Large wood delivery from buried dead wood: the use of Ground Penetrating Radar (GPR) to characterize excess pyroclastic deposits in the Blanco River, southern Chile

Galo Valdebenito[1], Andrés Iroumé[2], Carlos Jara[1], David Alvarado[1], Carlos Fuentes[1]

[1]*Universidad Austral de Chile, Faculty of Engineering Sciences, Chile*
[2]*Universidad Austral de Chile, Faculty of Forest Sciences and Natural Resources, Chile*

Abstract

In steep forested headwater catchments, wood delivery to streams is dominated by snow avalanches, landslides and debris flows. In larger watersheds, tree mortality and bank erosion are relatively more important in recruiting large wood. However, explosive volcanic eruptions can fill river valleys with excess pyroclastic sediment and dead wood generating deposits several meters thick. Post-eruption fluvial reworking and channel adjustment erode these deposits and buried dead wood enters the channel. This is the case of the Blanco River in southern Chile, which was severely affected by the 2008 Chaitén volcanic eruption. In order to characterize the stratigraphy of these deposits and the signature of buried dead wood, geophysical surveys were performed based on the Ground Penetrating Radar (GPR) technique. Preliminary results indicate that the GPR technique was able to describe the internal morphology and structure of thick volcanic deposits along the Blanco River and identify buried dead wood pieces. Future studies will be oriented to improve the characterization of the volcanic deposits through high resolution subsurface mapping by means of 3D surveys and spectral analysis of the reflections, which will allow calculating spatial location and volume of buried dead wood

Keywords: *Ground Penetrating Radar; Dead wood; Pyroclastic deposits: Blanco river; Chile.*

Introduction

Large wood (LW) delivery to streams is an important geomorphic process (Martin & Benda, 2001; Reeves et al., 2003). In steep, forested headwater catchments, avalanches, landslides and debris flows are the dominant LW delivery agents. In larger watersheds tree mortality and bank erosion are relatively more important in recruiting LW (Martin & Benda, 2001; Reeves et al., 2003). However, in volcanic areas, the process of wood delivery is poorly understood. This is because explosive volcanic eruptions can fill river valleys with excess pyroclastic sediment and dead wood, generating complex deposits several meters in thickness. Post-eruption channel adjustments erode these deposits and buried dead wood is delivered into the stream networks (Ulloa et al., 2015).

Since external visual identification of buried wood is not possible, electromagnetic geophysical surveys using Ground Penetrating Radar (GPR) appear as a possible solution for studying the internal morphology and structure of thick volcanic deposits (Gómez et al, 2008; Jara, 2015). GPR has been used to clarify the geomorphologic characterization and assess the evolution of the sedimentologic conditions. In studies aimed at detecting root patterns and biomass of living trees, GPR has proven to be a rapid and noninvasive technique compared with traditional methods that are highly destructive and non-repeatable (Butnor et al., 2001; Gómez et al, 2008; Satriani et al, 2010; Gertisser et al, 2012; Borden et al, 2014). However, to date

GPR has not been used (to our knowledge) to estimate the volume of dead wood buried in volcanic deposits.

Here we examine LW in pyroclastic material in the Blanco River in southern Chile, a site that was severely affected by the 2008 Chaiten volcanic eruption. Post-eruption fluvial reworking and channel adjustments have eroded these deposits and buried dead wood enters the channel along the network (see Fig. 1-A). The objectives of this study are to: (a) Examine the potential for GPR to identify buried LW in ash deposits, and (b) Obtain the GPR signature of wood buried in these sediments. This preliminary analysis is intended to provide insights on the potential of using GPR to estimate the volume of LW buried in the deposits in volcanic settings.

Study Area

The study concentrates in a deposit of sediments of volcanic origin located in the right margin of the Blanco River, immediately upstream from the city of Chaiten. Detailed information of the Chaiten volcanic eruption and sedimentologic processes in the Blanco and location of the study area can be found in Ulloa et al. (2015).

Methodology

The GPR technique was applied along the edge of near-vertical gully wall. The gully provided access to characterize volcanic deposit layering and stratigraphic conditions. Four wood pieces with different but well known diameters and a metallic bar were inserted into the volcanic deposit at specific depths, in order to calibrate the GPR velocity parameters of the soil media. The wood pieces and the metallic bar were geo-referenced with a differential GPS. A RAMAC X3M GPR with 250 and 500 MHz shielded antennas was carried along the edge of the gully in order to generate a radargram (defined here as a bi-dimensional image of the subsoil).

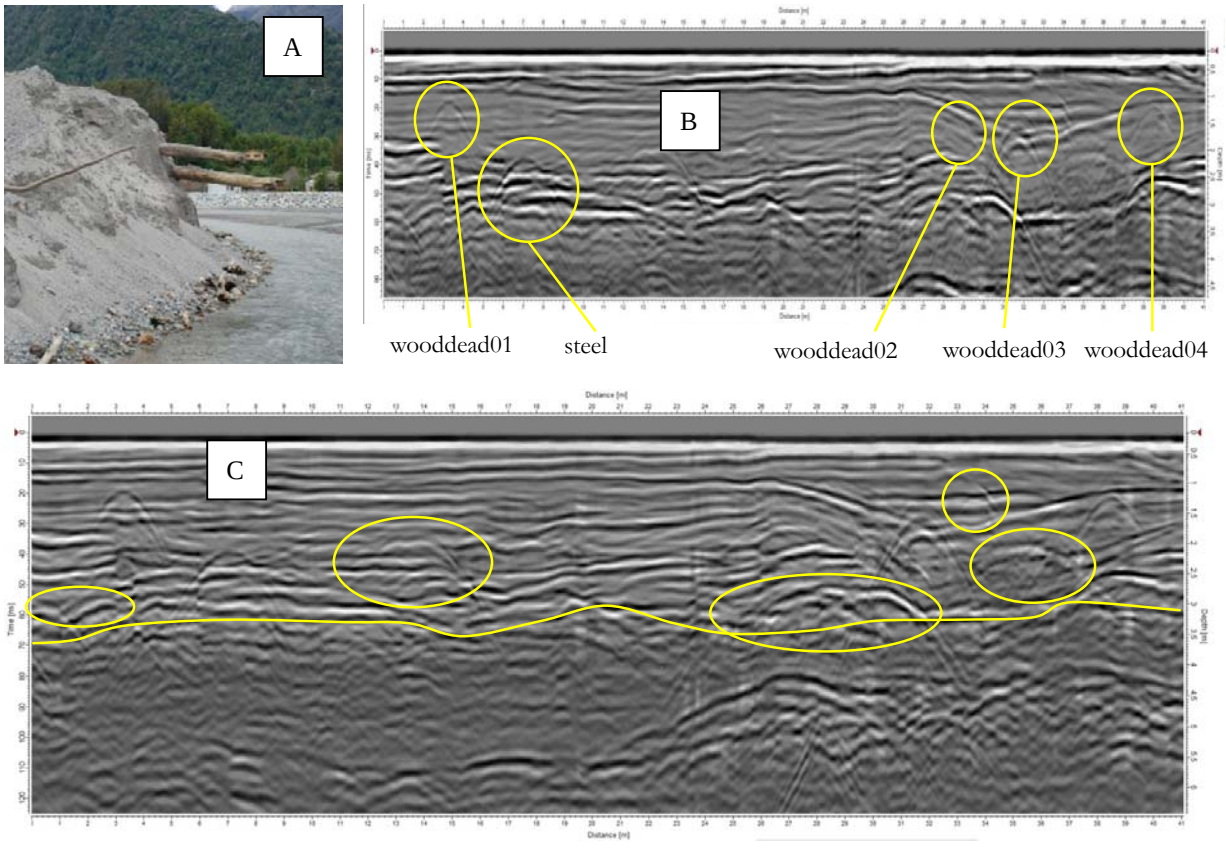

Figure 1: Buried dead wood exposed by channel reworking and bank erosion (A); radargram of the survey showing the buried dead wood (B), and the complete radargram (C).

Results

GPR radargram analysis using the 250 MHz shielded antenna yielded the best resolution and a depth penetration of 6 m. We found good resolution-parabolic reflections generated by the pieces of dead wood embedded in the sediments (Fig. 1-B). At position X = 7.2 m we observed important reflections generated by the metallic bar, in which the propagation speed was set to v = 100 m /μs. Longitudinal location and depth of the reflections coincided with the purpose-buried wood pieces, allowing the establishment of the dead wood signature for the pieces with different diameters.

Other reflections were also observed; their specific signatures corresponded to the buried wood pieces (Fig.1-C). At three meters deep, a clear stratigraphic change was observed which corresponded to the interface between the recent volcanic sediments and the soil surface from before the eruption (Fig. 1-C).

Discussion and Conclusions

This work shows the efficacy of the method to study the internal structure of the post- eruption sediments. GPR appears as a fast, economical and non-invasive way to characterize the buried LW in volcanic deposits. In this sense, it is possible to create 3D profiles using high resolution mapping of the sub-surface with precise location and volumetric characterization of buried dead wood. Our future work will explore high resolution subsurface mapping via 3D surveys and related spectral analysis to obtain dead wood volumes and estimates of sediment stratigraphy associated with geomorphic changes.

Acknowledgments

The research is funded by project FONDECYT 1141064 and is supported by Dirección de Investigación y Desarrollo, Universidad Austral de Chile.

References

Borden, K. A., Isaac, M. E., Thevathasan, N. V., Gordon, A. M., Thomas, S. C., 2014. Estimating coarse root biomass with ground penetrating radar in a tree-based intercropping system. Agroforestry Systems **88(4)**, 657-669.

Butnor, J. R., Doolittle, J. A., Kress, L., Cohen, S., Johnsen, K. H., 2001. Use of ground-penetrating radar to study tree roots in the southeastern United States. Tree Physiology **21(17)**, 1269-1278.

Gertisser, R., Cassidy, N. J., Charbonnier, S. J., Nuzzo, L., Preece, K., 2012. Overbank block-and-ash flow deposits and the impact of valley-derived, unconfined flows on populated areas at Merapi volcano, Java, Indonesia. Natural Hazards **60(2)**, 623-648.

Gomez, C., Lavigne, F., Lespinasse, N., Hadmoko, D. S., Wassmer, P., 2008. Longitudinal structure of pyroclastic-flow deposits, revealed by GPR survey, at Merapi Volcano, Java, Indonesia. Journal of Volcanology and Geothermal Research **176(4)**, 439-447.

Jara, C., 2015. Exploración geofísica mediante la técnica del Radar de Penetración Terrestre: un estado del conocimiento. Tesis de Grado para Optar al Título de Ingeniero Civil en Obras Civiles, Facultad de Ciencias de la Ingeniería, Universidad Austral de Chile, Valdivia, Chile.

Martin, D.J., Benda, L.E., 2001. Patterns of Instream Wood Recruitment and Transport at the Watershed scale. Transactions of the American Fisheries Society **130**, 940-958.

Reeves, G.H., Burnett, K.M., McGarry, E.V., 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon. Canadian Journal of Forest Research **33**, 1363-1370.

Satriani, A., Loperte, A., Proto, M., Bavusi, M., 2010. Building damage caused by tree roots: laboratory experiments of GPR and ERT surveys. Advances in Geosciences **24(24)**, 133-137.

Ulloa, H., Iroumé, A., Mao, L., Andreoli, A., Diez, S., Lara, L.E., 2015. Use of remote imagery to analyze changes in morphology and longitudinal large wood distribution in the Blanco River after the 2008 Chaitén volcanic eruption, southern Chile. Geografiska Annaler: Series A, Physical Geography (in press), doi:10.1111/geoa.12091