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A PRELIMINARY SURVEY FOR TESTING OPERATIVITY AND EFFICIENCY OF GPR TECHNOLOGY BY MEANS OF UNSHIELDED ANTENNA FOR THE STUDY OF CALDERONE GLACIER, CENTRAL ITALY

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ABSTRACT: During July 2015 a survey using GPR technology was carried out over the Calderone Glacier in the Gran Sasso d'Italia Massif (highest peak 2912 m a.s.l.). The main aim of the survey was to verify the usability of bistatic unshielded antenna, uncoupled with the ground, and to assess GPR data quality vs reached depth. The use of this kind of antenna is suggested by the need to operate also over rough and irregular surfaces.
The obtained results are to be considered very good, as they easily match with previous results obtained in 1992 and 1998 using GPR technology with a shielded antenna, coupled with ground. The interpretation of data highlights a good stability of the ice mass in the lower-middle sector of the glacier, and a maximum ice thickness evaluated about 26 m.
The choose system was a Radsys GPR with unshielded antenna of 150 MHz frequency, to cross an ice thickness lower than 30 m, as supposed by previous researches.

Keywords: GPR, Calderone, glacier, uncoupled antenna, Apennine, Italy.

1. INTRODUCTION

As well known, the Calderone Glacier, located in a cirque in the north side of Corno Grande, Gran Sasso Massif (central Italy), is the only glacier of Apennine and the southernmost of Europe (Pecci et al., 1997). As a consequence of the raising air temperature in recent decades, it has undergone a progressive and constant melting (Gellatly et al., 1994). Numerous studies (e.g., Marinelli & Ricci, 1916; Tonini, 1961; Smiraglia & Veggetti, 1992) have been conducted to define the glacier geometry and the evolution of the glacial apparatus. They all agree in indicating the presence of an icy mass, of not uniquely defined geometry, covered by a not uniform layer of heterometric debris (Fig. 1). The estimated maximum thickness was about 26 m (Fiucci et al., 1997; De Sisti et al., 1998).

In view of the logistical difficulties and peculiarities of the survey site, the GPR (better known in literature as Ground Penetrating Radar) has proved to be the most suitable instrument for the deep analysis of the glacier body (Bogorodskiy et al., 1985; Funk et al., 1993; Haeberly et al., 1983), thanks to the progressive reduction of the overall dimensions of the equipment and to its great resolution power and data processing capabilities. To Fiucci and collaborators is due the first campaign of investigations by GPR technique performed in the summer of 1992; De Sisti et al. (1998) conducted a similar survey in July 1998.

This report presents the results of a preliminary GPR survey performed on 26 July 2015 on the lower-middle sector of the glacier. The survey was carried out quickly with an unshielded antenna, uncoupled with the ground, which has large footprint but anyway a low weight making it possible to extend the acquisition profiles to rough zones, such as the edges of the glacier covered by seasonal snow (Fig. 2). The aim of the survey was to verify the effective operativity in such surface conditions, as well as the quality of the results obtained without adherence between antenna and ground, which usually leads to signal attenuation.

2. DEVICES AND METHOD

The principle which drives a GPR equipment can be summarized as follows:

- from the ground surface the antenna transmits a pulse-type signal (electromagnetic wave).
- intercepting an electromagnetic discontinuity in the crossed medium (caused by an object embedded in it or by a change of the medium itself), part of the incident wave is reflected toward the ground surface;
- the reflected wave is acquired by a receiving antenna at the ground surface.

Transmission and reflection of electromagnetic waves are driven by the following electromagnetic parameters:

- relative dielectric constant, generally indicated more briefly with the term "permittivity", that has the most influence on the waves speed;
- conductivity, a parameter that limits the investigation depth, since the greater the conductivity the greater is the absorption.

During signal acquisition, the GPR registers the travel time of the reflected wave, and subsequently converts it into distance covered by the wave, as a function

Fig.1 – A SW view of the Calderone Glacier. On the right the front moraine can be seen.

Fig.2 - The used GPR system: unshielded antenna and acquisition unit. Firn covers debris (T1 scan).

of the permittivity assumed for the medium. In the case of ice, the assumed value is equal to 4, in accordance with previous studies (e. g. Daniels, 2004)

The equipment used, mod. Zond 12e Radsys, consists of an acquisition and digitizing unit, compact and transportable by the operator, together with a netbook for recording and displaying data. The unit is connected to an antenna with a frequency suitable to the prospecting targets (depth and resolution), whereas low frequencies mean greater depth investigation and less resolution, and vice versa. Therefore in this survey, considering the expected thickness of the ice mass, a low frequency antenna (150-75-38 Mhz, set to 150 MHz) not coupled with the ground, was used.

The GPR scans were positioned using reference points from which distances and elevations were measured with a Nikon, model Forestry Pro 2 trigonometric diastimeter.

3. DATA ACQUISITION

The investigated area corresponds to the lower-middle glacier sector, down to the southern side of the terminal moraine (2696 m a.s.l.). All the height values in the scans below are relative to the snow conditions at the survey date; all the scans lengths are defined in a horizontal projection.

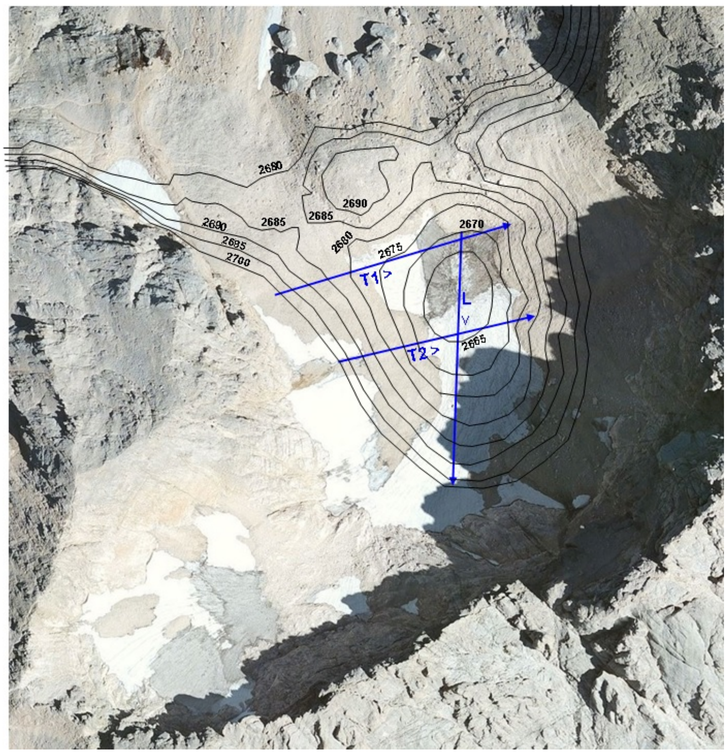

Fig.3 - The Calderone Glacier: aero-photographic image with contour levels and scan sec- tions.

Three scans were performed with the aim to draw the geometry of the glacier bottom. The scans location is shown in Fig. 3, on an aerial-photographic base.

A longitudinal scanning (scanning L, Fig. 4a) was performed in the north-south direction, parallel to the axis of the glacier. The starting point (to the north) was set at an altitude of 2670 m a.s.l., approximately corresponding with the contact between the moraine outcrop and the snow cover existing at the date of survey. The scanning passed through the lowest point, at an altitude of 2668 m a.s.l., and finally reached a length of 119 m, with the end point (to the south) at an altitude of 2700 m a.s.l.

Subsequently, a first transverse scan was performed (scanning T1, Fig. 5a) with a west-east direction, intersecting the longitudinal scan near its starting point. The tranverse length was 152 m, with a starting point (to the west) at an altitude of 2705 m a.s.l. and an end point (to the east) at a height of 2676 m a.s.l. The lowest point corresponds to the intersection with the longitudinal scan L.

The third scan (scanning T2, Fig. 6a) intersects, with a west-east direction, the midpoint of the longitudinal scan and is 120 m long. The starting point (to the west) is located at an altitude of 2697 m a.s.l., the lowest point at 2669 m a.s.l. and the end point (to the east) at 2678 m a.s.l.

In Fig.7 the location of the scans is shown on a photographic base illustrating the snow conditions on July 11, slightly higher than those found on July 26, 2015.

4. RESULTS

First step in data rendition was the examination of glacial and snow conditions as visible in site at the survey time, on 26 July 2015, then the GPR analysis was carried out with the aim of checking the presence and thickness of the following homogeneous units:

1. shallow firn;
2. debris cover blanket;
3. ice;
4. limestone bedrock.

In the examination just basic processings were done, that is background removal run, appropriate signal gain and moveout correction, or rather parallax correction according to antenna size in order to get the right reading of deepness and achieve the correct reading of depth.

Under graphic rendering of soundings (radargrams) the elevation profiles of sections were drawn carefully getting a better view of glacier topography and a truly shape of the homogeneous units. Finally, the altitude references (i.e. zero point of the radargram depth scale) were aligned to the lowest points of the bedrock surface in each profile, thus allowing a more convenient comparison between the different soundings.

In the figures 4b, 5b and 6b coloured areas show the existence of a well-marked discontinuity, easily ascribable to the contact surface between the shallow firn layer and the underlying debris cover blanket. This interpretation is confirmed by the outcrop of such a contact surface on the initial section of profiles L and T1 (Fig. 2,

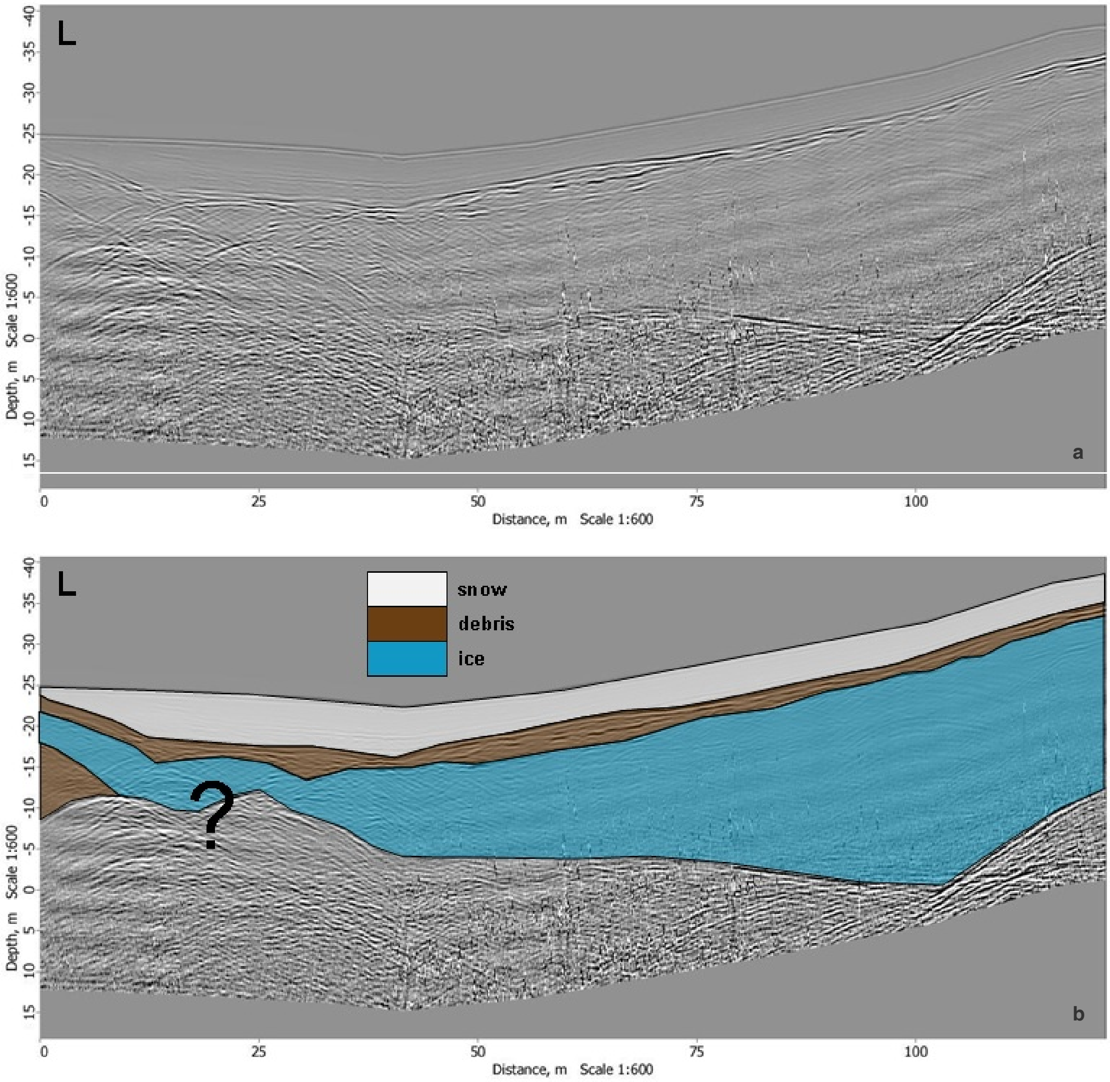

Fig. 4 - Georadar scan section L (a) and the same section with the units enhanced using different colours (b) .

fig. 4b and 5b).

All the radargrams show a well-defined discountinuity at the basis of the debris layer, confirming its scarce thickness as already pointed out to by Fiucci et al. (1997) and De Sisti et al. (1998). Below this discontinuity, the lack of anomalies in the reflected signal allows to characterize the existence of a uniform mass, recognizable as ice.

In the L scan radargram, the excellent signal quality allowed a reliable interpretation of the shape of the Calderone Glacier lower-middle part along the longitudinal axis of the glacial basin (Fig.4b). The deepest discontinuity looks particularly clear; it is most likely ascribable to the contact between the glacier and the bedrock. A little beyond the point of 100 m the maximum depth is visible with regard to the firn surface at the moment of sounding, valuable about 32 m. As a result, the maximum ice thickness would amount to 26 m, bearing an overlying debris cover one meter thick and a 5 m thick firn blanket. The initial section (north) of the scan appears to be easily construable; the bedrock "rise" making up the basin threshold, and the above debris stock- pile of the front moraine are well marked.

In the final portion of T1 scan (Fig. 5b) the contact between the glacier and the bedrock appears less clear, so that the direct contact between debris cover and limestone bedrock is possible, there locating the probable margin of ice mass at the glacier eastern side, just before the frontal moraine. Similar reading uncertainty does exist in the neighborhood of point 100 m of scan T2 (Fig. 6b), where presence of ice with a large amount of debris inside (rock glacier) is conceivable. Anyway, T2 scan points out an unexpected thickness of ice at the western side of glacier basin, that as about 15 m in the first section (west) of the scan. Ice shows fair thickness in the eastern side of the basin, too.

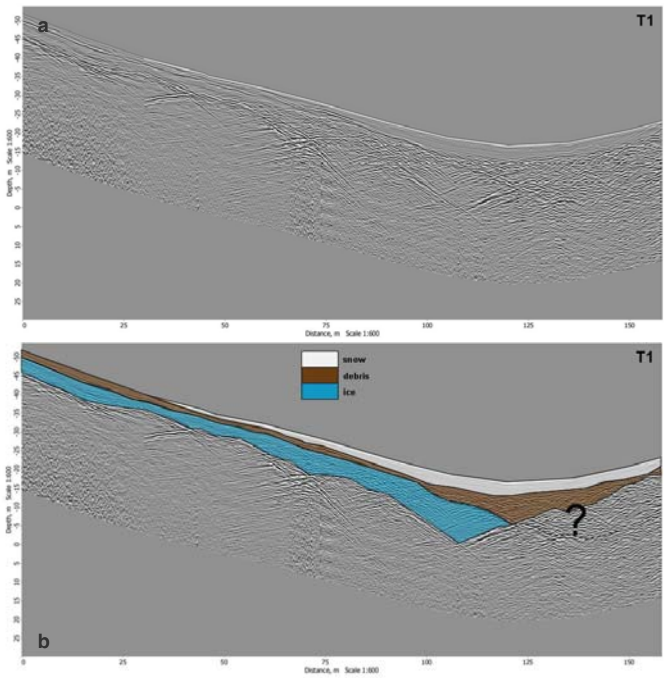

Fig. 5 - Georadar scan section T1 (a) and the same section with the units enhanced using different colours (b).

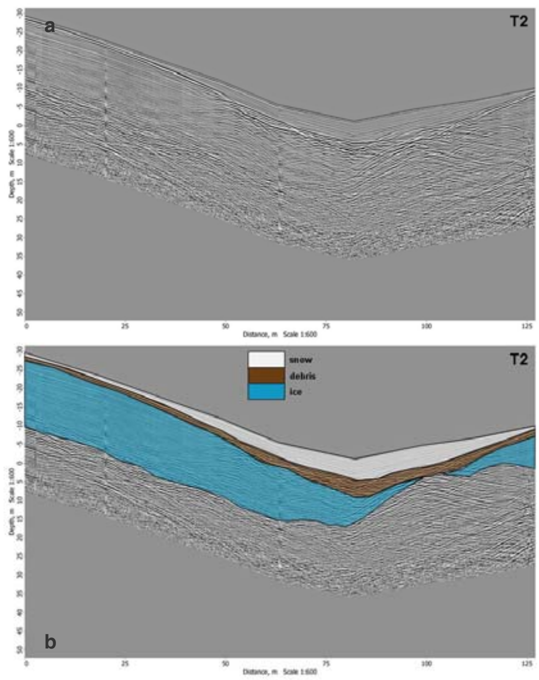

Fig. 6- Georadar scan section T2 (a) and the same section with the units enhanced using different colours (b).

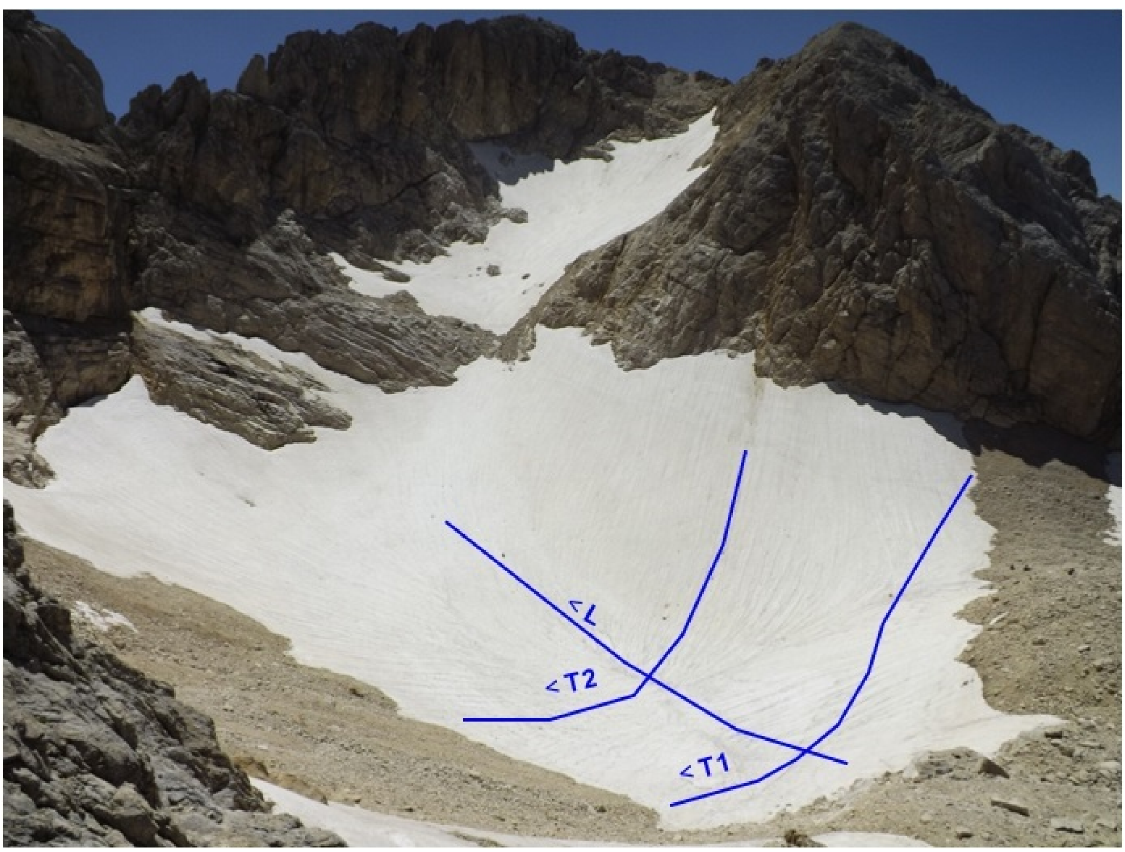

Fig.7 - The georadar sections in a 3D view.

5. CONCLUSIONS

The execution of a preliminary survey on the Calderone Glacier, carried out with GPR technique and non surface-coupled antenna, has allowed to check the full practicality and efficiency of such a system, which permits to overcome inconveniences and limitations resulting from operating with surface-coupled antenna in case of strongly roughed surfaces.

The quality of recorded signal has proved to be pretty good and satisfying, allowing an excellent depth of survey; the ice maximum thickness, as detected in the longitudinal scan, resulted equivalent to 26 meters, perfectly in agreement with previous studies, proving a significant and unexpected preservation of the icy mass in the last two decades.

The scan processing has provided useful hints about the possible shape of the units that make up the glacier complex, with special regard to the front moraine morphology and the bedrock basal surface. Furthermore, important information has been obtained concerning the unexpected thickness of sides of the glacier in the central area.

Positive results achieved with the carried out preliminary survey allow the planning of a more thorough and careful survey with the same technique and equipment, focused to get a detailed mapping of the glacier shape, that will be obtained by means of a regular grid of scans and based on a careful land survey.

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