Preliminary data about sporadic permafrost on Peristeri and Tzoumerka massifs
(Pindos chain, Northwestern Greece)

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Abstract: Inactive Rock Glaciers have been recognized and mapped on the Peristeri and Tzoumerka massifs, northern Pindos chain, Northwestern Greece, at around 2.000 m in altitude. Because of the lack of conclusive elements for dating them, with an inductive method we propose they could be chronologically attributed to the Dryas (17,000 – 14,000 years BP). Anyway, it must be noticed that Hughes et al. (2003) have dated back the RG found on Tymphi Mt, not very far to the north from Peristeri and Tzoumerka, to the Last Glacial Maximum (Late Würm). We do not have data to discuss or to disprove the proposal of those authors.
At the moment Peristeri – Tzoumerka represent the most southern permafrost landforms in Europe.

1. Geological setting and meteorological situation

The Pindos chain, extending from NNW to SSE, constitutes the backbone of the Greek peninsula, and is the largest mountain chain of Greece. It constitutes the continuity of the Dinaredes and therefore it is a part of the wider system of the western Balkan Peninsula.

In this article, we present a census and preliminary consideration concerning some remains of discontinuous permafrost recognized on two adjacent massifs, Peristeri (also known as Lakmon) and Tzoumerka (also known as Athamanion). They are situated between 39°22'N - 39°43'N and 21°05'E - 21°15'E in the Epirus region, northwestern Greece (fig. 1). The Lakmon group reaches the maximum height on the Peristeri (2294 m), Pyramida (2240 m), Giannaki (2184 m) and Frougouras (2132 m) peaks. It is separated from the Peristeri group by the valley of the Kalaritikos River and it includes the highest peaks of the northern Pindos, such as Kakarditsa (2429 m), Chilia Exida (2254m), Katafighi (2098m), Strogoula (2112 m), Gerakovouni (2364 m), Sxismeno Lithari (2306 m), Katafidi (2393 m), Megalolivado (2199 m) and Sklava (2088 m).

From the geological point of view the region is part of the "Ionian zone", constituted by Upper Eocene - Lower Miocene sedimentary sequences, as well as part of the "Pindos zone", where Upper Cretaceous - Eocene sedimentary sequences outcrop. In the southern part of the studied area the formation of "Gavrovo zone" is present, mainly constituted of Triassic - Upper Eocene sedimentary sequences (Brunn 1956, Aubouin 1959, Vakalas 2003).

The mean annual temperature ranges in the area between 10.5 °C at Metsovo (1156 m a.s.l., north boundary of Lakmon) and 12.5 °C at Pramanta (835 m a.s.l., north side of Athamanion). The minimum absolute temperature, –15.4 °C, has been registered in Metsovo during the second half of the last century. At the weather stations around and inside the Massifs annual amounts of rainfall have been recorded, as follows: in Metsovo, 1486 mm; in Pramanta, 1683 mm; in Agnada (660 m a.s.l.), 1577 mm; at Theodoriana (960 m a.s.l.), 2562 mm; at Matsukion (1079 m a.s.l.), 1788 mm, and Mikro Peristeri (1040 m a.s.l.), 1315 mm. The number of days of total frost at Metsovo has been of about 10 (Soulis 1994).

The upper limit of the forest is, at present, at about 1700 - 1800m of elevation, depending on the exposure.

2. Previous knowledge on periglacial traces in Greece

Systematical studies of the periglacial features in the study area do not exist.

According to Sestini (1935) debris accumulations of periglacial origin could be observed from Albania and southwards along the Epirus chain until Acarnania not far from the gulf of Patras, as well as in some Ionian Islands. The author does not specify which kind of landforms are present there.

Mistardis (1935, 1937c), used, for the first time in Greek literature, the term Rock Glacier in his “Geomorphologic research in NE Epirus”.

Afterwards, a relict Rock Glacier has been noticed (Pechoux, 1970) on Mount Parnassus, southern Pindos chain, not far from its highest peak, Liakoura (2450 m) at an altitude of about 1950m. The author correlated this RG with adjacent moraines, and suggested a würmian age.

As far as Lakmon and Athamanion massifs are concerned, traces of relatively recent frost events are noticed by Hagedorn (1969) on the higher surfaces of the last one, where at around 1800m of altitude he observed very diffuse remains of gelifracted and ice transported debris, in the form of talus cone.

Hughes et al. (2003) have recently carried out periglacial research on the Tymphi massif, not far to the north from Peristeri and Tzumerka. There, the authors studied and mapped relict and inactive Rock Glaciers preserved in some glacial shaped cirques. These remains (RG) represent evidences of sporadic permafrost during a relatively recent cold-stage in an area which shows widespread evidence of Pleistocene glacial activity. According to the authors, it is likely that these features have been built during or at the end of the maximum of the last Great Glacial Expansion (Late Würm), about 21,000 – 22,000 years BP.

This hypothesis is coherent with the suggested chronology proposed by Smith et al. (1997) for similar remains found on the Olympus Mount, in eastern Greece. The authors pointed out that the periglacial unit has been probably constructed during a periglacial cold-dry climatic regime, maybe during the early - middle Pleistocene.

3. Peristeri-Tzoumerka Rock-Glaciers

Rock glaciers are debris masses containing, when active, underlying or widespread internal ice, which slowly creep down slope. On the Peristeri and Tzoumerka massifs 14 of these forms have been found and studied, all characterized by the same or similar lithology.

Recognized and mapped RG are extensive and enough well preserved. Their main characteristics are summarized in Table 1, and their location is shown in Fig. 1.

The more voluminous RG are exposed to the north and north-east (Fig. 2; Table 1), where slopes are less warm because exposed to coldest and arid air masses arriving from the north – north-west. Probably the scarcity in RG on the slopes towards south and west could be due to the effect of the Phoen, and also to the fact that along the western side of the chain cold masses from north-east meet the warm ones from the Mediterranean area, which rapidly increase the temperature.

Fig. 3 and Table 1 show that the length of each RG increases between 250 and 2500m, as well as that they are located at an elevation between 1330 and 2080m. The relationship between length and maximum altitude of each of the RG is synthesized in Fig. 4, where it can be noticed that their length is not connected with their position in altitude, so that the longest ones are placed at around 1800 m a. s. l.

On the other hand, the exposition appears to have strongly influenced the length of the RG, in such a way that the greatest and longest ones have been found onto slopes exposed towards NNE and N (Fig. 4).

The inclination of the surface underlying each RG as well as the extension in altitude of each tributary surface have also been studied (Fig. 5); it can be noticed that all studied rock glaciers are located not far from the best-fit line, except for the RG n° 11. In general the situation confirms that the dimension and the length of rock glaciers increase progressively with the extension of the over hanging tributary surface.

Regarding the slope gradient, the greatest concentration of rock glaciers is correlated to slopes of between 12% and 30%, while the longest ones are on slopes of 12% to 38% (Fig. 6). Greater dips do not seem suitable for the formation and activity of rock glaciers.

Concerning the age of the studied Rock Glaciers, there are not conclusive elements for dating them precisely. Consequently, we are obliged to use an inductive method, successfully utilized for inferring the age of rock glaciers found in the Albanian Alps by Palmentola et al. (1995). This kind of approach starts from the knowledge that RG are and were active where the mean annual temperature is/was of about −2°C. Based on the sea level paleo-temperatures (Emiliani, 1955; Ryan 1972; Thiede, 1978) and knowing the present day altitude of the –2°C isotherm, we can calculate that RG have been active when sea level temperature was about 6°C - 7°C lower then today. The result of this operation permits to suggest that RG on the Peristeri and Tzoumerka massifs could be referable to a period of time between 17,000 and 14, 000 years BP, Dryas period, which probably represents the most recent large-scale cold-climate in the region.

A different chronological supposition, proposed by Hughes et al. (2003), which attributes RG found on the Mt. Tymphi, in the northwestern part of Greece, not very far from Peristeri, to the Last Glacial Maximum, 21,000 – 22,000 years BP, could also be taken into account.

Table no 1

Location and essential data about Rock Glaciers on Peristeri and Tzoumerka massifs

R G.	Rock glacier Location	Max altitude (m)	Min altitude (m)	Length (m)	Width (m)	Exposure	R. G. Slope (%)	Tributary Surface Extension (m)	Tributary Surface Slope (%)
1	Peristeri 39° 41' 36" 21° 08' 06"	2000	1780	750	500	N	38	120	60
2	Spana 39° 41' 10" 21^0 06' 28"	1830	1720	1000	250	N	12	300	33
3	Diamandi 39° 41' 36" 21° 07' 00"	1940	1800	800	300	N	15	400	35
4	Asprovrisi 39° 40' 00" 21° 07' 45'	2080	2000	250	400	SE	16	150	53
5	Piramide 39° 39' 36" 21°07'45'	1960	1840	550	250	NW	38	500	32
6	Megas Trapos 39° 39' 44" 21° 08' 02"	1980	1920	400	250	ENE	20	400	21
7	Suflomiti 39° 38' 11" 21° 09' 00"	2000	1860	500	250	N	28	40	50
8	Baros 39° 37' 23" 21° 09' 49"	1780	1690	250	100	N	40	300	21
9	Lakkos 39° 35' 44" 21° 12' 01"	1890	1750	450	200	E	22	750	50
10	Splatura 39° 33' 34" 21° 12' 45"	1800	1690	900	400	E	28	800	4
11	Kokkinovrisi 39° 29' 16" 21° 13' 45"	1800	1500	1500	450	NNE	21	600	36
12	Neraida 39° 28' 01" 21° 12' 24"	1540	1330	450	200	ESE	30	750	60
13	Sclava 39° 24' 13" 21° 09' 48"	1880	1820	500	250	N	12	650	23
14	Sclava 39° 23' 55" 21° 10' 44"	1800	1760	250	200	ENE	30	300	23

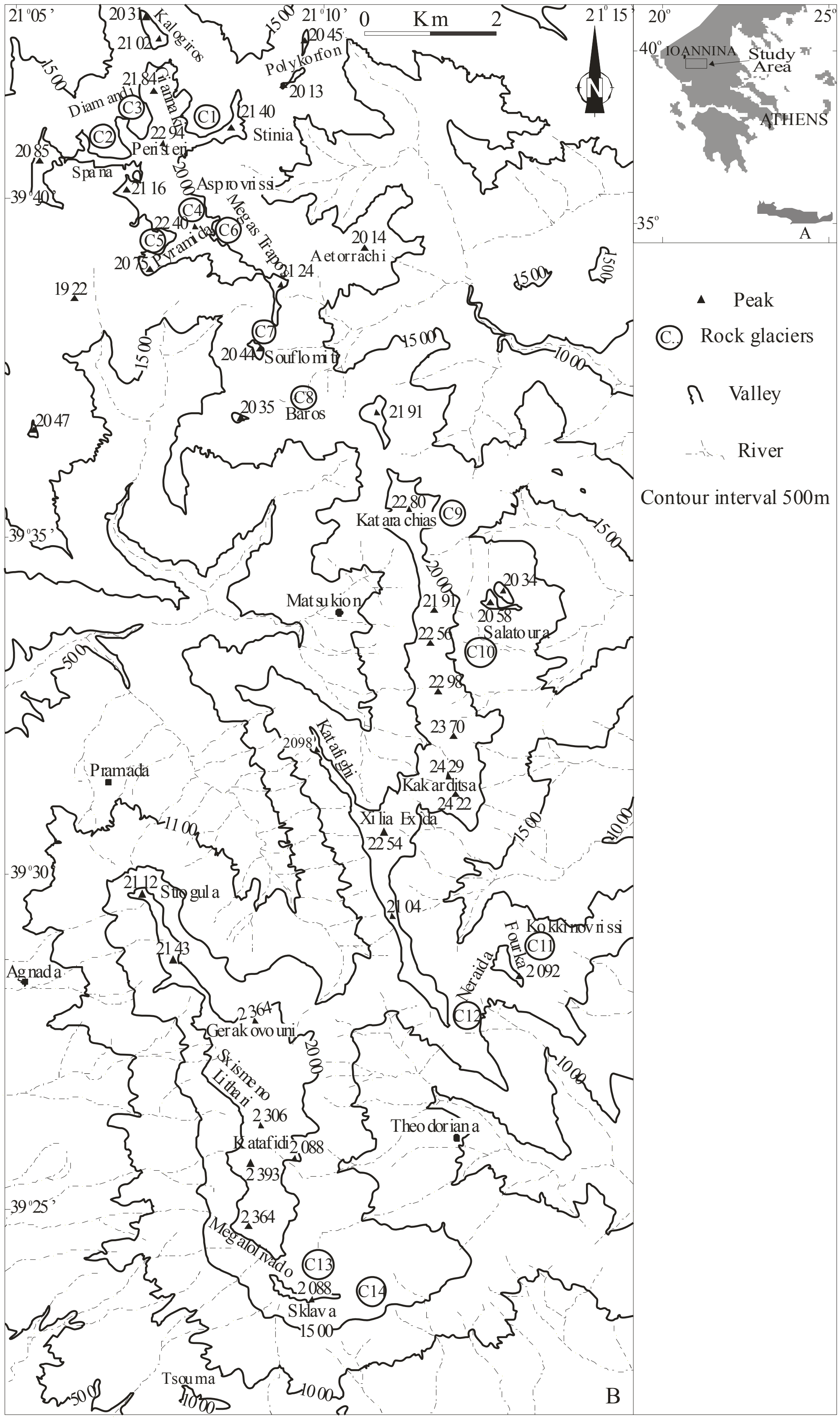

Figure 1. **Location map of the investigated area and position of the Rock Glaciers found**

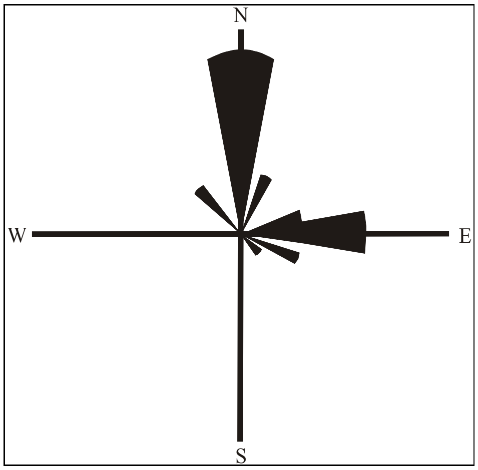

Figure 2 **Rose diagram of the rock glaciers orientation**

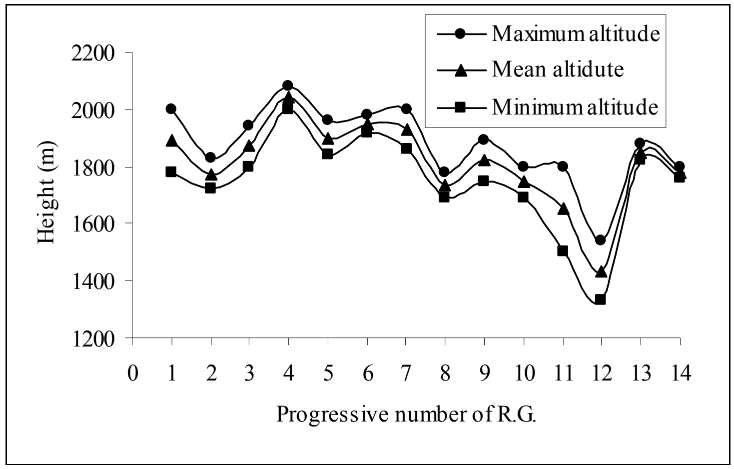

Figure 3 **Extent of each Rock Glacier in altitude**

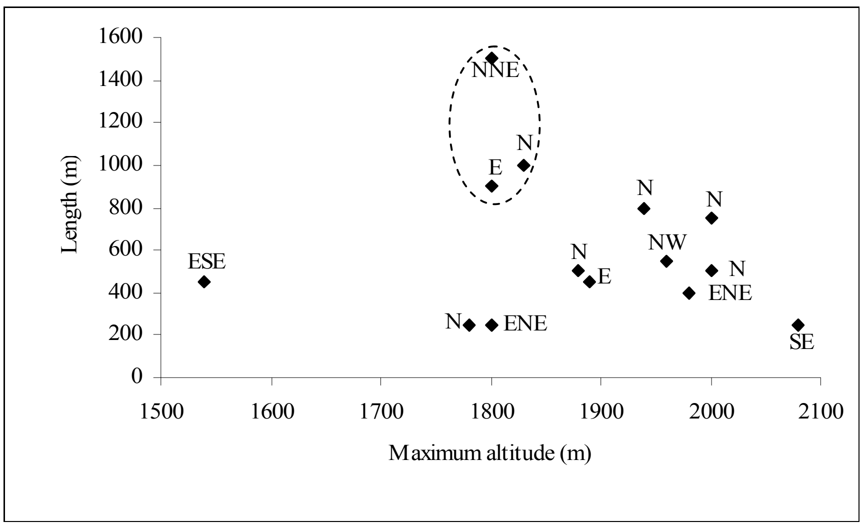

Figure 4 **Relationship between maximum altitude and length of each RG and its own exposure**

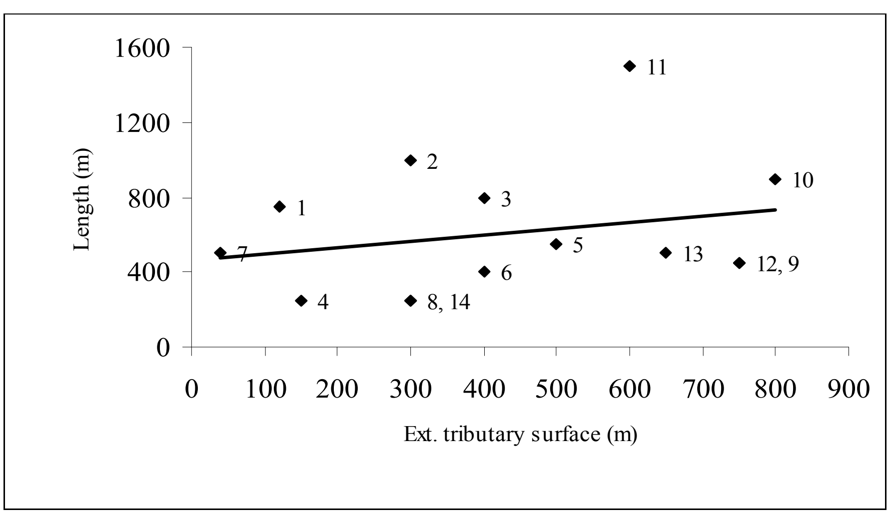

Figure 5 **Relationship between the length and the extension of the tributary surface**

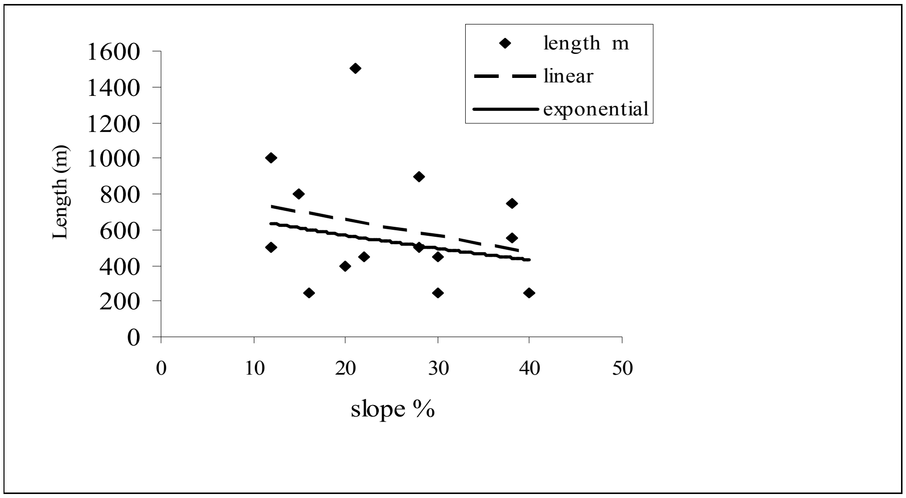

Figure 6 **Relationship between bedrock mean slope and length of each Rock Glacier**

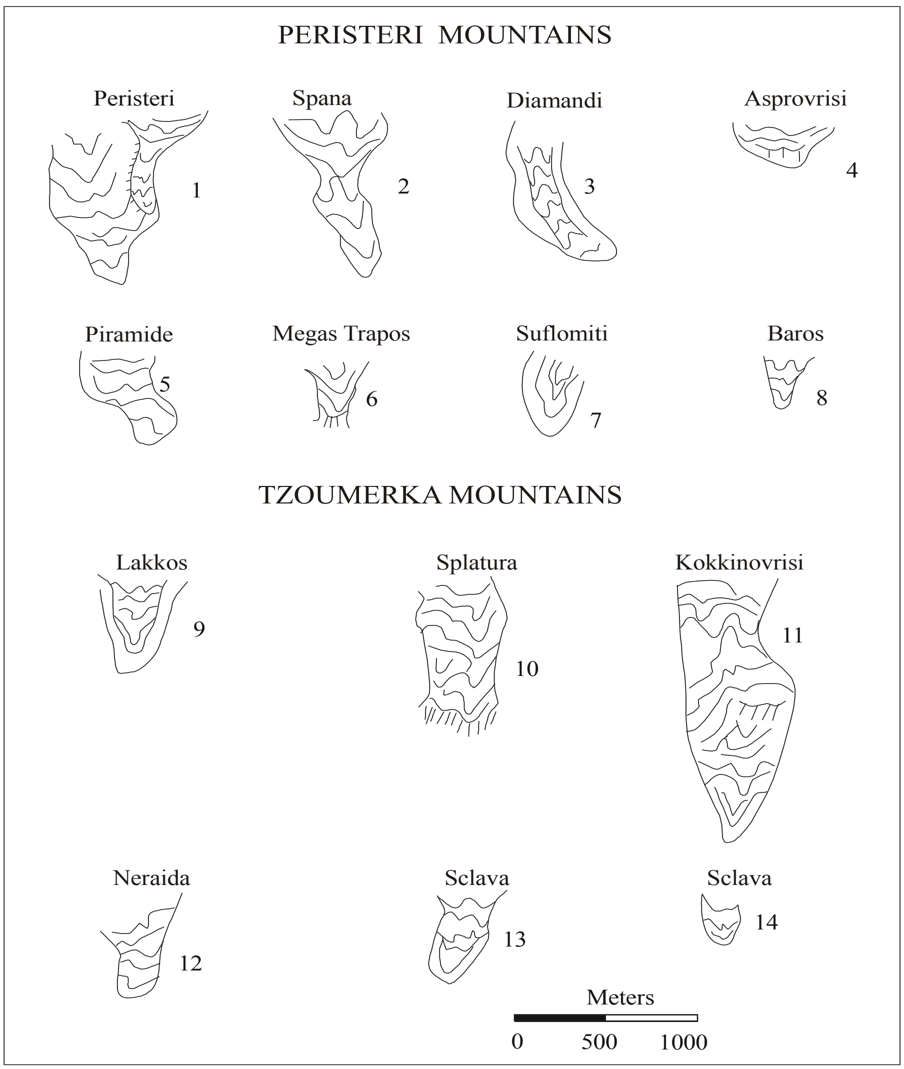

Figure 7 **Outline and morphology of Rock Glacier on the Peristeri and Tzoumerka massifs in the Northern Pindos chain**

Conclusion

Researches on Peristeri and Tzoumerka massifs, in the northern Pindos chain, allowed the recognition of several remains of sporadic permafrost, represented by lobate rock glaciers with a great variety in size and shape (Fig. 7). Most of these landforms are exposed towards north and north-east. Their lengths result not to be in relation with altitude; so that the longest have not the most elevated position (they are located at around 1800m a. s. l.). On the contrary, the exposure appears to have decisively influenced their length. The greatest concentration of rock glaciers has been found where slopes dip between 12% and 30%, while the longest are on slopes of 12% to 38%.

The necessary environmental conditions for their origin and activity, very difficult to calculate, could be found at about 21 000 – 23 000 years BP, according to Hughes et al. (2003) who referred rock glaciers on Mount Tymphi to the Last Glacial Maximum, or at about 14.000 – 17.000 years BP according to Palmentola et al (1995) who referred RG found on the Albanian Alps only to the Dryas.

Anyway, Rock Glaciers on the Peristeri and Tzoumerka massifs represent the southernmost permafrost landforms until now recognized and mapped in Europe, apart from one similar remain noticed by Pechoux (1970) on the Parnassos massif.

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