledica čezmernega odtisa nekaterih starih morenskih grebenov, saj se je v ugodnih primerih morenski pokrov na stiku pokrova in kamnine osnovnega apnenca počasneje zniževal v primerjavi z okoliškimi skalnatimi površinami, ki jih ne prekrivajo nanosi meljevca, kar je povzročilo nastanek skalnatih grebenov. Vendar je začasni vodonosnik, ki je visel znotraj morene, spodbudil razvoj pokritih škrapelj v apnencu, z izoliranimi skalnimi vrhovi ali stebri. Opisani so grebeni, ki jih večinoma ali v celoti oblikujejo kamnine na mestu, za katere se glede na vse dokaze zdi, da so posledica čezmernega odtisa starih morenskih grebenov, ki so delno ali v celoti erodirani.
Ključne besede: reliktne ledeniške oblike na kraških območjih, morenski grebeni, čezmerni odtis, kraško raztapljanje, Beneške predalpe.

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1. INTRODUCTION

Some relicts elements of a local glacial system in the Lessini Mountains (Venetian Pre-Alps) are investigated in this paper (Figure 1). Such system is indicated with the toponym of its most typical glacial form (Valon del Malera) (Figure 2, Figure 3), a glacial trough present in the NE sector of the main plateau. This system shows forms of medium and small size, given that the relative glacier has never reached 10 km in length.

At this point it is important to underline that in research on ancient glaciations it is essential not to limit oneself to the analysis of single forms of erosion or deposition, but must consider as a whole the complex of

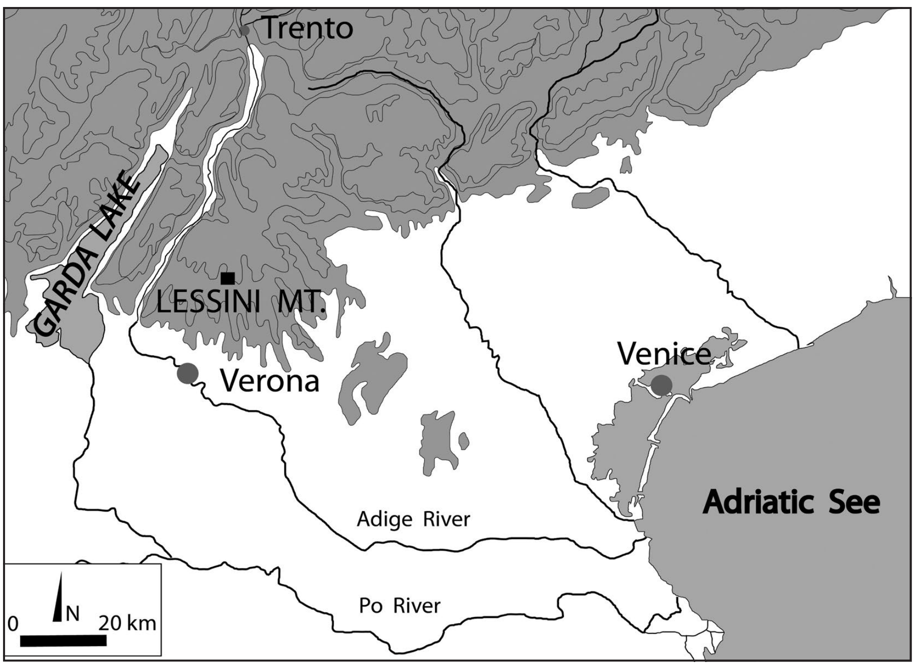

Figure 1: Location of the studied area.

Figure 2: The glacial trough of Valon del Malera, on the right, and the Carega Group (maximum elevation of 2259 m asl), on the left.

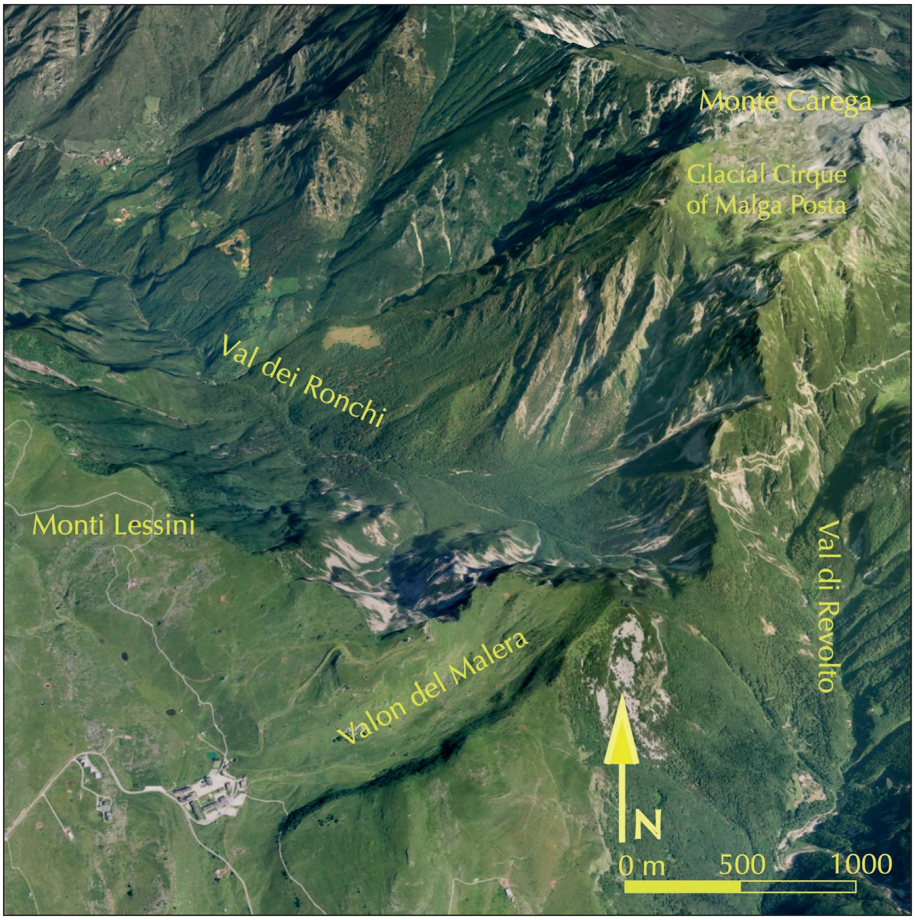

Figure 3: The furrow of the Valon, below, and the cirque of Malga Posta, above. Between the two is the deep incision of the Val dei Ronchi.

forms, aiming at the reconstruction of the "ancient glacial systems". In other words, it is necessary to conceive models, albeit approximate, of the ancient glaciers, which are compatible with the relative complex of forms of erosion and deposition, considered in their topographic and morpho-dynamic contexts.

The primary purpose of this note, however, is not simply to analyse some relict forms and to identify the related 'system', investigating aspects that seem to be of predominantly local or regional interest. Instead, we try to demonstrate how the integrated analysis of some problematic forms, considered in their context, can lead to the definition of morphogenetic models in which the interferences between different processes, such as the glacial and the karst ones, are considered. The application and verification of models of this type in researches on similar glacial systems of the Pleistocene, recognizable in selected orographic karst units of the Alps and of the Dinaric Mountains, as well as in other mountain groups in soluble rocks, could, in perspective, provide further data useful for understanding the paleogeography and chronology of old local glaciations.

Fundamental premise for the study and 'reconstruction' of a glacial system is the fact that such system can never be considered the 'photograph' of a precise moment of the past. In fact, the 'current photo' of the traces and components of the system is the result of the overlapping of an undefined number of phases of formation, growth, retreat and extinction of a glacier that occupied the upper part of a given mountain, which has been changing over time. Therefore, we have to treat with a 'poly-chronological' and complex glacial system, within which it is possible to try to recognize a 'stratigraphy of forms'.

Another important consideration is that the history of Pleistocene glacialism is decidedly more problematic in the mountainous areas formed by carbonate rocks, such as limestone and dolomite, than in mountains made up of crystalline and metamorphic rocks. In fact, if the karst process can favour the conservation of large and medium-sized forms of erosion, the processes of erosion and dissolution can determine variations in the volume and shape of the moraines. A form of deposition, such as, for example, a morainic ridge made up mostly of calcareous diamicton, is subject to changes of volume and shape due to mechanical erosion and karst dissolution. Therefore, these depositional bodies tend to lose volume not only by mechanical erosion, but also by 'chemical erosion', becoming thinner, until they are completely removed. This explains, at least in part, the difficulty of reconstructing the ancient glacial history within the karst mountains.

In any case, it should be borne in mind that the reconstruction of the 'paleogeography of the glaciations' is particularly problematic also for the surfaces where crystalline rocks prevail, including the mountainous areas that hosted the great Alpine glacial systems, as can be seen from a review of studies of the past. For example: a) the fundamental work on the glaciation of the Alps (Penck & Brückner, 1909), has been the subject of countless discussions and 'corrections' by different authors, without ever reaching a solution deemed definitive; b) the Quaternary scholar Sergio Venzo, after having analysed the morainic amphitheatre of Garda Lake (Venzo, 1965, 1969), formulated, after a few years, different and contrasting reconstruction. This difficulty is explained by the fact that, during the Pleistocene, in a complex sedimentary building, such as the above mentioned Garda morainic amphitheatre, many phases of retreat and advance of the glaciers have occurred, with modification and reworking of the glacial deposits of the previous glaciations. Other more recent papers underline the complexity of the glacial history of the large glacial systems of the Alps (Ravazzi et al., 2014; Monegato et al., 2017). On the problems of the paleogeographic reconstruction of the evolution of Garda morainic amphitheatre, see also the works: Habbe, 1969; Chardon, 1975; Cremaschi, 1987, 1990; Castiglioni, 2004; Sauro, 2005.

2. RELICT FRAGMENTS OF AN OLD LANDFORM OF GLACIAL EROSION

In the high Lessini Mountains, understood in the strict sense (plateau between the Val d'Adige and the Valle d'Illasi), there is clear evidence of forms of glacial erosion and deposition referable to the Upper Pleistocene and in particular to the last phase (LGM) of glacial expansion known as Würm III, dating back to about 30-18 ky (Sauro, 1973; Ragnolini & Sauro, 1982). Here we do not resume the descriptions of the mentioned papers, which remain fundamentally valid with regard to the last glacial expansion. Instead, we will try to clarify some aspects relating to landforms and deposits that could be the result of more ancient events. In fact, as we shall see, some of the forms of glacial erosion and deposition certainly have a lifespan longer as a few tens of ky, of the order of magnitude of hundreds of ky, and in some cases, perhaps, of over one million years (1 My).

For simplicity, we will limit ourselves to consider a complex of forms as referable to a single ancient glacial system, starting from the analysis of the main forms of glacial erosion, and then delving into the problems of identifying and studying the traces of the related depositional forms.

In fact, in the Lessini Plateau the only truly typical form of glacial erosion is the Valon del Malera, which looks like a 'glacial trough', that is a valley with a U-shaped transversal profile, over 2 km long, about 500 m wide, extended between 1500 and 1865 m a.s.l., and relatively deep (Figure 2). At first sight, this glacial valley appears as oversized, if compared to the surrounding glacial forms. It also lacks a head in form of a 'glacial cirque', so much so that it seems that its upper part was dismantled following the retreat of the head of the Val dei Ronchi, a tributary of the Adige Valley. Also the morainic cover that occupies the high Vajo di Squaranto (the morphonym "vajo" means deep valley with canyon like characteristics), which constitutes the continuation of the Valon towards south, is of considerable extension.

The hypothesis that in ancient times the glacial trough of Valon extended further north, when the Lessini plateau was still connected with the Carega dolomitic group, has been formulated by several authors and is well presented and discussed by Corrà (1970a, 1970b, 1976). It is certainly plausible, as it justifies the relatively large size of this U-shaped valley, and, in part, also the characteristics of the high Vajo di Squaranto, which is particularly wide in its upper part.

If we look at the Carega group we can hypothesize that the ancient head of the Valon was located right at the glacial cirque of Malga Posta (maximum elevation of 2259 m asl), whose valley threshold is about 2.5 km far from the upper edge of the Valon (Figure 3). Between the two forms of glacial origin there is now the head of the spectacular Val dei Ronchi, which is set along a bundle of active faults and is subject to accelerated erosion, as well as the entire Carega dolomitic massif. This is demonstrated by the very frequent seismic crackling, detected by the seismic network of the province of Trento, which makes it one of the most active tectonic structures in the southern Alps (Sauro & Ferrarese, 2016).

So, the connection between the two glacial forms (Cima Posta cirque and Valon del Malera) must have been interrupted since the lower-middle Pleistocene (?) by the piracy action of the receding head of Val dei Ronchi, causing important geomorphological changes. But, we must consider that glacial currents are often able to overcome vertical obstacles. It is therefore possible that, in ancient glacial expansions (pre-upper Pleistocene), subsequent to the 'dismantling by piracy' of a long segment of the ancient Cima Posta-Valon trough, part of the glacial flow of Val dei Ronchi was transfluent in the Valon, helping to feed the relative glacial tongue.

In favour of this latter hypothesis, there are some forms, such as massive, overhanging and rounded limestone frames, which characterize the upper band of the right slope of the Valon trough, and particular glacial contact potholes present on the walls of the right side of the upper Vajo di Squaranto. Such evidences would suggest that, in not very ancient phases, the glacial tongue of Valon himself had a considerable thickness, almost to the point of filling the relative valley (Ragnolini & Sauro, 1982).

In favour of this interpretation, a wide 'rock-cut-terrace' like surface is also recognized, indicated with the name of 'surface of Malga Bosco', which extends downstream of the first segment of the upper Vajo di Squaranto, which can be interpreted as the relict of the ancient glacial valley bottom, hanging by about 70-110 m above the narrow fluvial incision that marks its western edge. Therefore the relict segments of the ancient glacial forms seem to document a glacial system with a total length of about 9 km and an altitudinal range of about 900 m.

3. FORMS AND CHARACTERISTICS OF THE GLACIAL DEPOSITS

The morainic deposits of the Valon glacier are present in the Valon segment located upstream of the confluence in the upper Vajo di Squaranto and, especially, in the upper part of the vajo itself, in the form of an almost continuous cover, characterized by large undulations and irregularities. It could be the result of several depositional phases, referable to the middle and upper Pleistocene (Figure 4). The surface of the deposits is dotted with medium and large boulders, which are affected by forms of karst solution. If man had not partially removed the stones to improve the grazing area, it would have been interesting to analyse the morphometry and distribution of the boulders, which on the oldest surfaces should have smaller dimensions and minor density.

Among the many forms worthy of attention, a relief located NW of Malga Porcarina deserves to be reported:

Figure 4: Overview of the terminal segment of Valon del Malera (bottom left) and the upper Vaio di Squaranto with its extensive morainic cover. Highlighted are the morainic covers of upper Vajo Squaranto (1); the "over-imprinted ridge" of Porcarina (2); the "over-imprinted ridge" of Malga Bosco (3); the "over-imprinted ridge" of Spiazzoi (4); the rock cut terrace of Malga Bosco (5); and the incision of the Vajo di Squaranto (6).

Figure 5: The "over-imprinted ridge" of Malga Porcarina (immediately upstream of the paved road and with some cows grazing above it), resulting from an ancient lateral moraine now almost completely removed by chemical erosion.

it is a low ridge that extends for a length of about 300 meters and a width of 60 meter (Figure 5, Figure 6), parallel to the asphalted road that descends from San Giorgio towards the Parpari locality. This could be the remains of a lateral morainic ridge deposited by a glacial tongue larger than that of Würm III. Curiously, this ridge is mainly formed by rock in place and only locally has a thin and discontinuous cover of weathered till material, as evidenced by some scattered boulders.

This shape could be explained by the fact that at first the morainic ridge was several meters thick, but later the karst solution processes consumed the moraine. The latter, on the other hand, 'protected' the underlying rock, in which the solution processes led to an average lowering of the 'moraine / bedrock interface' lesser than that which would have occurred if the moraine cover had not existed.

From a chronological point of view, on the ridge is

Figure 6: Forms of the 'covered karst' within the "over-imprinted ridge" of Malga Porcarina, which are explained by the action of the ancient temporary aquifer hanging within the moraine.

significant the presence, as well as weathered till deposits of modest thickness, of paleosols of the 'terra rossa' type, which are not found on the more recent moraines, on which loess-like sediments are instead observed, characterized by less evolved soils. In the paleosols, highlighted in correspondence with the excavation of a drinking ponds for cattle, flint tools from the Middle Palaeolithic were collected, referable to Levallois typologies. In the more recent moraines, flints of the Epi-Paleolithic (Epigravettian) have been collected (Chelidonio et al., 1990, 1992).

Returning to the shape of the ridge, it is obvious that it cannot be defined as a morainic ridge, since it is mainly made up of massive limestone in place. The only possible interpretation is that this shape is the result of a particular process of "over-imprinting" of a moraine on the underlying rock. It is therefore proposed to give this shape the definition: "*rocky ridge derived from the over-imprinting of a morainic ridge*", or the shorter one of "*over-imprinted ridge*".

About 1 km south of Malga Porcarina, on the left side of the Vajo di Squaranto, there is a wide rock cut terrace on which the buildings of Malga Bosco (elevation of 1363 m a.s.l.) are located. This is the terrace like rock surface, hanging of about 70-110 m above the current valley incision, previously described and interpreted

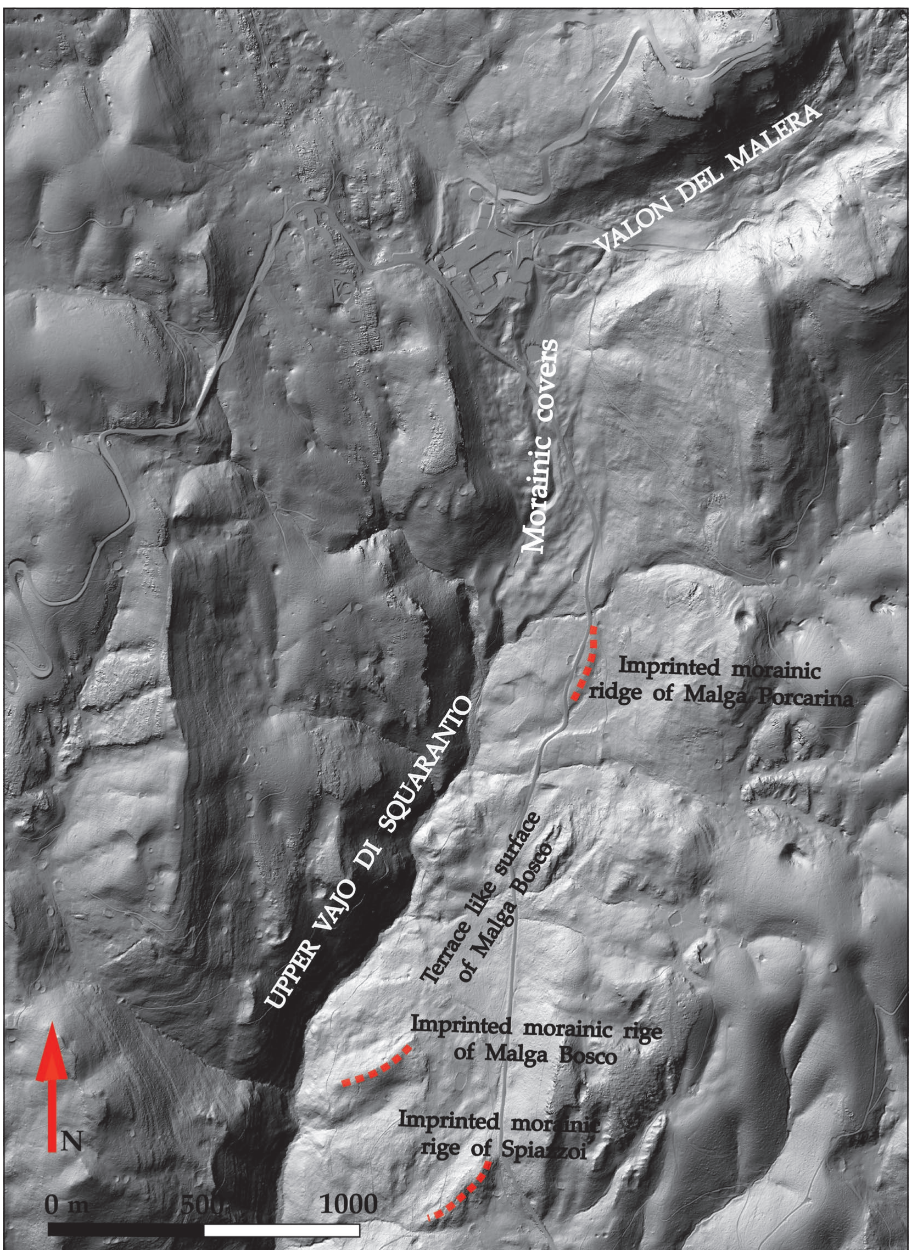

Figure 7: Lidar DEM of part of the studied area. The three broken lines show the ridges that could have derived from the over-imprinting of morainic ridges.

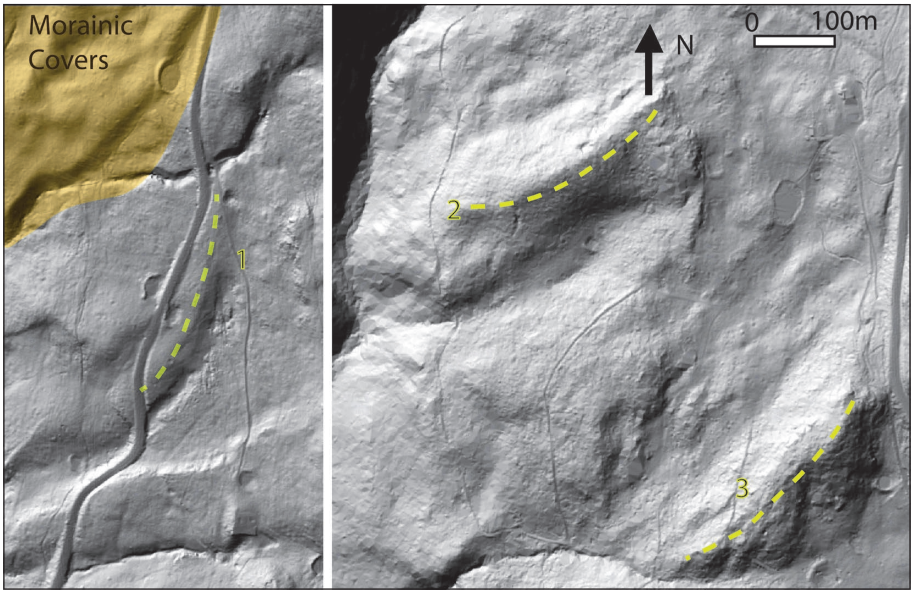

Figure 8: Details of the three "over-imprinted ridges" in a Lidar DEM. The more southern could derive from terminal morainic arches deposited when the connection between the Malga Posta cirque (Carega Group) and Valon del Malera still existed.

as a relict of the bottom of a wide glacial valley. It is the result of an ancient modelling, probably carried out in several advances of glacial tongues that favoured the enlargement of the valley floor. In the context of this 'terrace' we have tried to recognize others "*over-imprinted ridges*". In fact on the DEM-Lidar it is possible to distinguish two slightly arched ridges (Figure 7). One is SW of Malga Bosco and is about 300 m long and 100 m in width; its high range above the surrounding surfaces is of about 10-15 m; the other ridge is between the pasture areas of Malga Bosco to the north and those of Spiazzoi to the south, and presents about the same dimensions of the previous one. Both are covered by woods and, due to their planimetry, they could be interpreted as segments of arches with the concavity upstream. These are difficult landforms to explain, also due to their remarkable topographical evidence. Probably they are "*over-imprinted ridges*" corresponding to segments of terminal moraines of considerable size and thickness (Figure 7, Figure 8), deposited when the connection between the Malga Posta cirque and the Valon del Malera trough still existed.

These shapes, being entirely covered by the forest, are not well perceptible in their characteristics. Visiting them, it is possible to observe a high degree of karstification with scattered blocks of limestone and toppling phenomena affecting the slopes.

4. ASPECTS OF THE INTERFERENCE BETWEEN THE GLACIAL AND THE KARST PROCESSES

In the areas in soluble rocks, which have been affected by the expansion of glaciers, it is interesting to consider the inter-relationships between the glacial processes (erosion and deposition) and the processes of karst dissolution, which we prefer to call 'chemical erosion.' In fact, in some glacialized areas, chemical deposition phenomena at the ice/rock interface (known as '*sub-glacial calcite precipitates*') can sometimes be observed, as on certain mountain in the Alps and in the Rocky Mountains (Muir & Ford, 1985). In general, however, chemical deposition is clearly subordinated, in terms of entity, to chemical erosion.

The best known forms, deriving from the combination of the glacial and the karst processes, are the cirques and the closed glacio-karstic depressions in the bottom of the glacial cirques and valleys, and in the plateaux areas. These forms are the result of the cooperation between the 'over-excavation' operated by the glaciers and the chemical erosion of the rocks, which occurs mainly on the bottom of the depressions. However, while the first process operates when the glaciers are present, the second prevails after their extinction, favouring, among other things, the drainage of temporary lakes eventually present in the depressions. Thus, in the Dolomitic groups of Italy there are known both closed depressions completely devoid of bodies of water, and depressions within which there are lakes subject to strong variations in level and, in some cases, ephemeral, as they are present only for a few days in concomitance with the snow thawing (Bini et al., 1997; Sauro, 2007).

Less studied is the issue of the role that the karst process may have played in modifying the forms of glacial deposition. Obviously, chemical erosion causes a decrease in the volume of the moraines, which are, however, also affected by mechanical erosion, especially in the context of the steepest slopes.

Some methods make it possible to calculate chemical erosion at an areal scale, based on the hydrological balance of a basin and the mineralization of the runoff waters, in particular those of the karst base level springs (Meneghel et al., 1986; Pulina & Sauro, 1993). Thus, as an example, in the basin to which the studied area belongs (basin of the Montorio springs, near Verona), the average chemical erosion corresponds to a rock thickness of the order of 3,9 cm/1000 years (about 39 m per million years) and therefore, of about 1170 m, if extrapolated to about 30 million years, the estimated age from when this territory emerged from the sea. This is certainly a value higher than that of the thickness of the rock actually removed, which could be of the order of 300-500 m, about a third of the value mentioned above. There are numerous variables which make it difficult to calculate the average lowering of the topographic surface, including the fact that chemical erosion does not only affect the surface but also occurs in depth. Furthermore, in certain climatic phases the winds have deposited considerable thicknesses of loess, consisting mainly of silts deriving from carbonate rocks (Cremaschi, 1990); and again, within the carbonate sequences there could also be volcanic rocks.

For these considerations, on a morphometric basis it is almost impossible to establish the age of the overprinted ridges. The only chronological indication that at the moment can be provided for the ridge of Malga Porcarina is given by the presence of flint stone tools of the middle Palaeolithic within a 'terra-rossa' type of soil. But the two most southern ridges are much more weathered than the Malga Porcarina ridge.

5. DISCUSSION AND CONCLUSIONS

There is no doubt that the glacial valley of which we have described relict erosional forms is referable to a very ancient glacial system, even if at the present state of knowledge it is practically impossible to attribute a well defined age range to this system. The state of preservation of the relict elements denotes how the conservative forms are in contact with strongly modified forms resulting from accelerated erosion processes. In fact, a long segment of the great glacial valley, corresponding to the Cima Posta threshold - head of the Val dei Ronchi - upper margin of the Valon trough, has been completely dismantled, while the segments further downstream, within the Lessini mountains, corresponding to Valon del Malera - hight Vajo di Squaranto, are well preserved. In correspondence of the dismantled segment the maximum amount of vertical deepening reaches the impressive value of about 700 m (Figure 9).

In any case, the most problematic forms are those of

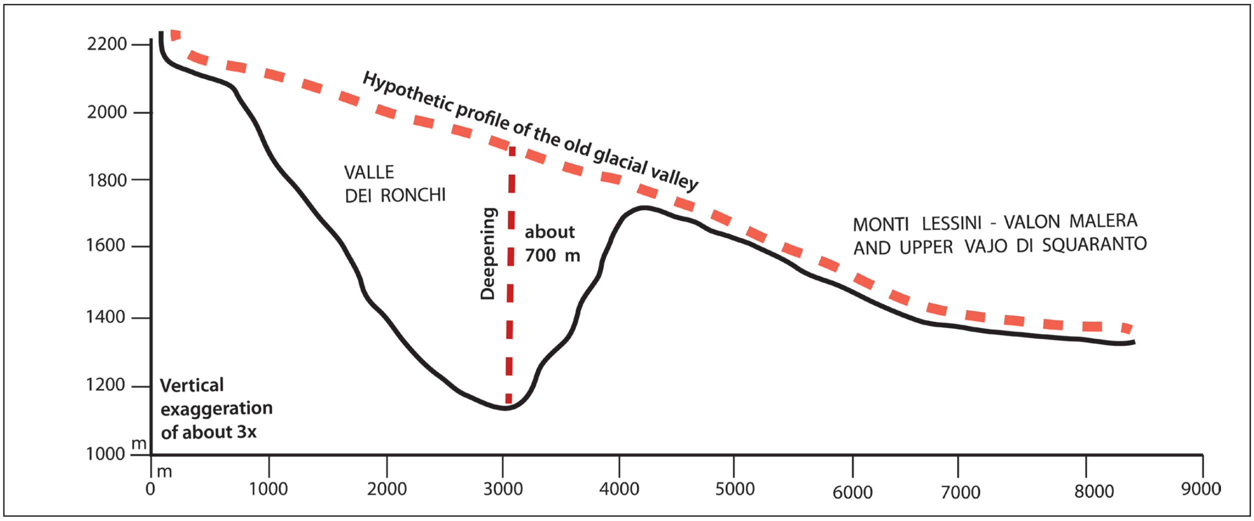

Figure 9: Approximate longitudinal profile along the axis of the old glacial valley (broken line), as it was before its capture, compared with the present day profile (solid black line). The maximum value of deepening, due to accelerated erosion, is of the order of 700 m.

deposition and among these worthy of attention are the ridges in limestone, which are actually erosional forms deriving from depositional forms, which, according to all evidences, are explainable as the result of the "*over-imprinting*" by a morainic ridge. These rock ridges may have formed only where morainic ridges of moderate or considerable thickness rested on sub-horizontal or slightly inclined erosional surface on limestone. On limestone surfaces of moderate and stronger inclinations, forms of this type are not present as the slope processes favour a relatively rapid dismantling of the morainic ridges. Also the lithology is important: these landforms develop especially in massive limestone; if the rock is very fractured these forms are not present or have less evidence.

In June 2010, at the invitation of the Institute of Karst Studies of Postojna, I took part in a fieldtrip in karst areas of the Dinaric karst, and I was able to observe from afar rock shapes that could derive from 'over imprinting' on rock by ancient morainic ridges. These are forms that arouse curiosity and are worthy of further study on the relative glacial systems. I hope that someone will accept the implicit invitation to study the glacial morphology of the Dinaric Karst mountains, keeping in mind the model proposed in this paper. Obviously, these forms can be identified only in areas with a modest slope, where the chemical erosion of the morainic ridges clearly prevails over the mechanical one.

Based on the characteristics of the few forms identified, it is possible to propose a model on the evolution of these forms (Figure 10): after the deposition of a morainic ridge and the deglaciation of the area, in humid periods a hanging aquifer forms inside the tills, which determines temporary conditions of water saturation at the moraine-rock interfaces. These conditions favour the penetration of water into the fissures in the rock (in this case limestone of the 'Calcari Grigi Group' of lower Jurassic age), resulting in the development of covered Karren, consisting of networks of grikes, that in time isolate rock pillars (Figure 6). Overall, the extent of chemical erosion of the rock in place under the moraine is lower than that which affected the surrounding rocky surfaces not covered by till. In fact, part of the solvent action of the infiltration water is exerted on the calcareous fragments of the diamicton of the till. In any case, it should be borne in mind that the rock located below the moraine is protected from other weathering

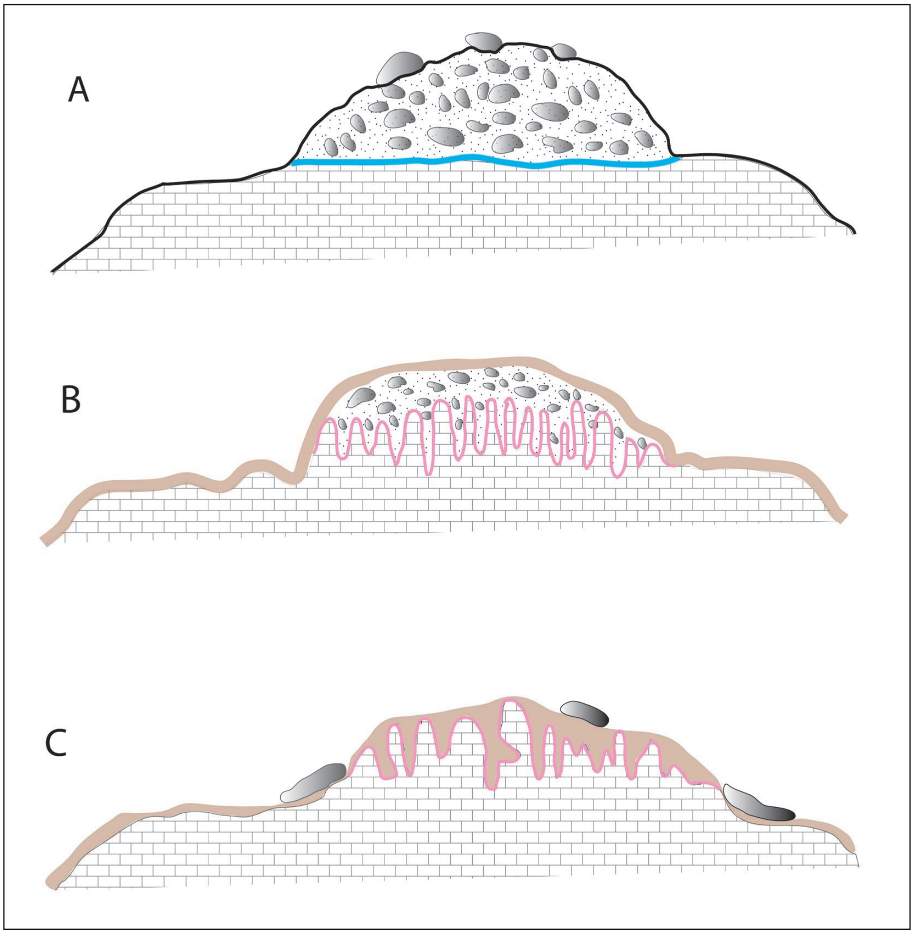

Figure 10: Sketch of the "over-imprinting" of a morainic ridge on the underlying calcareous rock: A) cross-section of a morainic ridge resting on a sub-horizontal calcareous surface (the moraine-rock interface is highlighted); B) the moraine is mainly removed by chemical erosion and covered karren develop at the moraine-limestone interface; C) in place of the moraine, which has been completely removed, there is a strongly karstified ridge hosting infillings of paleosols and loess like sediments.

Figure 11: Detail of the surface of the over-imprinted ridge of malga Spiazzoi. The strong karstification of the rock is evident.

processes, including cryoclastic processes. In this way, the surface of the rock below the ridge is subjected to an inferior rate of 'karst lowering' compared to that of the surrounding surfaces, not covered by the moraine. When the cover is almost completely removed, the rock in place began to emerge. The surface of these outcrops outlines a ridge in limestone that reproduces the form of glacial deposition, sometime hosting relict patches of the ancient covers trapped in karst pockets. However, the deep and strong karstification of a ridge of this type, mainly or totally in rock, can favour gravitational and mechanical erosion processes especially at the margins, due to stress release phenomena consisting of detachment and 'toppling' of rocky blocks deriving from the 'pillars', and consequent deconstruction of the rocky form. These phenomena show great evidence in the two ridges located respectively near Malga Bosco and the Spiazzoi, presenting ruiniform characters and which seem to be the result of the imprinting of segments of relatively large terminal morainic arches (Figure 8, Figure 11).

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