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A New Bedrock Map of the Dome C Area

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INTRODUCTION

A large number of airborne and ground-based radar echo sounding (RES) data were collected in the Dome C – Vostok region during the Italian Antarctic expeditions in 1995, 1997, 1999 and 2001. Tabacco et al. (1998) used the 1995 data to produce a topographic map of Dome C. We present a new map of bed topography based on all collected radar data.

RADAR SYSTEM, DATA COLLECTION AND PROCESSING

Different radar equipment was used in 1995 and in the following years (Tabacco et al., 1998,1999):

i) vertical resolution was enhanced from 512 samples in 1995 to 1024 in 1997 and 1280 in 1999 and 2001, with an accuracy of 100 ns in 1995, and 50 ns in 1997, 1999 and 2001;
ii) the total range time was increased from 51.2 μs in 1995 and 1997, to 64 μs in 1999 and 2001;
iii) pulse length was shortened from 1 μs in 1995, 1997 and 1999 to 0.5 or 0.2 μs in 2001;
iv) the number of acquired tracks per second was progressively increased from 0.3 tracks s^{-1} in 1995 to 1 track s^{-1} in 1997, and 10 tracks s^{-1} in 1999 and 2001.

The study area was covered by a total of 3480 km of airborne-radar survey and about 207 km of ground -radar survey. The airborne survey was completed at a cruising speed of 185-220 km h^{-1} and an average elevation of 350 or 700 m (controlled by a radio-altimeter). The ground-based survey was carried out in 1995 with a travelling speed of 7.5-18.5 km h^{-1}. Figure 1 shows the paths along which radar data were collected.

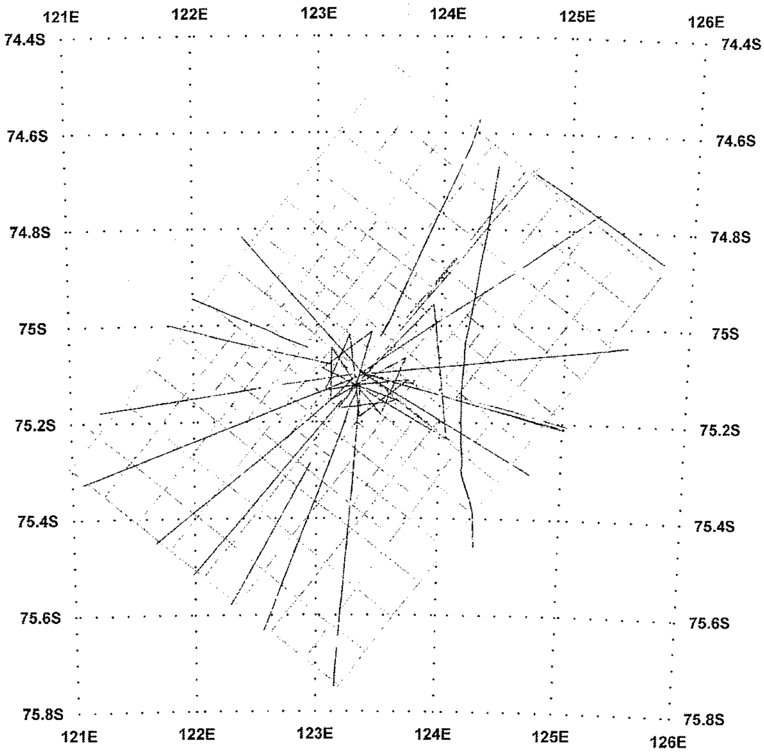

Fig. 1 – Data collected during the P.N.R.A. expeditions in 1995, 1997, 1999 and 2001.

The positioning of the radar paths was obtained by a GPS Trimble 4000SSE system synchronized with a radar system. The GPS data-acquisition frequency was 5 s.

Raw data consist of about 150 000 traces. Although radar data are not homogeneous due to differences in radar systems and track-acquisition rates, they were processed using the same criteria. A data set containing all field observations in the area was created.

ICE THICKNESS, SURFACE ELEVATION AND BEDROCK ELEVATION

Where the bottom reflection was easily-detected, a semiautomatic software allowed researchers to pick-up the echo from the ice-bedrock interface and to obtain the two-way time reflection. Assuming a constant electromagnetic wave propagation velocity in ice of 168 m μs^{-1} (Glen & Paren, 1975; Bogodorsky, 1985), we calculated the thickness of ice in each point. No correction for lower density firn was applied. Moreover, the correction for migration was not calculated.

Surface altimetry data was obtained from ERS-1 satellite imagery on a regular grid of 1/30 ° (Rémy et al., 1999).

Bedrock elevation was determined by calculating the difference between surface altimetry and ice thickness.

ERROR ANALYSIS

Errors in the calculation of ice thickness were mainly due changes in aircraft elevation and to the selected moment for sampling the reflection. These errors correspond to errors in surface measurements of about ±15 m for data collected in 1995 and of ±7.5 m for other data, and to errors in bedrock values of about ±8.4 m for data collected in 1995 and of ±4.2 m for other data.

All thickness values were underestimated by approximately 10 m (Paterson, 1994; Rasmussen, 1986) because no corrections were made for higher electromagnetic wave velocities in the firn layers. The wave speed is accurate to ±0.5 m μs^{-1} and corresponds to an error of 9 m in 3000 m of ice. Errors in the horizontal positioning of the aircraft using a GPS are estimated to be ±20 m. The induced error in surface elevation is completely negligible (4 cm), while it is 1 m in bedrock elevation (Retzlaff et al., 1983). The root square sum of all errors corresponds to a total error in ice thickness of about 22 m for data collected in 1995 and of 16 m for other data.

To evaluate the consistency between radar data collected in different years, we analyzed ice-thickness values at all points where radar legs intersect. The intersection is generally not defined by a single point, but by a couple of points belonging to two different legs. We consider the two points with the minimum distance (always less than 1000 m) as intersecting points. We identified 706 intersections in the area: 50% are less than 200 m apart and 71 % differ in ice thickness by less than 40 m.

THE BED TOPOGRAPHY MAP DISCUSSION

The previous map of bedrock topography was based on 2470 observations from the 1995 radar survey. There are now 51 386 data points thanks to new radar data and new processing techniques. To interpolate and contour the data, three different gridding methods (kriging, inverse of distance, minimum curvature) were compared: best results were produced by the minimum curvature method on a regular grid of 100 x 71 points, corresponding to a spacing between gridlines of about 1.3 km. Points between legs are subject to interpolation errors, and this error is greatest where the surface to interpolate is roughest. The map of residuals shows that the biggest differences are mainly east and south of Dome C, in mountainous areas where bedrock gradients are high. The interpolation error is estimated to be 15 m.

The new bedrock map (Fig. 2) confirms the main topographic features of the previous one, but is more accurate thanks to the greater number of data points and the smaller spacing of gridlines.

The central plateau around Dome C is quite flat, apart for some smooth undulations with a main wavelength of about 6 km and a slope gradient of 25 m/km. The plateau is bordered to the east by a well-defined, deep valley and a South-North ridge. The valley is about 15 km wide and deepens northward and southward from -100 m (WGS84) to -650 m (WGS84) and -500 m (WGS84) respectively. The ridge is about 600 m (WGS84). The plateau is surrounded to the south and southwest by a complex chain of mountains reaching a maximum altitude of 590 m (WGS84). Figure 3 shows a three-dimensional view of bed topography.

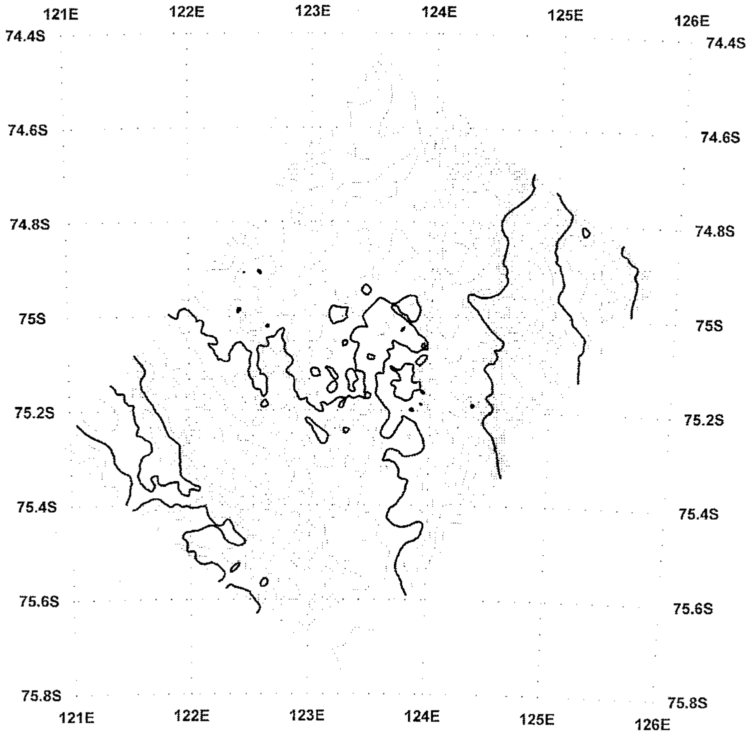

Fig. 2 – 2-D map of bed topography below Dome C. The bedrock contour interval is 50 m. Bold line is isoline 0 m (WGS1984).

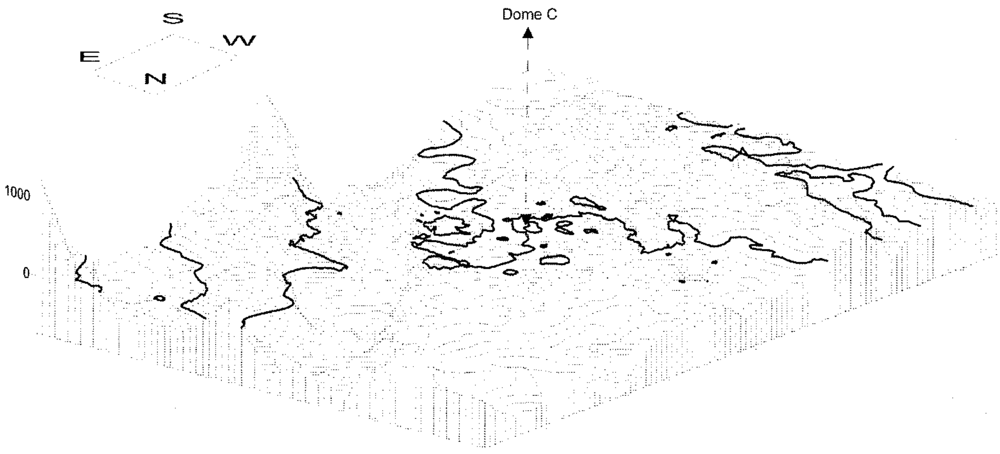

Fig. 3 – 3-D map of bed topography below Dome C. The bedrock contour interval is 50 m. Bold line is isoline 0 m (WGS1984).

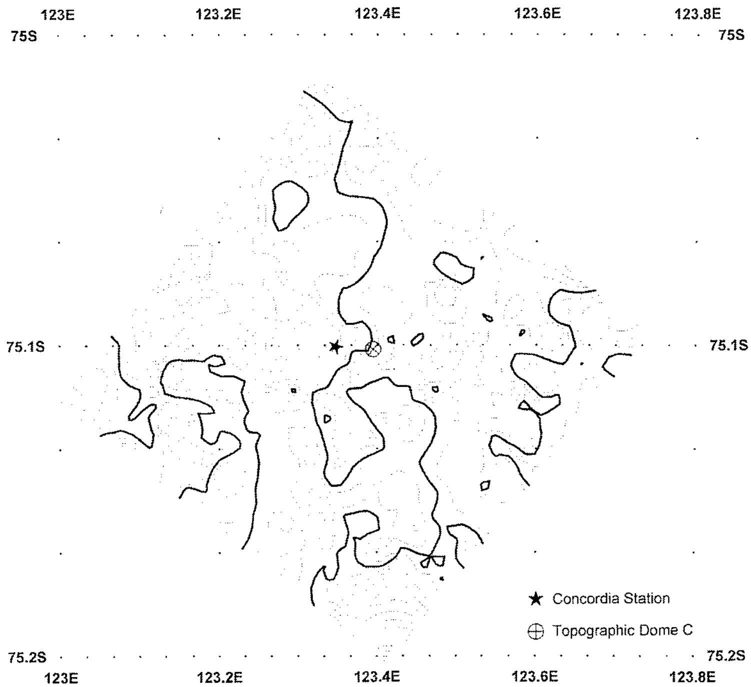

Fig. 4 – Detailed 2-D map of topography below Dome C. The bedrock contour interval is 25 m. Bold line is isoline 0 m (WGS1984).

EPICA DRILLING-SITE LOCATION AND ICE THICKNESS

Cefalo et al. (1996) indicate that Dome C culmination is located 75°06'06.35" S and 123°23'42.76" E using GPS survey of 1996. This point has been confirmed by Capra et al. (2000) using all GPS data acquired between 1996 and 1999. At this location Tabacco et al. (1996) calculated an ice thickness of 3250 ± 25 m and suggested that this was the best site for EPICA drilling. Note that the Base Summer Camp of Concordia Station is located about 1400 m west of the topographic Dome, at 75°06'03.74" S and 123°20'52.10" E (L. Vittuari, personal communication). Another measurement indicates that the Summer Camp is located 75°06'05.5" S and 123°20'51.3" E (C. Vincent, personal communication), and that the drilling site is about 40 m southeast of this point. The two coordinates for the Summer Camp differ by 55 m because the two measurements are probably referred to two different buildings of the Camp.

To recalculate the ice thickness below the true location of the Summer Camp we created a square map (15 km x 15 km) centred on the first point, with gridlines spaced 400 m apart (Fig. 4). As mentioned earlier, the plateau area is not perfectly flat. Smooth undulations are evident, and they are not produced by the method for interpolation. In fact, they are clearly visible in all legs of the 1995 ground survey. We note that topographic Dome C, where the previous calculation was made, is situated over a crest, whereas the Summer Camp lies over a little hump. Near the location of the Summer Camp indicated by Vittuari there is a radar leg collected in 1995. The nearest point of this leg is 35 m far from the Summer Camp, and the measured ice thickness at this location is 3309 ± 22 m.

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