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GLACIAL FEATURES ON THE GALICICA MOUNTAINS, MACEDONIA: PRELIMINARY REPORT

ABSTRACT: RIBOLINI A., ISOLA I., ZANCHETTA G., BINI M. & SULPIZIO R., *Glacial features on the Galicica Mountains, Macedonia: preliminary report.* (IT ISSN 0391-9839, 2011).

Glacial features were described for the first time on the Galicia Mountains, a mountain range separating the lakes of Ohrid and Prespa in Macedonia. The geomorphological mapping of part of this range allowed to document the existence of frontal and lateral moraines, as well as trimlines, cirques and polished rocks. These glacial features allowed the reconstruction of the original topography of the glaciers that deposited the frontal moraines. The Equilibrium Line Altitude (ELA) of three different phases of expansion was calculated (ca. 1850 m, ca. 2000 m and 2130 m a.s.l.) through the Area-Altitude Balance Ratio (AABR) method, and correlated with the values available for the Balkan region and northern Greece. An attribution to Last Glacial Maximum (LGM) and Lateglacial (Oldest and Younger Dryas) was argued for the glacial phases of Galicica Mountains, in agreement with the ELAs of dated moraines in the region, as well as in the Apennines and Maritime Alps. Through the extrapolation of summer temperatures at the ELAs for the single glacial phases, the amount of precipitation needed to sustain the glaciers existence was calculated (3500-3700 mm of w_{eq}) using a well established polynomial regression.

The attribution to the LGM of the lowermost frontal moraine points out to an older age for the till found well below the examined area, near the Prespa Lake shore. This indicates that a more extended glaciation phase occurred during the Middle Pleistocene.

KEY WORDS: Mid-latitude glacialism, Glacial geomorphology, Glacier reconstruction, ELA, Macedonia.

АПСТРАКТ: RIBOLINI A., ISOLA I., ZANCHETTA G., BINI M. & SULPIZIO R., Глацијални карактеристики на планината Галичица, Македонија: предиминарен иэвештај. (IT ISSN 0391-9839, 2011).

За прв пат се истражувани глацијалните карактеристики на планината Галичица, планински масив кој ги одвојува Охридското и Преспанското езеро во Македонија. Геоморфолошкото мапирање на дел од овој масив покажа дека се присутни фронтални и латерални морени, тримлини, циркови и глацијални карпи.

Овие глацијални карактеристики овозможуваат да се направи реконструкција на оригиналната топографија на глечерот кој ги креирал фронталните морени.

Рамнотежната линија на надморска висина (Equilibrium Line Altitude-ELA) на три различни фази од ширењето (ca. 1850 m, ca. 2000 m and 2130 m a.s.l) беше пресметана со помош на методот на AABR (Area-Altitude Balance Ratio) во корелација со вредностите кои се достапни за Балканскиот регион и северна Грција.

Улогата на Последниот глацијален максимум (ЛГМ) и Касноглацијалниот период не се поклопува со глацијалните фази на планината Галичица според ЕЛА од регистрираните морени во регионот како и со тие на Апенините и Маритимските Алпи.

Со екстраполација на летните температури преку ЕЛА за глацијалните фази, со употреба на полиномална регресија пресметано е количеството на врнежи (3500-3700 mm of weq.) неопходно за да се одржи постоењето на глечерот.

Значењето на ЛГМ на најдолната фронтална морена упатува на подлабока старост на глацијалниот тил кој е пронајден во долното истражувано подрачје, во близина на брегот на Преспанско езеро. Ова значи дека подолгата глацијална фаза се случила за време на среден Плеистоцен.

КЛУЧНИ ЗБОРОВИ: Среднонадморска глацијација, глацијална геоморфологија, глацијална реконструкција, ЕЛА, Македонија.

INTRODUCTION

Besides the Alps, repeated Quaternary phases of glaciation affected many other mountains of the Mediterranean basin, i.e. those chains that border and drain into the Mediterranean Sea. The interest on morphological traces of past glaciers in the Mediterranean mountains has been

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constantly present in the scientific research since the beginning of 20th century, and it was notably synthesised firstly by Messerli (1967) and recently by Hughes & *alii* (2006). Thanks to the modern dating techniques, many of these glacial evidences have been recently constrained inside chronological frameworks, allowing a more confident depiction of timing, style and extension of glaciation in some of the Mediterranean ranges (Hughes & Woodward, 2008; Federici & *alii*, 2008; Federici & *alii*, 2011; Kuhlemann & *alii*, 2009). These new results demonstrated that the Mediterranean glaciers were sensible to the most relevant environmental changes occurred during the Quaternary, correlating with the climate records of many marine and continental proxies in the Mediterranean basin (Giraudi & *alii*, 2011; Hughes & *alii*, 2010, Hughes & *alii*, 2011, Woodard & Hughes, 2011). On the other hand, some sectors of Mediterranean mountains still remains at the level of the reconnaissance studies provided by the first pioneering works, limiting the regional syntheses based on cross-correlation of the palaeoclimatic data retrieved by the reconstructed glacier behaviours.

Among the Mediterranean mountains, the Balkan region has been intensively studied because the abundance of mountain ranges overcoming 2,000 m a.s.l.. Following the first studies (Cvijić, 1889; Penk, 1900; Cvijić, 1917; Niculescu, 1915; Nowack, 1921; Sestini, 1933), data about glacial geomorphology, stratigraphy and chronology were provided by numerous authors and, today, this region is among the best known areas of the Mediterranean as regard the reconstruction of the Quaternary glacial environments (Hughes & *alii*, 2006a,b; Hughes & *alii*, 2007; Hughes, 2007; Hughes and Woodward, 2008; Hughes & *alii*, 2010; Kuhlemann & *alii*, 2009; Woodward & Hughes, 2010).

However, among the several mountains chains composing the Balkan region, the knowledge of those belonging to the Former Yugoslavian Republic of Macedonia (FYROM, Macedonia in the following) area is still lacunose and based on relatively old observations. This is surprising because the geographic position of these mountains points out to their relevance for completing the glaciation history framework of a vast region including the northern chain of Greek, the mountains of Albania and Kosovo.

Through a geomorphological map, in this paper we want to illustrate the characteristics of the glacial features of the Galicica Mountains, placed in the south-west of Macedonia between the lakes Ohrid and Prespa (fig. 1). This range is relatively close to the Pindus Mountains (Greece), only 80-100 km far from the Korab and Šara Mountains in Albania and Kosovo respectively. From the calculation of the Equilibrium Line Altitude (ELA) based on the shape of the Galicica past glaciers, we aim to compare our reconstructions with those chronologically constrained of other mountain sectors of Balkans and Greece.

The documentation and description of glaciations over the Galicica mountains is of particular relevance for the paleolimnological studies of the hydrologically connected lakes Prespa and Ohrid (e.g. Lezine & *alii*, 2010; Wagner & *alii*, 2009a), now the subject of a drilling projects (Wagner & *alii*, 2009a,b). Glacial deposits recovered in these lakes are substantially free of carbonate and clastic-rich compared to Holocene. The absence of carbonate component can be related to a deactivation of karst system connecting the lakes along with differential calcite preservation between glacial to interglacial condition. On this discussion Belmecheri & *alii* (2009) have proposed that calcite precipitation were most likely inhibited by the complete interruption of calcium supply from karsts springs, which were inactive during the glacial periods due to permafrost in large parts of the mountains also dominated by a large glacier with front reaching the Prespa Lake shore (about 700 m a.s.l.). The presence of glaciated areas can have also an important influence for clastic supply in both lakes.

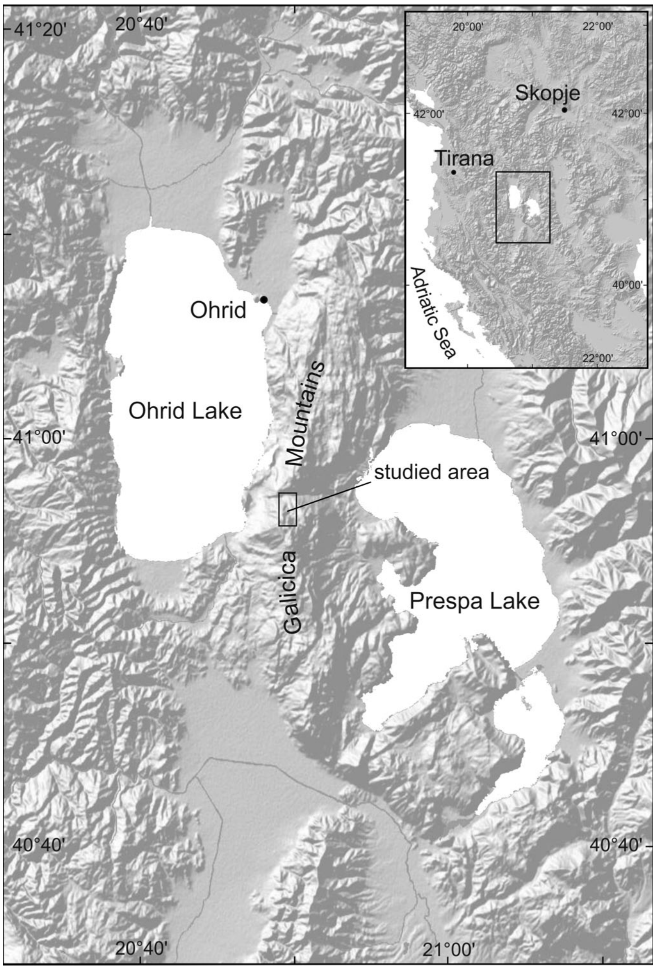

FIG. 1 - Geographic sketch map of Ohrid region. The studied area on the Galicica Mountains is indicated.

METHODS

The geomorphological mapping was carried out in spring 2011 during a field work campaign extended to the other mountain ranges bordering the Ohrid and Prespa lakes. Quickbird satellite images (15 m spatial resolution) with SRTM (Shuttle Radar Topography Mission)-derived contour lines were used in the field, and many ground control points and topographic profiles were acquired with a GPS device in correspondence of relevant geomorphological features.

The original glacier topography was reconstructed on a digital elevation model, according to the guidelines of Porter (1975), by considering the position of the frontal and lateral moraines, evidences of the trimlines on the valley flanks, and the overall topography of the valleys. Among the different techniques used for ELA calculation, we adopted the Area-Altitude Balance Ratio method (AABR) (Osmaston, 2005) due its sensitivity to local topoclimatic variability. The AABR analysis was directly done on the reconstructed glacier surface in a GIS environment using a contour interval of 20 m. The use of a value of AABR consistent with that typical of the region's glacier type is a crucial point for the efficiency of the method. The absence in the Balkan region of a modern analogue of the reconstructed glaciers with a record of mass balance measurements led us to use an AABR value of 1.6, which is that considered valid for the Alps (Rea, 2009).

Modern mean air temperature at the ELAs of the reconstructed Galicica glaciers were calculated applying a thermal lapse rate of 0.6 °C/100 m to the temperature record of the Ohrid meteorological station. The modern summer air temperature (June-July) at ELA elevation was calculated following the method of Brugger (2006). Using this approach, the derived daily mean temperatures were distributed over an expected mean annual temperature range on a sinusoidal mean monthly temperature. A modern amplitude of yearly temperature (1/2 of the annual temperature range) of 10.8 °C was used. Accepting values of thermal depressions regionally known for specific glacial phases, former summer temperatures at the ELAs of the reconstructed Galicica glaciers were inferred. These values were eventually used to calculate the annual precipitation through the polynomial regression established by Ohmura & *alii* (1992).

THE GALICICA MOUNTAINS

The Galicia Mountains is a N-S elongated carbonate mountain range separating the Lake Ohrid and the Lake Prespa in the SW of Macedonia. The mountain range culminations frequently exceed 2000 m a.s.l., with maximum elevations reached in the southern part of the dorsal (2265 m a.s.l.), near the border with Albania (fig. 1).

For the period 1961-1990, an average annual air temperature of 11.1 °C was registered at the Ohrid meteorological station (760 m a.s.l), being July-August the warmest months (27 °C) and January the coldest (5.4 °C). The average annual rainfall amounts to 759 mm, with over 50% of total annual concentrated in Winter (Popovska & Bonacci, 2007).

The Ohrid Basin is the largest tectonic depression in the basin and range geodynamic setting that characterizes the Dinaride-Alpine mountain belt of the Balkans, affected by a E-W extension active since the Neogene (Dumurdzanov & *alii*, 2005). In this context, the Galicica Mountains corresponds to a horst structure separating the Ohrid and Prespa grabens, partly occupied by the homonymous lakes. Indeed, the several and well evident scarps along the stepped flanks of Galicica mountains are strongly controlled by NNE-SSW trending normal faults bordering these tectonic depressions. In addition, the southern part of the Galicica Mountains is cross-cut by an E-W normal fault, generating an evident wind-gap in the mountain ridge flanked by facet spurs (Dumurdzanov & *alii*, 2005; Hoffmann & *alii*, 2010). The valley studied in this paper terminates to the north at right angle with this E-W normal fault, and develops southward along NNW-SSE and NNE-SSW tectonic lineaments.

As almost the totality of the Galicica Mountains, the bedrock of the studied area consists of Triassic and Jurassic limestones and locally dolomites (Hoffmann & *alii*, 2010). The intense karstification affecting the carbonate bedrock has generated the features dominating the landscape. Most of the valley exploited dolinas and uvala which, in turn, are aligned following the N-S tectonic lineaments.

THE GLACIAL FEATURES

We studied the terminal part of the main valley that drains the southern Galicica Mountain following the chain structural axis. In detail, we focused on two tributary valleys that depart from the main trunk on the left side, both extending upward up to more than 2150 m a.s.l. (in the following called the northern and southern valley respectively).

The lowermost glacial deposit extends downward to the valley terminus at about 1550 m a.s.l. (fig. 2), partly invading the E-W valley that cross-cut the Galicica Mountains (fig. 3a). This accumulation starts at about 1800 m a.s.l., initially confined inside the valley channel and then assuming a fan shape when spreads out in the lowermost plain. The deposit is made up by rounded boulders of various sizes, clast-sustained by a brownish gravelly-sandy matrix. The lowermost portion of this deposit shows evidences of reworking acted by mass transports and fluvial processes. The surface characteristics show the existence of a moraine ridge (G1) placed in the terminal right side of this glacial deposit (fig. 2). The ridge shows a slight convergence toward in the inner of the valley, compatibly with the right side of a frontal moraine no more preserved. Rising the deposit, a well evident lateral moraine was individuated at about 1780 m a.s.l.. The crest is relatively well preserved and results punctuated by several large blocks, as well as the sparse glacial deposit infilling the valley.

The frontal moraine (G2) damming the northern lateral valley at 1870 m a.s.l. (fig. 2) is composed by some concentric ridges (fig. 3b). The ridge crests are made up by clast-supported boulders and cobbles, with a coarse gravel-sandy matrix. The development of dolinas inside this deposit in some cases enlarged the intra-ridge depression.

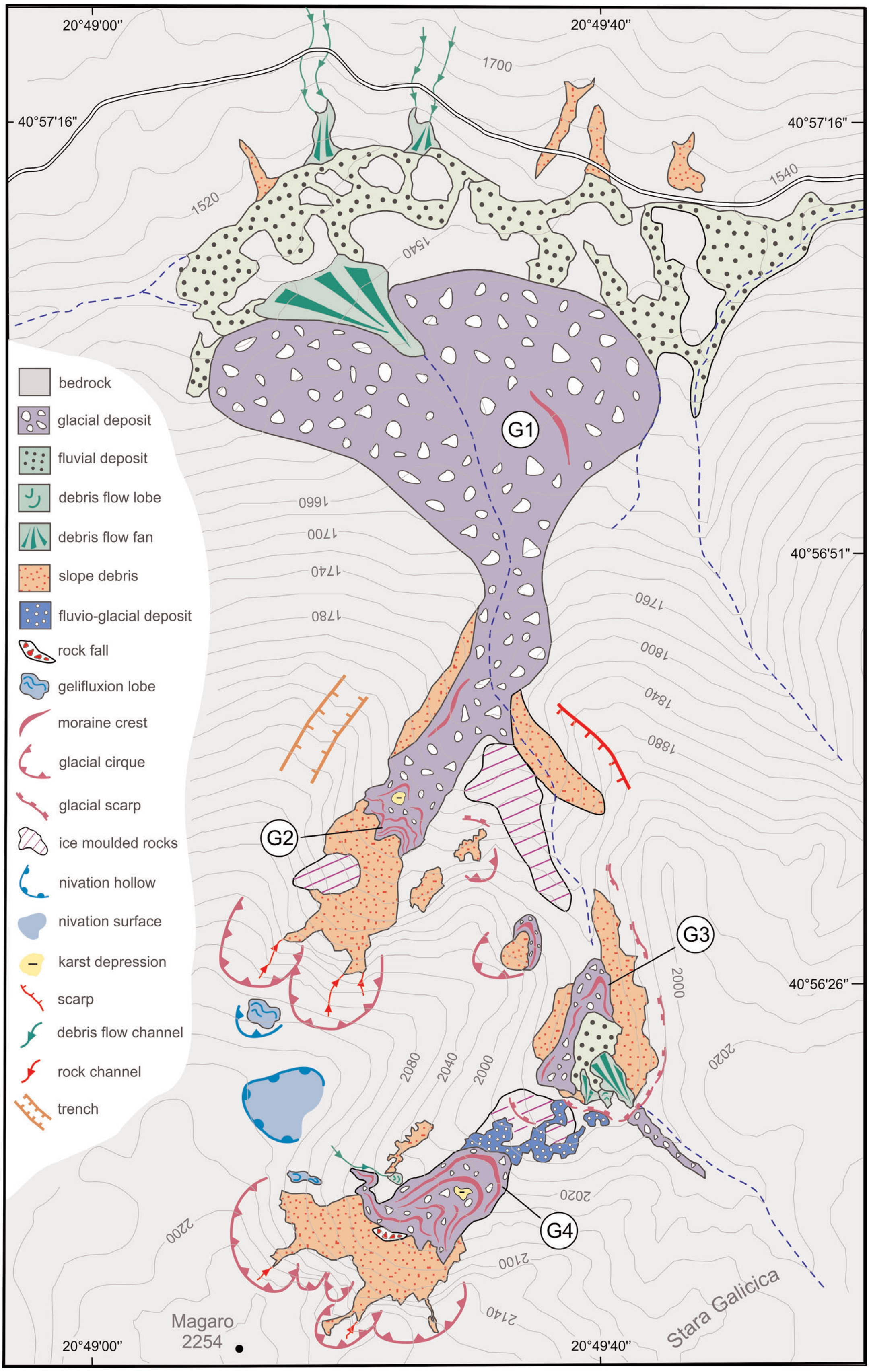

FIG. 2 - Geomorphological map.

The debris intensely supplied from the cirques walls partly cover the back side of the moraine ridges.

A single clear frontal moraine (G3) is situated at ca. 1930 m a.s.l. in the main valley and is associated with a left lateral moraine that extends discontinuously for hundreds of metres (figs. 2, 3c). Both these moraines are placed inside a hollow delimitated by glacial scarps marking the upper limit (trimlines) reached by the glacier during a phase earlier than G3 deposition.

An alluvial plain partly invaded by debris flows fans has formed backward G3. A 4 m-depth borehole allowed to observe that the sediments infilling the plain prevalently consist of brown-reddish silt with dispersed pebbles. No datable material was collected within this core.

The glacial deposits in the topmost part of the southern valley consist in a serie of prominent nested moraines (G4) (fig. 2), made up by big blocks, pebbles and a coarse gravel matrix (fig. 3d). Again, the intra ridge depression were exploited by karts dissolution, likely favoured also by long-lasting snow permanence. The sinuosity of some ridges cannot exclude *a priori* that the composing material may have been in a criotic condition with a consequent permafrost formation. Permafrost creep may have deformed part of the original topography of some ridges. However, the lack of a general turgid shape and of surface flow features organized in a sequence of ridge and furrows exclude that this deposit may be a rock glacier (see also fig. 3c). The presence of a several big blocks on the surface of most of

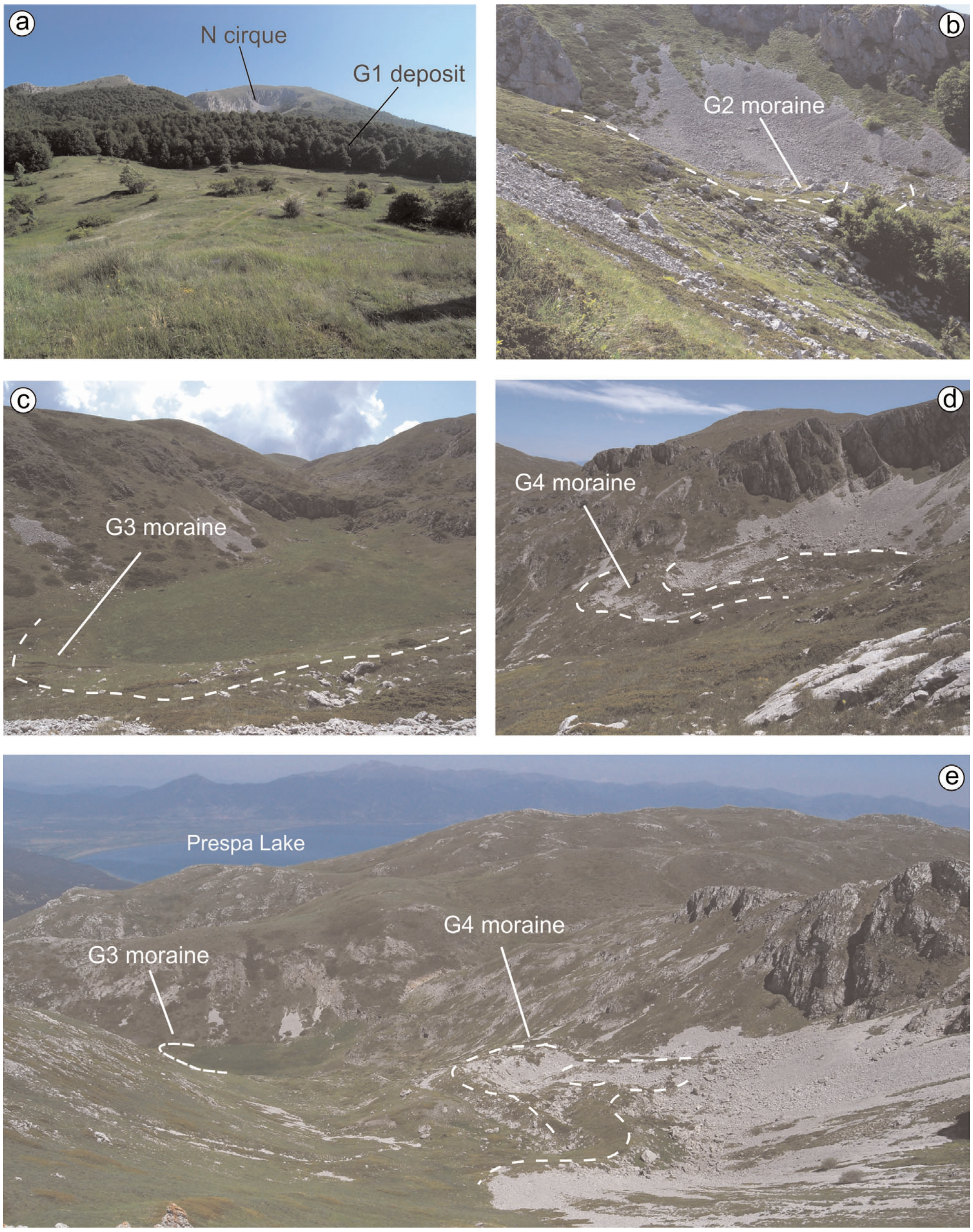

FIG. 3 - The lowermost glacial deposit (G1) at the terminus of the studied valley (a); the frontal moraine (G2) closing the northern valley (b) (see fig. 2 for location); the frontal moraine (G3) along the principal valley (c) (see fig. 2 for location); the frontal moraine (G4) at the topmost part of southern valley (d) (see fig. 2 for location); general view of G4 and G3 moraine (Prespa Lake in the foreground) (e).

the moraine ridges can be ascribed to rock falls affecting the cirque walls, accumulated on the glacier surface, transported for a short distance and than incorporated in the frontal moraine as a supraglacial melt-out till. Rock falls in the cirque walls are active also today, and form a belt of huge blocks at the base of the talus scree partly covering the glacial deposit (fig. 3c). Downvalley the front of the more external moraine, coarse fluvio-glacial deposits (gravel and pebbles) discontinuously infill the depressions of the bedrock, likely carved by (sub-) pro-glacial melt-out channels. Despite the karst dissolution, in this area the bedrock shows evidences of glacial erosion, with small rock drumlins, stoss and lee erosive features and polished surfaces.

Along the main valley toward SSE, we identified and separated out further glacial deposits, not reported in the map. This finding allow us to figure out that when G4 was deposited the correspondent glacier was already separated by that flowing along the main valley.

The top most part of the slope, above the cirque limits, shows features related to the snow cover persistence on the surface which has exploited pre-existing dolinas up to form semi-circular depression with flat bottom. Moreover, we believe that seasonal soil freezing and freeze/thaw processes are active, although not intense, above 2100 m a.s.l., as testified by gelifluxion lobes and frost heave features.

DISCUSSION AND CONCLUSION

The original Galicica glaciers topography was reconstructed for the different phases of expansion (fig. 4) on a digital elevation model. The reconstructed glacier profiles, when Nye's (1952) theoretical parabola is used as a profile descriptor, are characterized by an overall C* values (fig. 4) within the range observed for modern valley glaciers (Ng & *alii*, 2010) and can therefore be considered realistic.

The AABR analysis, directly carried out on the reconstructed glacier surfaces in a GIS environment using a contour interval of 20 m, gave ELA values of 1848 m (G1), 1950 m (G2), 2040 m (G3) and 2130 m (G4). We adopted 1.6 as Balance Ratio value, analogously to the cirque glaciers of the Alps (Rea, 2009).

These values, along with the geomorphological evidences, suggest that three glacial phases occurred on the sector examined in the Galicica Mountains. During the first phase, glacial deposits (G1) were abandoned up to 1550 m a.s.l., and the glacier did not reach the flanks descending to the Lakes Ohrid and Prespa shores (G1 phase) (fig. 4a).

Looking at the ELAs, we assume that the glaciers that deposited G2 and G3 moraines belong to a same glacial phase (G2-3 phase) (fig. 4b). The difference between the ELAs of about 100 m may be justified by different topoclimatic factors between the two valleys, i.e. the steepness of the valley floor, shading effects of cirque walls. Alternatively, a missing frontal moraine might be figured out downvalley G3, coeval with G2 and eventually destroyed by erosive processes.

It is unsure whether the glacier flowing along the main valley and that descending from the southern valley (G3) were separated at the G3 phase. We inspected the upper-

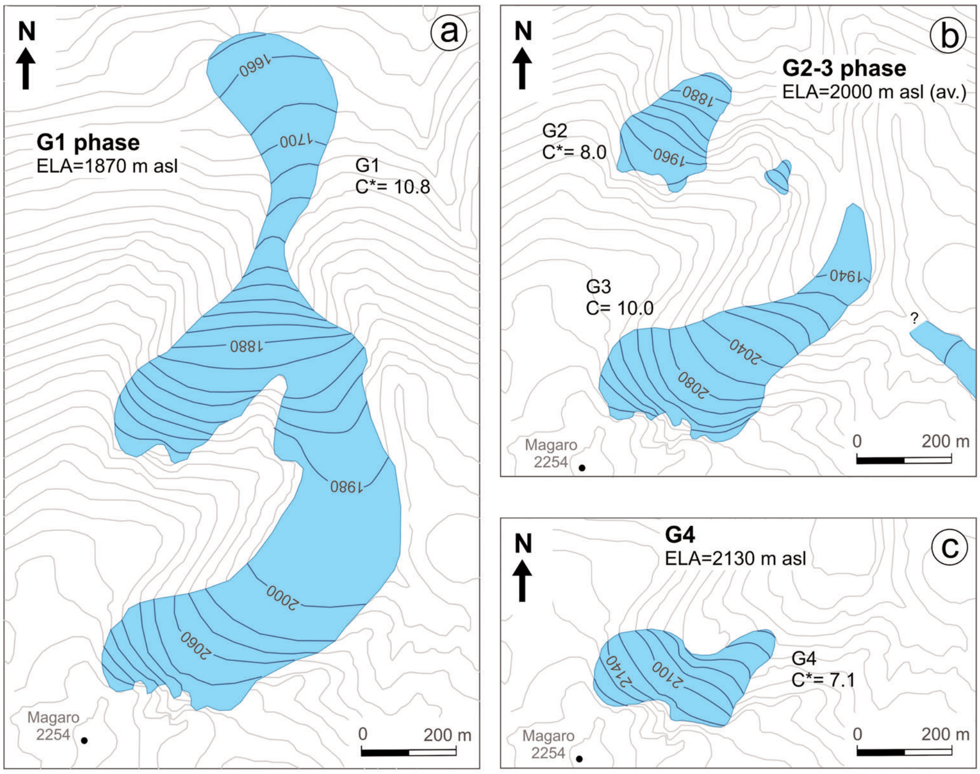

FIG. 4 - The reconstructed glaciers shape for the G1 (a), G2-3 (b) and G4 (c) phases.

most part of main valley and we found abundant glacial deposits and frontal moraines closing lateral valleys. This suggests that to this glacial phase may have corresponded a fragmentation of the G1 glacier into separated bodies confined in lateral valleys. Interestingly, the lateral-frontal moraine of the small glacier developed in the dorsal separating the northern and southern valleys (fig. 2) presents its uppermost termination very close to the cirque wall at 1980 m, providing the value used when calculating the ELA with the Maximum Elevation of Lateral Moraines (MELM) method. This value must be considered as a minimum altitude of the former glacier ELA (Benn & Lehmkuhl, 2000).

The glacier that deposited G4 moraine (fig. 4c) corresponds to the last one developed in the examined sector, and the related glacial phase (G4 phase) was likely the last one occurred on the whole Galicica Mountain considering the general topography of this range. The complex topography of G4 moraines, i.e. more ridges with sinuous geometry, may be attributed either to a glacier stagnation or to post-depositional deformation caused by permafrost creep.

The chronological data obtained with U-series (Woodward & *alii*, 2004; Hughes & *alii*, 2006; Hughes & *alii*, 2010; Hughes & *alii*, 2011) and recently with cosmogenic radionuclides (Kuhlemann & *alii*, 2009) allow to constrain the phases of glacial advances occurred in the Balkan region and northern Greece inside a common framework provided with the relative ELAs. Reporting a summary of ELAs *versus* ages in the Balkans and northern Greece (fig. 5), it appears clear the scattering affecting the ELAs data, likely due to the difficulties in reconstructing the shape of old glaciers and to the occurrence of different style of glaciation (ice cap *vs* cirque glacier).

The oldest glacial deposits dated at > 350 ka (U-series) were deposited by glaciers with ELA of 1741 m a.s.l. and 1256 m a.s.l. respectively (fig. 5). On the basis of the ELA values, we believe that this glacial phase predates the one that deposited G1 moraine in the Galicica Mountains (G1-phase, ELA=1870 m a.s.l.). This implies that the glacial deposit found well below the examined area, near the Lake Prespa shore, can be potentially associated to MIS 12. Indeed, the deposits described here by Belmecheri & *alii* (2009) are characterised, according to our observations, by very deep and strongly weathered reddish soil profile, compatible with a Middle Pleistocene instead of Late Pleistocene (Last Glacial Maximum) age.

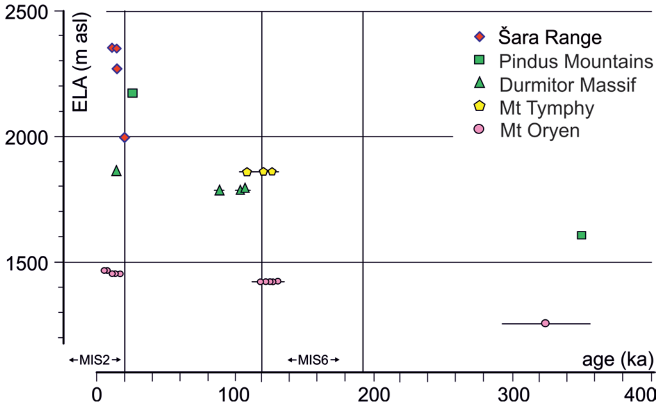

FIG. 5 - Equilibrium Lines Altitudes *versus* ages in the Balkans. The ages were obtained with Uranium series and cosmogenic radionuclides (Šara Range) methods. Sources: Hughes & *alii*, 2011 (Durmitor Massif, Central Montenegro), Hughes & *alii*, 2010 (Mt Orjen, Montenegro), Hughes & *alii*, 2006 (Pindus Mountains, Greek), Woodward & *alii*, 2004 (Mt Tymphi, Greek), Kuhlemann & *alii*, 2009 (Šara Range, Kosovo).

It is hard to say if the glacial phase that deposited G1 (ELA=1870 m a.s.l.) may have formed during the Last Glacial Maximum (MIS 2) or earlier (MIS 6) because the reconstructed ELAs in the Balkans potentially account for more than an attribution (fig. 5). However, the glacial deposit does not show a deep and altered soil profile, unlike the moraines of the Vlasian Stage (MIS 6) described by Hughes & *alii* (2010 and 2011). For this reason a Last Glacial Maximum (LGM) age can be tentatively proposed for the G1 phase, with an ELA similar to that calculated for the coeval phases in the Durmitor Massif and sensibility higher (about 300 m) than the values inferred for Mt Orjen (fig. 5). Interestingly, the ELA of G1 phase is very similar to those calculated for the LGM glaciers in the Maritime Alps, ^{10}Be-dated at 20.1±1.0 ka (Federici & *alii*, 2011), and in Central Apennines (Gran Sasso area), ^{14}C-dated at 22.6 ±0.6 ka (Giraudi & Frezzotti, 1997).

Lateglacial phases in the Balkans were cosmogenically dated at the Older Dryas (14.7 ka) and Younger Dryas (12.8 ka) in the Šara Range (Kuhlemann & *alii*, 2009). Similarly, in the Orjen Massif, Montenegro, minimum ages of 8-10 ka from cemented moraines were used to infer that the last glaciers on this mountain formed during the Younger Dryas (Hughes & *alii*, 2010). Depending on slope aspect, the ELAs values for these Lateglacial phases vary between 2100 and 2350 m a.s.l., and 2300 m and 2400 m a.s.l. respectively (fig. 5).

In this respect, the ELAs for G2-3 and G4 glacial phases (about 2000 and 2130 m a.s.l. respectively) agree with a Lateglacial attribution. The modest increase of ELA between the G2-3 and G4 phases may be attributed to local topoclimatic effects favouring the accumulation of wind-blown snow inside the northern cirque. Our Lateglacial reconstruction partly fits with the stadia of glacier retreat dated in the Central Apennines (Gran Sasso area) at about 16.0 ka and 11 ka, with reconstructed ELAs of 2150-2200 m a.s.l. and 2300 m a.s.l. respectively (Federici, 1979; Giraudi & Frezzotti, 1997).

Interestingly, during the Oldest Dryas the G2-3 glacier assumed an ELA similar to that calculated in the Maritime Alps (1910 m a.s.l.) for the glacier advance ^{10}Be-dated at 16.5±0.9 ka (Federici & *alii*, 2011), i.e. the Gschnitz phase in the Alpine glacial chronology. Differently, the ELA of the G4 phase is about 200 m lower than that (2380 m a.s.l.) assumed by the glacier advance ^{10}Be-dated at 11.3±0.3 ka (Federici & *alii*, 2008), i.e. the Egesen phase in the Alpine glacial chronology.

Modern values of air temperatures at the ELAs of the reconstructed Galicica glaciers were calculated applying a thermal lapse rate of 0.6 °C/100 m to the temperature record of the Ohrid meteorological station. The derived temperatures were distributed over an expected mean annual temperature range on a sinusoidal mean monthly temperature (Brugger, 2006), adopting an amplitude of yearly temperature of 10.8 °C (today measured in Ohrid). In this way, we calculated modern summer temperatures at the ELAs for the single glacial phases. The unavailability of a temperature proxy, i.e. rock glacier front (Finsinger & Ribolini, 2001, Hughes & *alii*, 2006), does not allow to directly estimate the summer temperatures at ELAs at the time of glaciers existence and, in turn, to calculate annual precipitations using a polynomial regression (Ohmura & *alii*, 1992). However, to have a reliable simulation, we can associate to our glacial phases the values of temperature depressions proposed by Hughes & Braithwaite (2008) for the glacial phases of Mt Thympi (Pindus Mountain, Greek), only 100 km south of Galicica Mountains. The authors calculated air temperature depressions of –6.9 to –6.0 °C for the glacial phase attributed to the LGM (Tymphian Stage, MIS 5d-2), and –5.3 to –4.4 °C for a Lateglacial phase corresponding to the Younger Dryas. Associating these temperature depressions to the G1 and G4 phases, we calculated summer temperatures at the ELAs of about 7.9 °C and 8.3 °C respectively. These values would require mean annual precipitations (winter accumulation + summer precipitation) of about 3500 and 3700 mm of water equivalent to sustain a glacier existence.

It is clear that a more extended survey is needed to depict the glacial geomorphology of the Galicia Mountains and surroundings, along with chronological data constraining the phases of glacial expansions. This may open to a striking correlation with the environmental-controlled events recorded in the cores of the Ohrid and Prespa lakes. However, in this paper we documented the existence of glacial features in an area essentially unknown from this point of view, documenting the presence of LGM and Lateglacial deposits related to glaciers that did not reach the lakes Ohrid and Prespa shores. This implies that during the LGM (and later) only limited parts of the Galicica Mountains were occupied by glaciers, and permafrost would have been restricted to the uppermost slopes. Research is in progress to analyse the Middle Pleistocene till on the lake shores and on the other mountain ranges bordering the lakes. This till records older and more extensive phases of Middle Pleistocene glaciation.

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