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ORIGINAL ARTICLE

Testing the utility of *Nothofagus pumilio* for dating a snow avalanche in Tierra del Fuego, Argentina

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Abstract

In the subalpine forest zone, snow avalanches are potentially stand-devastating disturbances. Historical data regarding past avalanches in Argentina are scarce, but sufficiently old trees can show signs of past avalanche episodes that can be accurately dated using dendrochronological methods. Tree-ring analysis has not yet been used for dating avalanches in Tierra del Fuego, even though these disturbances are important to the dynamics of these southern forests. In this study, we evaluated the quality of *Nothofagus pumilio* for dating the avalanche that took place in the Martial Valley in 1976. Tree-ring data, complemented with vegetation analysis, was used to study the avalanche path. The dendrochronological study consisted of the analysis of wood samples taken from living trees located on the boundary between the undisturbed forest and the avalanche path. The vegetation analysis compared the forest structure within the avalanche path with the unaffected nearby forest. Wood scars and the abrupt increase in tree growth confirmed the occurrence of an avalanche event in 1976 in the Martial Valley of Tierra del Fuego, Argentina. The vegetation structure within the avalanche path was considerably different than that of the undisturbed forest. We found an important relationship between sapling abundance within the avalanche path and their distance from the undisturbed forest and their altitudinal position. The dendrochronological dating obtained in this research confirmed that the techniques and methodology used for *N. pumilio* in this study can be successfully applied for dating other avalanches that lack historical information.

Keywords: Wood scar; Forest disturbance; Dendrochronological dating; Landscape changes; Andes Cordillera

Introduction

Snow avalanches are disturbances that result in distinctive vegetation patterns in mountainous environments. Avalanche paths, as landscapes patches, greatly increase the ecosystem's structural diversity in mountainous environments, because they represent a chronic preclusion of advanced forest development. Stand structure, not composition, change over time in these forests. As relatively small scale, localized disturbances, avalanches are part of healthy, dynamic, montane ecosystems. Avalanche severity, as well as regeneration conditions, may vary across the avalanche path.

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Thus, the resulting vegetation structure after the avalanche may be different along the altitudinal gradient inside the path (Butler, 1979).

During an avalanche that is large enough to damage established trees, the scars are caused not only by the snow impact, but also by debris, such as broken trees and rocks, that are incorporated into the avalanche at higher altitudes (Burrows and Burrows, 1976). The resulting external features on trees include tilted trees, injured trees with scars, broken stems and branches, and derived tree shapes (Schweingruber, 1996). These morphologies have associated tree-ring anatomical features, which can be detected and accurately dated using dendrochronological analysis (Potter, 1969; Butler, 1985; Butler and Malanson, 1985; Pelfini et al., 2001; Molina et al., 2004) which is important for events where historical data are scarce (Carrara, 1979; Bryant et al., 1989).

Nothofagus pumilio (Poepp. et Endl.) Krasser forest dynamics in Tierra del Fuego are affected by intense and recurrent disturbances like earthquakes, windthrow and avalanches (Rebertus and Veblen, 1993; Veblen et al., 1996; Rebertus et al., 1997; Frangi et al., 2005). These disturbances have important effects on the pattern of seedling distribution in the gaps (Schmidt and Urzúa, 1982; Rebertus and Veblen, 1993). The upper tree limit in Tierra del Fuego forms a continuous and sharp boundary that is sometimes interrupted by paths resulting from snow avalanches and landslides. Following the disturbance of the subalpine forests by an avalanche, dense thickets of *N. pumilio* seedlings are established, eventually developing into the even-aged stands that are very common near the upper forest limit (Veblen, 1985). Thus, the frequency and intensity of snow avalanches and landslides strongly influence forest structure and landscape. In the sub-Antarctic forests of Argentina, historical reports of these kinds of episodes are practically nonexistent.

In Tierra del Fuego, Boninsegna et al. (1990), Gutiérrez (1992), Roig et al. (1996), Aravena et al. (2002), and Lara et al. (2005) developed tree-ring chronologies for *N. pumilio* and *Nothofagus betuloides* (Mirb.) Blume. Boninsegna et al. (1990) provided first-time estimates of climate–growth relationships for the region. However, dendrochronological techniques have not been used until now for avalanche dating in Tierra del Fuego.

In 1976, a large snow avalanche took place on the western slope of the Martial Valley between 490 to 620 m of altitude. Local inhabitants and members of the Club Andino Ushuaia remember the episode because the avalanche destroyed one of their mountain shelters.

The main objective of this study was to evaluate the quality of *N. pumilio* for dating the snow avalanche that affected the forest of the Martial Valley in 1976, by taking advantage of this well-documented event.

Materials and methods

Study area

The study was carried out in the western slope of the Martial Valley (54° 47′ 38.9″S – 68° 23′ 06.7″W) on Isla Grande, Tierra del Fuego (Fig. 1). Martial Valley is located on the southern slope of Mount Martial. The Martial range lies east of Cordillera Darwin, in the Fuegian Andes and reaches an altitude of 1300 m.

The Argentinean Fueguian forests cover 712,000 ha (Collado, 2001) and correspond to the temperate and sub-Antarctic forest type that is distributed along both flanks of the Andes between 37°S and 55°S. These forests are mainly composed of two broadleaved decidous species of *Nothofagus* (southern beeches), *Nothofagus antarctica* (G. Forst.) Oerst (locally named "ñire") and *N. pumilio* ("lenga"), and the evergreen *N. betuloides* ("guindo"). On Isla Grande, the *N. pumilio* forest extends from sea level to ca. 600–700 m a.s.l. (treeline boundary) on the slopes of the Andes.

The regional climate in the area is influenced by the ocean (Prohaska, 1976). At the meteorological station at

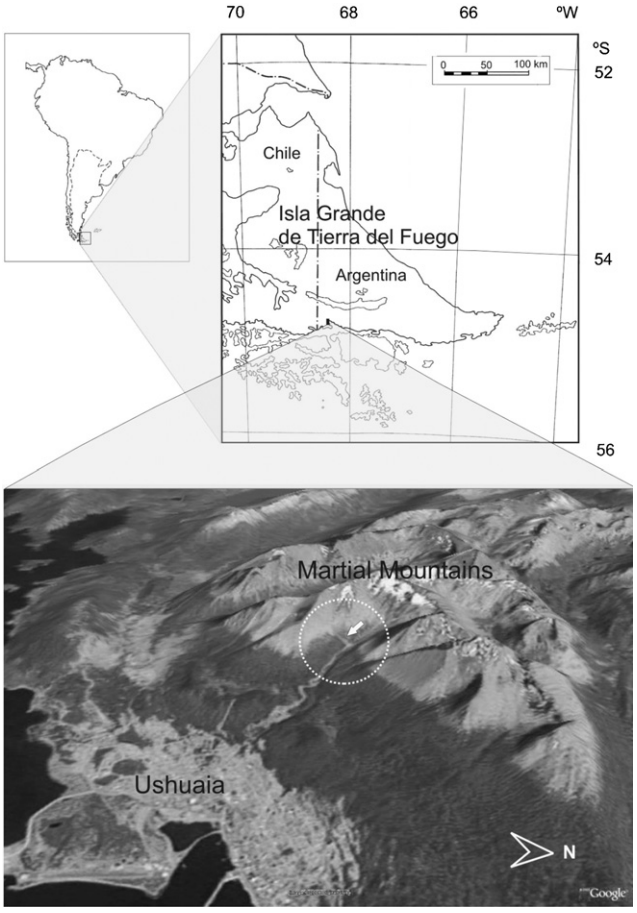

Fig. 1. 3D-satellite map of the study area. The encircled arrow indicates the studied avalanche path.