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THE EPHEMERAL EPIGLACIAL LAKE OF THE GHIACCIAIO DEL CALDERONE (GRAN SASSO, ITALY)

ABSTRACT: CAPPELLETTI D., CROCCHIANTI S., D'AQUILA P., IURISCI C., PECCI MASSIMO & PECCI MATTIA, *The ephemeral epiglacial lake of the Ghiacciaio del Calderone (Gran Sasso, Italy).* (IT ISSN 0391-9838, 2014).

The extreme rainfall event around 14-15 September 2012 (estimated cumulative value of approx. 300 mm in the summit area of the Gran Sasso d'Italia mountain range, Central Italy above the elevation of 2500 m) generated an ephemeral epiglacial lake at the bottom of the depression of the Ghiacciaio del Calderone. In this short communication a description of the atmospheric triggering phenomena and of the ephemeral lake evolution is presented and some geomorphological remarks briefly discussed.

KEY WORDS: Epiglacial ephemeral lake, Extreme events of precipitation, Calderone Glacier (Gran Sasso, Italy).

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Le precipitazioni estreme del 14-15 Settembre 2012 (stimate in circa 300 mm sull'area di vetta del massiccio del Gran Sasso d'Italia, al di sopra dei 2500 m) hanno dato vita ad un lago epiglaciale effimero nella parte più depressa del settore inferiore del Ghiacciaio del Calderone. In questa nota vengono presentati e brevemente discussi i fenomeni atmosferici innescanti la formazione del lago effimero e la sua veloce evoluzione.

TERMINI CHIAVE: Lago effimero epiglaciale, Eventi pluviometrici estremi, Ghiacciaio del Calderone (Gran Sasso).

INTRODUCTION

The Gran Sasso d'Italia is the highest elevation in the Apennines (2912 m) and, together with its glacier (Ghiacciaio del Calderone - WGS84/UTM Zone 33N coordinates: 382324, 4703290; elevation: 2650-2830 m), is a system in a continuous evolution with an extremely active morphodynamics. This small glacial system, the European southernmost example of its kind, appears to be very sensitive to climatic changes. The case of study is the ephemeral epiglacial lake (fig. 1), generated at the bottom of the glacier depression in the middle of September 2012 in consequence of heavy rainy precipitation directly on the debris covering the ice. To this respect the present phenomenon is substantially different in genesis and evolution if compared with the well known lake Sofia (fully described for the first time in Tonini, 1952 and 1963), which formed almost regularly every year, until summer 1995, directly on the snow cover, during the ablation season (usually in June). In this Short Communication we describe the geomorphology and main processes of this ephemeral system and its evolution towards the disappearance. A hypothesis on the mechanism at the basis of its formation will also be drawn and briefly discussed, with the aim of contributing to for the knowledge of the phenomenon of ephemeral lakes formation on a debris covered glacier on carbonatic rock affected by karst dynamic. The latter shows a different evolution whith respect to other Alpine epiglacial ephemeral lakes, like, for example, the Ghiacciaio del Belvedere in the Monte Rosa Chain (Mortara & Tamburini, 2009).

Figures 1-3 provide a time series of pictures that allow a comparison of the environmental conditions observed during the month of September 2012 at the Gran Sasso d'Italia. In particular, fig. 2 illustrates the state of the central area of the glacier one week before the exceptional

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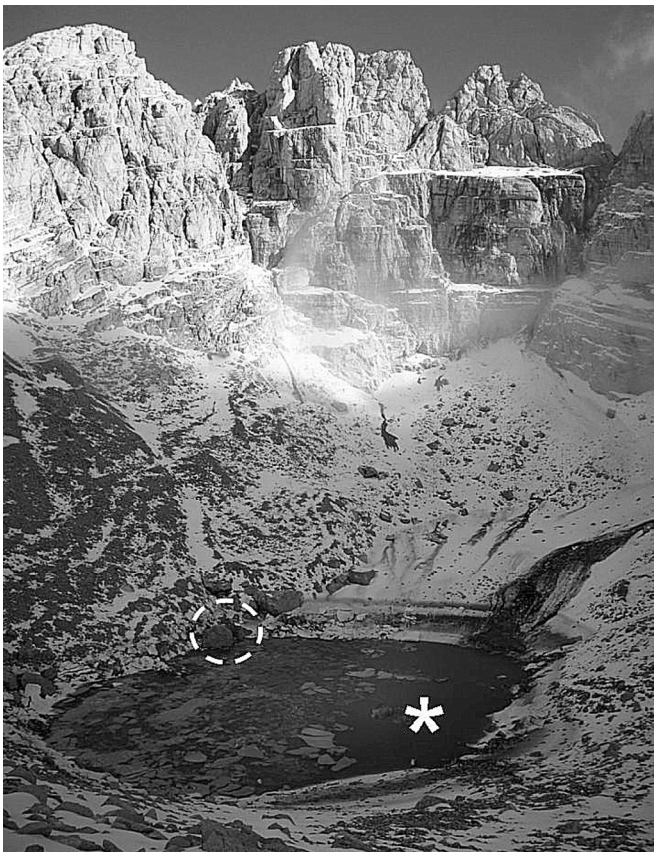

FIG. 1 - Overview of the ephemeral lake of Ghiacciao del Calderone the 16th of September 2012 (photo by Cristiano Iurisci); with asterisk is marked the same area of fig. 2 and 3, and with the dashed circle the same area of fig. 5.

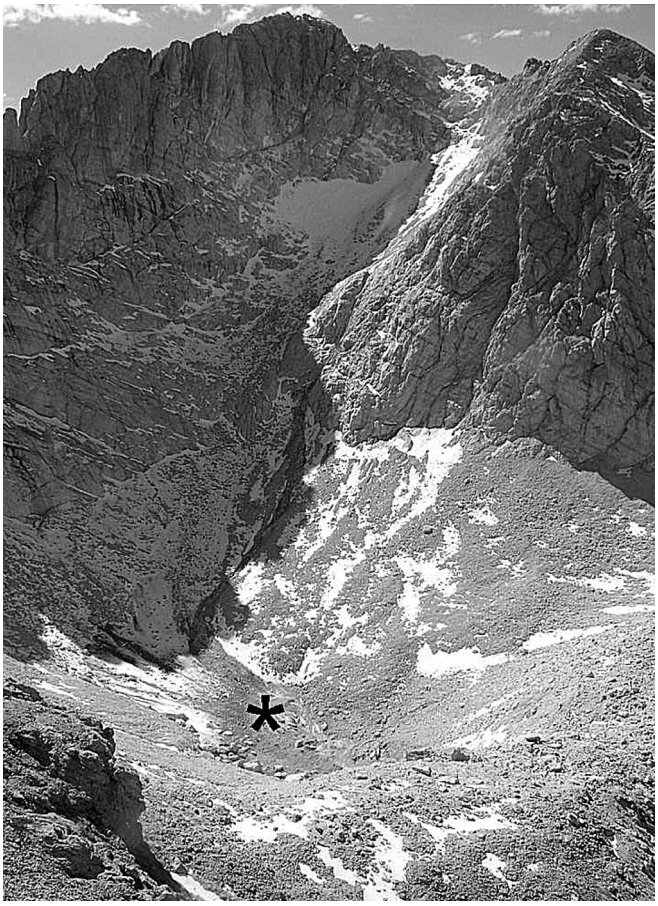

FIG. 3 - The glacier cirque after the lake disappearance, the 22nd of September 2012 (photo by Massimo Pecci).

FIG. 2 - The cirque of the Ghiacciaio del Calderone the 9th of September 2012 (photo by Cristiano Iurisci).

weather event which led to the formation of the lake: the picture was shot from the Vetta Occidentale of the Corno Grande the 9th of September. Fig. 3 shows an overview of the central area of the glacier basin, shot from the Vetta Orientale during the glaciological survey performed by the Authors the 22nd of September 2012, i.e. one week after the formation of the ephemeral lake. The overall scenario, with the exception of the ephemeral lake in fig. 1, well represents the conditions typically observed the last few years at the Ghiacciaio del Calderone basin at the end of the ablation season, in synthesis a full epiglacial debris mantle above the residual ice.

METEOROLOGICAL CONDITIONS

The synoptic conditions at the beginning of September 2012, in particular the first week, have been characterized by the influence of a low pressure vortex from the Western Mediterranean sea, which led to precipitations widely spread all over the Italian territory, with abundant snowfalls in the alpine west sectors at elevations of 1800-2000 m. In the second decade of September, a second, more intense, cyclonic figure, centred on the Southern Mediterranean sea, drove over Italy a cold pool from the North Atlantic area. The particular configuration and persistence of

the low pressure vortex over the Naples gulf resulted in heavy rains which started from Sardinia and extended to the whole Italian peninsula and towards the Adriatic side with the occurrence of «self-sustaining thunderstorms», especially on the eastern slopes of the Apennines. The rain events reached an exceptional maximum around the 12-15 September with an apex the 14 and 15, as it can be evinced from geopotential maps and meteorological data from monitoring sites in the vicinity of the Gran Sasso d'Italia massif (De Albentiis, 2012). With the aim of reconstructing the meteorological scenario, ECMWF operative runs, with resolution of 0.125x0.125 degrees (T1279), have been used, including geopotential height and surface pressure (forecasts integrated by data assimilation, see ECMWF 2013). In this way - summing forecast convective precipitation and large scale precipitation interpolated over the Ghiacciaio del Calderone area - 12h-cumulated precipitations of 7 mm and 39.8 mm for the morning (0-12) and afternoon (12-24) of 13 September, respectively, and of 52.1 mm and 20.9 mm for the morning and afternoon of 14 September have been calculated. The ECMWF data, once integrated on the 24h, are consistent with the measured precipitations at meteorological stations at low altitudes in the vicinity of the Gran Sasso d'Italia massif: for example, the daily cumulative precipitations recorded at the Teramo station (279 m; N393348,4724007) the 14th of September were 100.8 mm, comparable to ECMWF data of 80.7 mm.

On the contrary the total precipitation at the higher elevation stations were larger with respect to the coastal ones and clearly underestimated by the ECMWF operative run: for example, for the 14th of September the daily precipitations recorded at the Isola del Gran Sasso station (420 m; N389042,4706182; www.caputfrigoris.it) were 178,2 mm, not comparable to ECMWF data of 72.8 mm, as well as in Castelli (TE) station (640 m; N394120,4704898; www.caputfrigoris.it) with 208 mm (ECMWF, 71 mm) and in Campo Imperatore (AQ) station (2130 m; N381567, 4699648; www.abruzzometeo.it) with 275 mm (ECMWF, 46.5 mm).

In summary, as deduced from the ECMWF data, the event started in the afternoon of 13 September: the amount of precipitations recorded in 24h after the 15:00 of the 13th of September in the mountain areas of the Gran Sasso d'Italia, both on the Northern and Southern sides, were of high intensity (an average of 150 mm) and comparable with those observed at lower elevations in the region and also along the coast (De Albentiis, 2012). In the following 24h the distribution of the precipitations changed, with an intensity focused on the mountain area, even at the higher elevation, leading to a cumulative value of approx. 300 mm (mixed rain/snowfalls early in the morning).

The event can be considered actually of maximum intensity: in fact the top values recorded in Castelli and Campo Imperatore stations are higher than the maximum daily intensity of precipitation (190.6 mm) recorded in the studied catchment basin of the Vomano river (Isola del Gran Sasso station, 7 November 1999), within the last decadal series of observations (Servizio Idrografico e Mareografico della Regione Abruzzo - years1994-2003), available on the web.

EVOLUTION OF THE EPHEMERAL LAKE

The maximum intensity rainfall event described above (more than 340 mm of rainfall in a 48-hour period recorded at Campo Imperatore station) was able to locally satu-

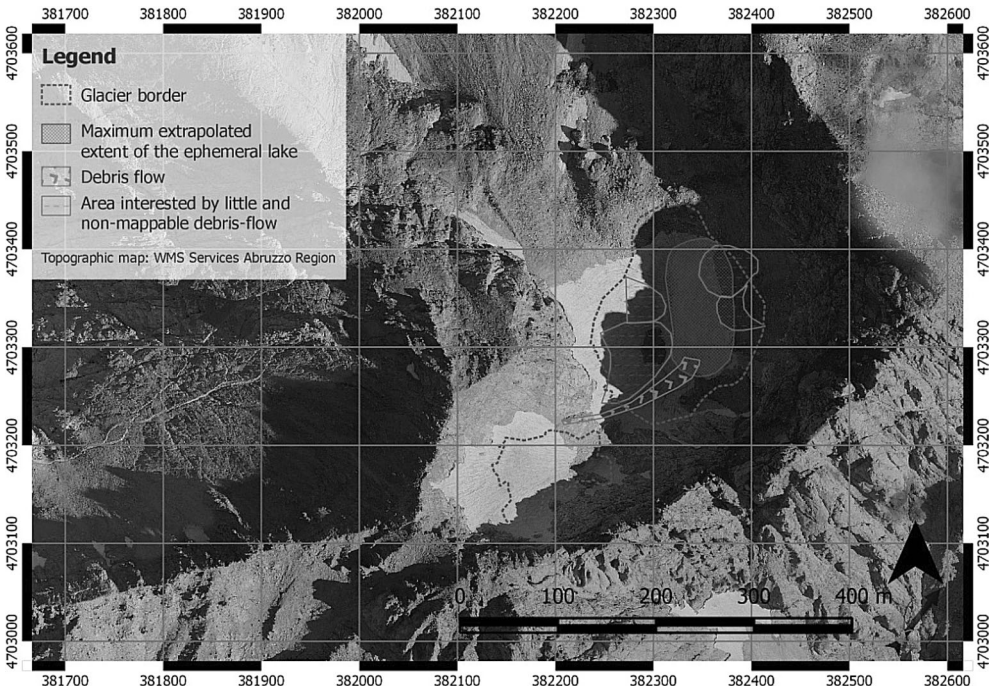

FIG. 4 - Geomorphological map of the Ghiacciaio del Calderone area; main landforms and phenomena connected to the precipitation event described in the text are illustrated.

rate the epiglacial debris, as a consequence of the direct effect of the precipitations and of the hypothesised contribution from the snow and ice melting. The latters were reasonably promoted by the positive temperature framework following the evolution of central Mediterranean low pressure in slow eastern ward movement. One principal consequence was the generation of a number of debris flows, the major of which is clearly identifiable in fig. 1 and also mapped in fig. 4; moreover also the blocks placed along the deepest rock couloirs and the instable debris at the toe of the rock walls were capable to locally trigger widely spread, but limited debris flows (fig. 1).

A reasonable hypothesis on the mechanisms that led to the ephemeral lake formation is based on the evident huge amount of silt that have been mobilised principally by the hydro-saturation and the intense running water, with the contribution of ice/snow melted water: the wide spread presence and availability of silt (fig. 5) promoted the temporary filling up of the karstic canyon/sinking stream localized at the bottom of the glacial cirque (D'Aquila & *alii*, 2009) and, at the same time, the presence of a less permeable surface sustaining a glass-like lake. A reconstruction of the maximum water levels, as appreciated in fig. 1 and corresponding to the highest black line, was

FIG. 5 - General view of the depression of the lower sector of the Ghiacciaio del Calderone, showing the mantle of silt covered the surface with a particular of the sampling for chemical and environmental analyses 16 September 2012. With the dashed circle the same area of fig. 1 is shown at the same scale and with the full line circle the dimension of a man is shown.

performed in a GIS environment (fig. 4), having as base the detailed topographic 1:750 map of Gellatly & *alii* (1994) on the vector ortophotomap of Abruzzo Region (2010), equivalent scale 1:5.000, taking into account the dimension of the authors (less than 2 m), in the full black circle of fig. 5, to be compared to the level of fig. 1, well marked by the presence of the same boulder of limestone in dashed circle in both the figures. In this way a maximum depth of 5±0,5m was estimated and, mapping in GIS environment the contour line corresponding to the limit and to the isoline of 5 metres above the bottom, a maximum extension of 8200 m^2 was calculated for the lake surface, with a consequent maximum estimated volume of approximately 41000±4100 m^3. After the end of the meteorological event the ephemeral lake lasted for about 24-36 hours, as estimated by successive surveys. We calculated roughly that the overall dynamics of formation, evolution and endings had taken about 60 hours. On this basis we also evaluated an outwash in correspondence of the basal sinking stream of about 190±32 l/s. The uncertainties above derive from the error of 0.5 m in the estimate of filling height of the lake.

DISCUSSION AND FINAL REMARKS

Since the last fifteen years the «high altitude environment» of Gran Sasso d'Italia, as already noticed in previous works (i.e. Pecci, 2006; Pecci & Scarascia Mugnozza, 2007; Pecci, 2009; D'Aquila & *alii*, 2009; Pecci & D'Aquila, 2011) has been characterized by the presence of fast evolving phenomena and landforms which can be associated in general to the effects of global warming and more specifically to a rapid transition of the glacial environment towards a paraglacial landsystem (*sensu* Ballantyne, 2002).

In this context, a prompt monitoring of the relevant phenomena, such as the formation of the ephemeral lake described here, has a great relevance. Indeed, the fast evolution and the ability of the high mountain environment to mask suddenly the traces of such events (i.e. a light snowfall followed the disappearance of the lake) make it highly probable to miss any evidence of similar occurrences. Specifically, the morphological evidences of the formation of the ephemeral lake and of the evolution of the debris flows nearly disappeared, in fact have been cancelled in few weeks (fig. 3 and 5). Furthermore, in the studied scenario the flow in the proximity of the sinking stream at the base of the glacier apparatus basin has been estimated in about 190 l/s and corresponding to the outwash. The case study discussed here, i.e. the formation of an ephemeral epiglacial lake structure due to an anomalous water concentration and to a possible fast melting of snow and ice, although considerable as a sporadic event, probably already happened in the past and is possibly a reproducible phenomenon in the near future at the Gran Sasso d'Italia. The begin, evolution and conclusion of the extraordinary precipitation event have evidenced the delicate balance among geomorphological conditions and dynamic processes that substantially impact on the glacier evolution and determine a clear progress of a fast paraglacial process.

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