Location of a new ice core site at Talos Dome (East Antarctica)

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Abstract

In the frame of glaciology and palaeoclimate research, Talos Dome (72°48′S; 159°06′E), an ice dome on the East Antarctic plateau, represents the new selected site for a new deep ice core drilling. The increasing interest in this region is due to the fact that the ice accumulation is higher here than in other domes in East Antarctica. A new deep drilling in this site could give important information about the climate changes near the coast. Previous papers showed that the dome summit is situated above a sloped bedrock. A new position on a relatively flat bedrock 5-6 km far from here in the SE direction was defined as a possible new ice core site for an European (Italy, France, Swiss and United Kingdom) drilling project named as TALDICE (TALos Dome Ice Core Project). This point, named as ID1 (159°11′00″E; 72°49′40″S), became the centre of the Radio Echo Sounding (RES) flight plan during the 2003 Italian Antarctic expedition, with the aim of confirming the new drilling site choice. In this paper 2001 and 2003 RES data sets have been used to draw a better resolution of ice thickness, bottom morphology and internal layering of a restricted area around the dome. Based on the final results, point ID1 has been confirmed as the new coring site. Finally, the preliminary operations about the installation of the summer ice core camp (TALDICE) at ID1 site carried out during the XX Italian Antarctic expedition (November 2004-December 2005) are briefly described.

Key words *radio echo sounding – radio glaciology – ice thickness measurements – internal layering*

1. Introduction

Talos Dome is an ice dome at 72°48′S; 159°06′E on the edge of the East Antarctic plateau adjacent to the Victoria Land mountain about 290 km from the Southern Ocean and 250 km from the Ross Sea. This site has a good geochemical and palaeoclimate record preserved in the ice, because the accumulation (80 kg m^{-2} a^{-1}) is higher here than at other domes in East Antarctica. Moreover, according to the thickness/snow accumulation ratio, a 120-150 thousand years (BP) palaeoclimatologic history is expected (Deponti and Maggi, 2003). For this reasons Talos Dome, from previous studies (Frezzotti *et al.*, 2003), was selected as new drilling site in order to study the response of near-coastal sites to climate change and Holocene history of accumulation rates in the Ross Sea region. The knowledge of bedrock topography of Talos Dome region and its internal layering are of great importance, not only for the obvious reason of knowing how deep to drill, but also because the lower part of deep ice cores can only be dated by modelling studies (Reeh *et al.*, 1985).

In this paper, a reconstruction of ice thickness, bedrock morphology and some internal layers has been made by Radio Echo Sounding

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data analysis. RES system is an active remote-sensing method based on the generation, propagation and reflection of an electromagnetic wave due to one or more discontinuities in the media dielectric properties (Bogorodsky *et al.*, 1985).

This work reports the results obtained by the integration of the last two Antarctic campaigns (2001 and 2003) focused on the selection of the Talos Dome best drilling site position. The 2003 survey was planned to achieve a more detailed information in the area close to the topographic summit of Talos Dome.

2. Field data acquisition and analysis

Since 1997 the Istituto Nazionale di Geofisica e Vulcanologia (INGV) and University of Milan have been developing their own airborne radio echo sounding system for remote-sensing studies of the polar ice sheet and glaciers in Antarctica (for details see Tabacco *et al.*, 1999). This system (named INGV-IT, Tabacco *et al.*, 2002) has been used to map ice thickness and internal layers of glaciers, ice sheets and ice shelves (Tabacco *et al.*, 1998, 2000; Capra *et al.*, 2000; Frezzotti *et al.*, 2000; Remy and Tabacco, 2000; Bianchi *et al.*, 2001; Siegert *et al.*, 2001).

The RES system has been slightly modified during each expedition. Main radar system improvements have been applied between 1996 and 2001 concerning the total range time (which increased from 51.2 μm to 64 μm), the number of samples for each radar track (enhanced from 1024 to 1280 samples) and the number of acquired tracks per second (raised from 0.3 track s^{-1} to 10 tracks s^{-1}).

Figure 1 shows the aircraft legs along which the measurements have been recorded during 2001 and 2003 expeditions (black and red lines respectively) in UTM coordinates WGS84. About 18% of data could not be used due to the

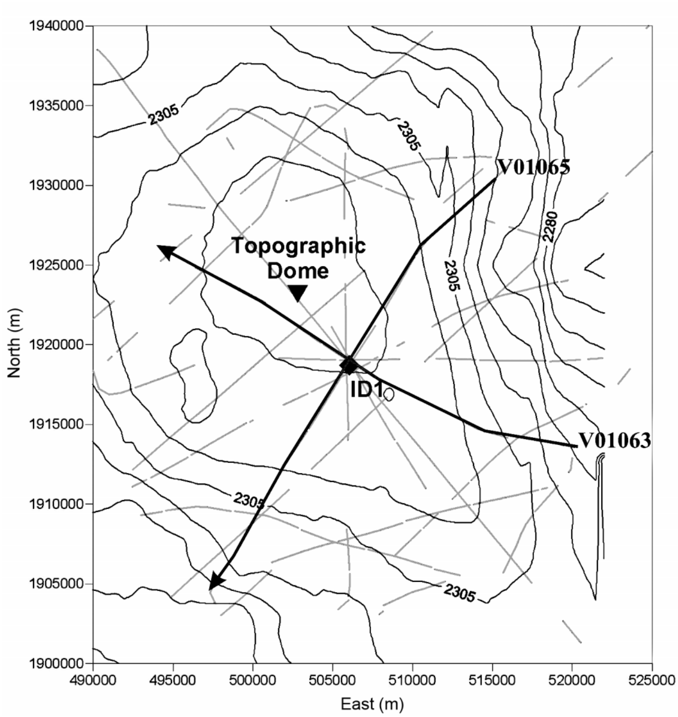


Fig. 1. Aircraft legs covered during 2001 and 2003 Italian Antarctic RES expeditions (black and light grey lines respectively). The position of the selected drilling site is indicated as ID1.

lack of returned echoes from the bedrock but, on the whole, results can be considered good. In fig. 1 flight lines are interrupted where the bedrock reflection signal has not been received.

The first data set (2001) did not permit the detecting of regular and continuous internal layers especially in the dome area. The technical improvements introduced in the 2003 RES instrumentation allowed to identify three reflecting horizons characterized by good regularity and continuity.

RES raw data post-processing flow consisted basically in deconvolution, gain adjustment, vertical and horizontal filtering, data stacking and, in some cases, migration. All data were processed following the same criteria and finally were cross-checked. Crossover point analysis pointed out that ice thickness values in different RES profiles are in good agreement. Indeed, counted cross points on all legs were 59: 30% of cross points exceed a distance greater than 200 m and about 51% have a difference in ice thickness less than 40 m. Ice thickness was calculated using a constant velocity of 168 m μs^{-1} (Glen and Paren, 1975; Bogorodsky *et al.*, 1985) while spatial resolution was around 1 scan/7 m.

After the described preliminary analysis the same processing parameters (and not the processing flow) have been changed for a better layering resolution.

Whole 2001 and 2003 RES data sets have been used to model the three-dimensional view of the bedrock topography and of the internal layering. The investigated region covers an area of about 1400 km^2. All thickness profiles data sets have been gridded by Kriging method with a square grid cell size of about 500 m.

A preliminary RES data analysis pointed out that Talos Dome is a mountainous area with a rough morphology as the neighbouring Frontier Mountains region. Moreover, the RES survey of the investigated area did not show evidences of subglacial lakes or basal melting.

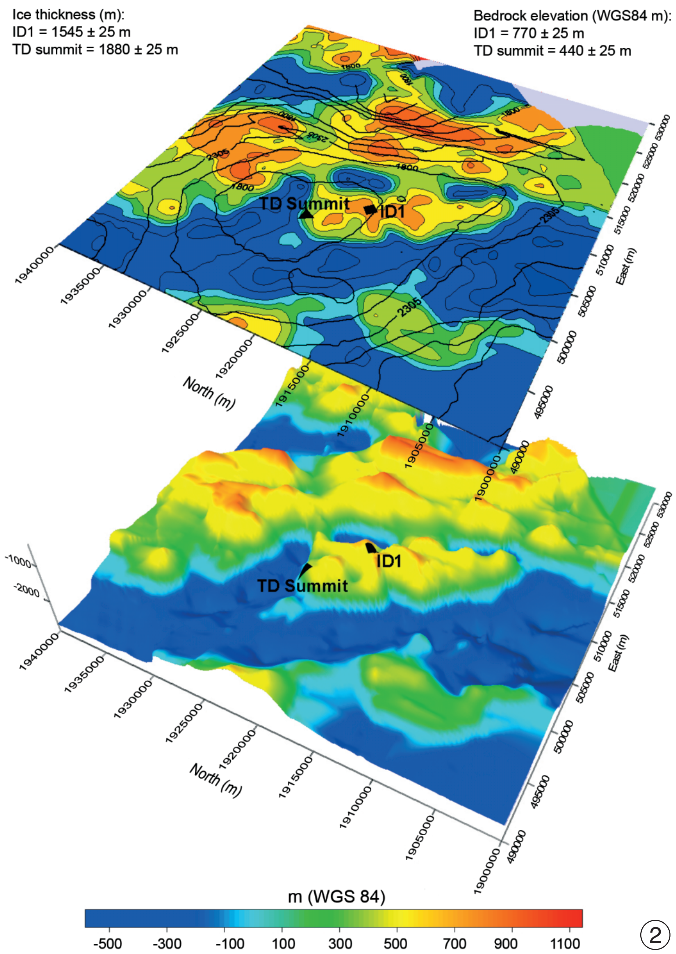
3. Drilling site characteristics

It is known that a good drilling site has to be characterized by a relatively flat condition of both the bedrock and the main internal layering. In fact, an accurate time-depth core correlation is possible only where regular and horizontal snow layering occurs. Moreover, in this area, snow radar and GPS surveys show that the shallow (100 m) internal layering is continuous and horizontal up to 15 km from the summit (Frezzotti *et al.*, 2004).

Figure 2 shows the ice surface and sub-glacial topography of the Talos Dome region. A detailed surface elevation map was made using data from many GPS altimeter surveys. The geographic position of Talos Dome, located at Long 159°04′E and Lat 72°46′S (Frezzotti *et al.*, 1998, 2003) is indicated in the figure by a triangle symbol. The bedrock depths have been referred to the accurate elevation model obtained using the altimetric measurements for the whole investigated area. As shown, the bedrock topography consists of a deep basin where the ice thickness ranges from 800 to 2900 m. The deep basin is connected to a low bedrock zone. In particular, bedrock of the Talos Dome Summit (TDS) is about 440 m in elevation (WGS84) and it is covered by about 1900 m of ice. The dome summit is situated above a sloped bedrock over a kind of isolated ridge and for this reason it is not the ideal drilling site. Following the main ridge structure (elongated to SE direction) 5-6 km far from this point, bedrock became relatively flat and it is characterized by an elevation of about 750 m (WGS84) covered by 1550 m of ice (Frezzotti *et al.*, 2003). This point, named ID1 (159°11′00″E; 72°49′40″S indicated as a black square in the figures 1 and 2) was the centre of the 2003 RES flight plan. Previous campaign data analysis showed also the presence of internal layering below the dome, but reflecting horizons were irregular and discontinuous. By a focused data post processing, 2003 RES dataset allowed to detect three internal layers ($L1=1850$ m; $L2=1690$ m; $L3=1240$ m (WGS84)) characterized by a good continuity along the profiles.

Mountain and valley morphologies orientation follows the ice-divide line (NW-SE) and clearly influence the dome and the internal layers stratigraphy.

The new more detailed 3D maps carried out by 2001-2003 RES datasets integration, also supported by new internal layering analysis (fig. 3), confirm that the position of point ID1



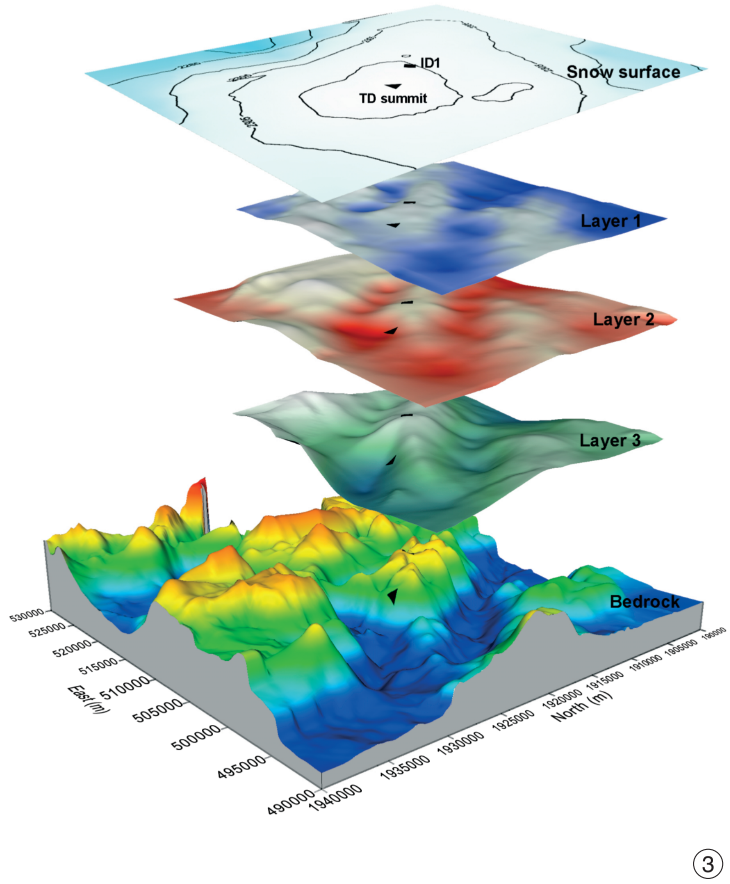


Fig. 2. Bedrock topography of the Talos Dome area in 2D and 3D maps. On the 2D bedrock map also the ice surface contour lines are reported.

Fig. 3. Ice surface, bedrock topography and three internal layers over Talos Dome area. The internal layers stratigraphy is deformed according to the morphology of the bedrock. The positions of ID1 site and of Talos Dome summit are also reported.

can be considered a good choice for a new deep ice drilling.

Based on the above considerations, during the XX Italian Antarctic expedition (austral summer 2004-2005), some preliminary works were carried out in order to start the drilling operations. Once localized ID1 point, a wide trench (50×5.5 m) was excavated by a Pisten Bully in order to contain all drilling instrumentations. Coring operations started, reaching the depth of about 128 m. The coring project plan (TALDICE) foresees the end of the drilling operations in the next two austral summer campaign.

5. Conclusions

Talos Dome is an ice dome on the Antarctic plateau 250 km from the Ross Sea and about 290 km from the Southern Ocean. It was selected as new drilling site to study the response of near-coastal sites to climate change. Frezzotti *et al.* (2003) showed that the dome summit was not the ideal drilling site because it is situated above a sloped bedrock and they defined a new point on a relatively flat bedrock, 5-6 km more to the SE. This point, named ID1 was deeply investigated during 2003 Italian Antarctic RES survey.

The integrated 2001 and 2003 RES data sets allowed a better resolution of ice thickness, bottom morphology and some internal layering of a restricted area around the dome, in order to confirm ID1 as the new drilling site. Datasets were collected by airborne INGV-IT radar and cover an area of about 1400 km^2 around the dome. This paper shows the bedrock of the investigated region in two and three-dimensional maps. Moreover, ice surface topography defined by GPS altimeter has been reported to have a more complete view of the region. Data analysis confirmed that Talos Dome summit was an inadequate drilling site. On the other hand, ID1 site was localized on the top of a buried mountain ridge where both bedrock and internal layering showed a flat and regular trend. Considering that snow radar and GPS surveys (conducted on the Talos Dome area) showed that the shallow (100 m) internal layering is continuous and horizontal up to 15 km from the summit (Frezzotti *et al.*, 2003), the results carried out by the 2001-2003 RES data integration confirmed ID1 position as a potential optimal drilling site.

These results were used during the last XX Italian Antarctic campaign (austral summer 2004-2005), in which some preliminary work was carried out to start the new drilling operations. Coring operations started, reaching the depth of about 128 m. The coring project plan (TALDICE) foresees the end of the drilling operations in the next two austral summer campaigns.

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