# A GPR Survey in Permafrost at Cerro Tupungato

J. M. Travassos & G. C. Stael

Observatório Nacional, Rua General José Cristino, 77, 20921-400, Rio de Janeiro, Brazil, jandyr@on.br, Stael@on.br

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

**Key-words:** GPR, Permafrost, Andes

## Abstract

In this paper we demostrate the use of GPR method for subsurface exploration in a permafrost area of Tupungato Volcano located in Central Andes of the South America. The GPR survey is part of an ongoing geophysical-glaciological study in the area. The objective of the GPR survey is to image the permafrost structure.

## Introduction

The South American subcontinent presents three great structural areas. The oriental part is constituted by plains and mountains: the plateau of Guyana, the Brazilian plateau and Patagonia (Barsa, 2003).

A geologically young system, the Andes were originally uplifted in the Cretaceous and Tertiary periods. They are still rising; volcanoes and earthquakes are common. The folded ranges are discontinuous—merging and bifurcating within the system—but as a whole they form one of the world's most important mountain complexes. They are loftier than any other mountains except the Himalayas, with many snowcapped peaks more than 6,700 m high. Andean waters reach the Pacific Ocean, the Orinoco, the Amazon, and the Río de la Plata.

The highest range of the Andes is on the central and northern Argentine-Chilean border, Figure 1. The Aconcagua (6,960 m; highest mountain of the Western Hemisphere) and Tupuncato (6,550m) are found there. Figure 2 shows a view of Cerro Tupungato.

Permafrost is defined on the basis of temperature, as soil or rock that remains below 0°C throughout the year, Figure 3, and forms when the ground cools sufficiently in winter to produce a frozen layer that persists throughout the following summer (Wolfe, 1998a; Heginbottom, 2000; Burgess, 2000).

The atmospheric climate is the main factor determining the existence of permafrost. However, the spatial distribution, thickness and temperature of permafrost is highly dependent on the temperature at the ground surface. The temperature at the ground surface, although strongly related to climate, is influenced by several other environmental factors such as vegetation type and density, snow cover, drainage, and soil type (Arcone, 1996; Wolfe, 1998a; Heginbottom, 2000; Burgess, 2000).

## Data Acquisition

The GPR is a tool for relatively shallow penetration. Usually depths of less than 50 meters are examined. But in ice depth penetrations above 1000 m have been achieved (Arcone et al., 1995). GPR has a very good resolution compared with other RES techniques which are used for a greater depth penetration for example to view bedrock under a thick ice sheet (Gruber & Ludwig, 1996).

Ice is a low-loss and low-conductivity material dominated by polarisation therefore amenable for GPR sounding (Davis & Annan 1989). Variations in permittivity are the basis for GPR remote sensing (Gruber, 1996).

The GPR data was collected on permafrot in Cerro Tupungato, Argentina (lat., log.), in march 1997, Figure X. The data was collected with a PULSE EKKO IV GPR, with performance of 155 dB, fed by a battery of 12V DC and controlled by a portable computer. This equipment possesses time window from 32 to 2048 ns and a sampling interval from 800 to 8000 ps. We used two antennas of 50 Mhz, of 1.84 m of length and 2kg of weight, and a voltage of the transmitter of 1000 V, with a tax of repetition of 30kHz.

The antennas were tragged along the profiles with a constant step of 0.20 m. The antennas were kept 2 m apart in the fixed-offset profiles. We have also done CMP profiles with increasing distance between antennas in steps of 0.2 m. The latter were done to estimate of the speed of wave propagation in the subsurface. A correct estimate of the speed is fundamental in the conversion of the double time (TWT) in depth.

Two fixed offset reflection profiles with 51.0 m each were done, the first one 96° N and the second presents 134° N. The two profiles are linked by their ends. The two CMP profiles were done in the same location, one is perpendicular to the other. The two profiles CMP are centralized in the middle of the first reflection profile. The length of both profiles is 31.0 m.

## Results and Conclusion

Figure 5 displays the f-k migrated fixed-offset section on the permafrost. We have limited the section to 1000 ns. The subsurface can be easily be divided in three zones, as seen in Figure 4. The top zone (A) is characterized by many diffractions caused by coarse material of a frontal moraine. This is on the top of a truncated layer of weak reflectors (B), probably mainly ice. The remaining of the section is constituted of sub-horizontal stronger reflectors (C), reaching the end of the section.

## Conclusions

The use of GPR in the study area was shown quite useful in the visualization of several structures in subsuperfices.

This work will continue with CMP analysis and the interpretation of the structures visualized in the GPR sections.

## Acknowledgments

We are indebted to our Argentinian colleagues from CRICYT-CONICET and to the Argentinian Army that gave all support both scientific and logistic to the work. JMT acknowledges a grant from the CNPq.

## References

**Adalkar, A., 2003.** University of Washington, Seattle, USA.

**Arcorne, S.A., Lawson, D.E. and Delaney, A.J. 1995.** Short-pulse radar wavelet recovery and resolution of dielectric contrasts within englacial and basal ice of Matanuska Glacier, Alaska, U.S.A. Journal of Glaciology 41 (137), 1995. pp. 68-86.

**Arcone, S. A.; Delaney, A. J. and Williams, C. 1996.** Geological and Geophysical Investigations of the Hydrogeology of Fort Wainwright, Alaska, Part I: Canol Road Area, CRREL REPORT 96-496-4, pp.1

**Barsa Encyclopedia. 2003.**
**(**www.geocities.com/SoHo/Coffeehouse/2902/america2.htm)

**Burgess, M.M. and Smith, S.L. 2000.** Shallow ground temperatures. *in* The physical environment of the Mackenzie Valley, Northwest Territories: a baseline for the assessment of environmental change, L.D. Dyke and G.R. Brooks (eds.), Geological Survey of Canada Bulletin 547, pp. 89-103.

**Davis, J.L. and Annan, A.P. 1989.** Ground-penetrating radar for high resolution mapping of soil and rock stratigraphy. Geophysical Prospecting 37, 1989. pp. 531-551.

**Gruber, S. and Ludwig, F. 1996.** Application of Ground Penetrating Radar in Glaciology and Permafrost Prospecting Arctic Studies Programme at the Arctic Centre, Rovaniemi, Finland pp. 5-6

**Heginbottom, J.A. 2000.** Permafrost and distribution and ground ice in surficial materials. *in* The physical environment of the Mackenzie Valley, Northwest Territories: a baseline for the assessment of environmental change, L.D. Dyke and G.R. Brooks (eds.), Geological Survey of Canada Bulletin 547, pp. 31-39.

**Network, Family Education (Encyclopedia). 2003.** (www.infoplease.com/ce6/world/A0856608.htm)

**Wolfe, S.A. (ed.) 1998a.** Living with frozen ground - A field guide to permafrost in Yellowknife. Geological Survey of Canada, Miscellaneous Report 64, 71 pp.

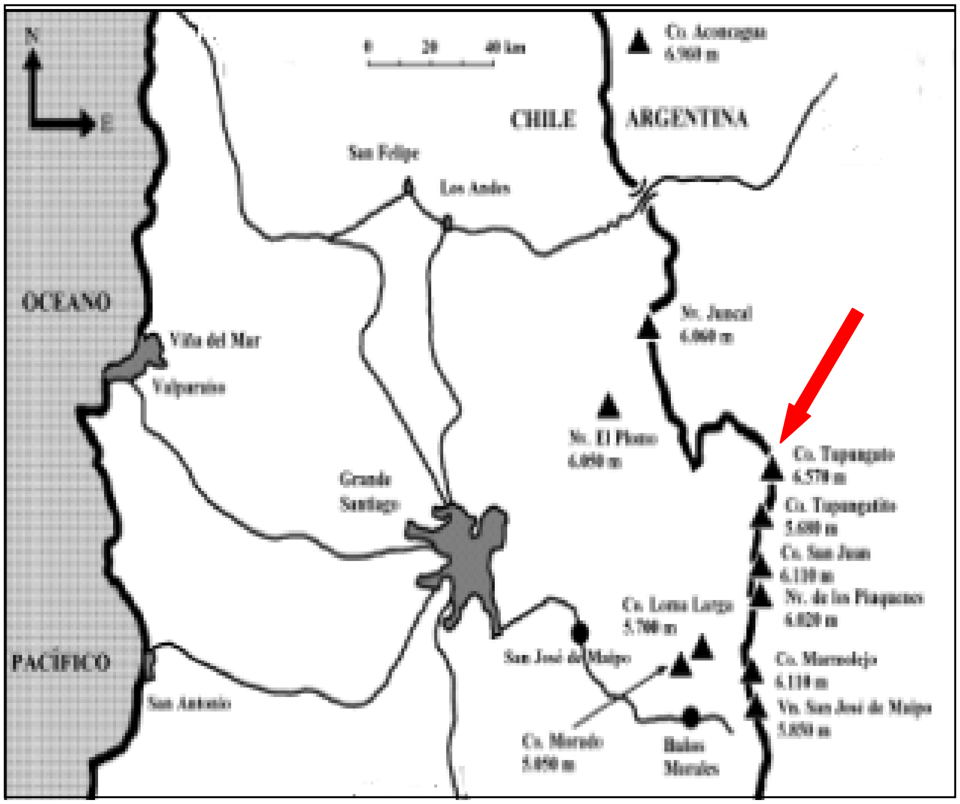

**Figure 1**. A map of the Andes cordillera between Chile and Argentina showing the main peaks (Barsa, 2003). The red arrow shows the location of mount Tupungato.

**Figure 2.** Cerro Tupungato (Adalkar, 2003)

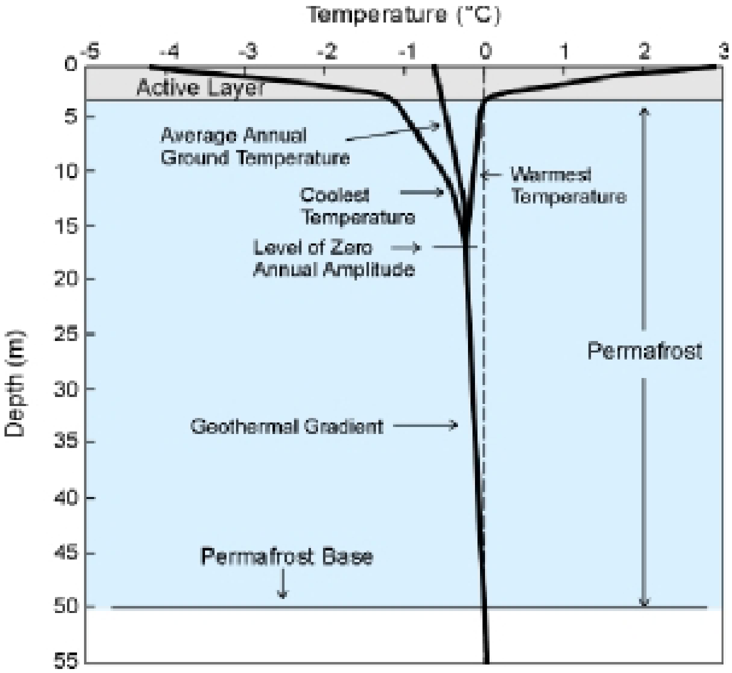

**Figure 3**. An illustration of the range in temperatures experienced at different depths in the ground during the year. The active layer (shown in grey) thaws each summer and freezes each winter, while the permafrost layer remains below 0°C (Wolfe, 1998a; Heginbottom, 2000; Burgess, 2000).

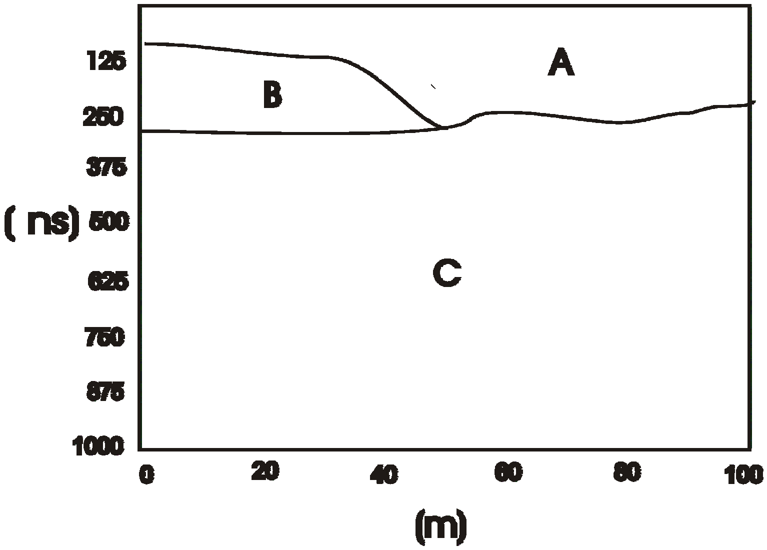

**Figure 4.** Interpretetion of the radar section shown in Figure 5.

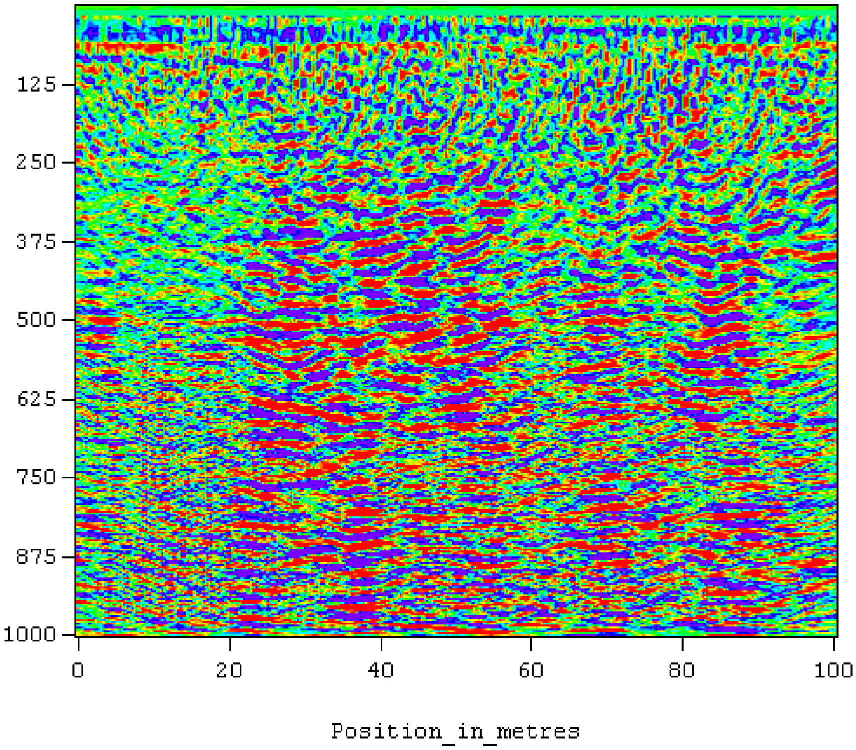

**Figure 5.** the f-k migrated fixed-offset section on the permafrost.

**Figure 6**. Field crew with the antennas on permafrost