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Geomorphological dynamic changes during the Holocene through ephemeral stream analyses from Northwest Argentina

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ABSTRACT

This paper studies the changes in the geomorphological dynamics recorded in 18 ephemeral streams located on the east side of Loma Pelada (Tafi Valley), a part of the Sierras Subandinas (Northwest Argentina). The applied methodology is based on photointerpretation, field survey, and descriptions of the Holocene alluvial fillings dated by tephras, archaeological artefacts, and absolute datings. The records show a coupled system of slope-terrace-alluvial fans resulting from the environmental changes of four alternating aggradation/degradation stages. The oldest stage (1) was generated by climatic causes and covers Early to Mid-Holocene (*ca.* 13,000–10,000 BP to *ca.* 4200 BP). After the incision of these accumulations, a new aggradation stage (2) was triggered by anthropogenic activity occurring from right before 2500 BP to the 15th century. During that time human occupations of the Tafí Valley were intense. Two wetter events occurred around 4200 and 2800 BP in the area, related to global cooling phases. Lastly, two more recent phases (3 and 4) are associated with the climatic variability of the LIA and the Present Warm Period. The results highlight the sensitivity of headwater catchments of dry subtropical mountainous areas to climate changes, anthropogenic impact, and their relationship with global climatic data.

1. Introduction

Holocene geomorphic system changes are important to paleoenvironmental reconstruction. In the case of drylands, although there are several potentially available proxies, the identification of aggradation/degradation stages in fluvial systems are of high value, given the high sensitivity of these systems to small anthropogenic pressure and neotectonics could help to reach critical thresholds that accelerate geomorphological dynamics and changes (Brunsden and Thornes, 1979). Moreover, several local factors (*i.e.* lithology, slope, *etc.*) determine different responses according to the sensitivity of the landscape (Harvey, 2001, 2002).

Fluvial systems in drylands have different capacities to record the changes that could be interpreted as having a paleoenvironmental origin. Particularly sensitive are first order ephemeral streams with short paths and steep longitudinal gradients. These streams flow sporadically due to short and high density rainfalls. Their records result from the connectivity or coupling between the component parts of a coupled system (Brunsden and Thornes, 1979; Brunsden, 1993) linking hill slopes, valley floors, and alluvial fans. From a geomorphological point of view, this coupling is shown as a combined evolution in the aggradational/degradational stages.

Many studies regarding Holocene evolution of ephemeral streams and their dynamics have been conducted using a geoarchaeological approach in the Mediterranean basin (Brückner, 1986; Van Andel et al., 1990; Peña-Monné et al., 2004; Butzer, 2005; Constante et al., 2010) and in the SW of the United States (Huckleberry et al., 2013; Onken et al., 2014), including the effect of human settlements. In South America, the only studies following this approach have been conducted in the valleys and coastal plains of the Atacama Desert (*i.e.* Manners et al., 2007; Gayo et al., 2012; Keefer et al., 2003). The main difficulty in this type of studies is discerning whether the processes that caused the accumulations are anthropogenic or climatic (Fuchs, 2007; Zielhofer et al., 2008; Constante et al., 2011; Bellin et al., 2013; Ackermann et al., 2014).

The drylands in NW Argentina contain mountainous areas with deep valleys (Andes, Sierras Pampeanas) that present a great variety of fluvial types. Some valleys are formed by large arid basins (*quebradas*) and their behaviour is that of desert *wadis*, many having their headwaters in glacial, periglacial or nival environments that provide seasonal meltwaters feeding large alluvial fans. However, ephemeral streams are in general less abundant and much less understood and they have remained unstudied to date.

The Tafí Valley (Tucumán Province, NW Argentina), located in the subtropical Sierras Pampenas (Argentina), is characterised by large alluvial fans of major basins with massive discharges coexisting with small

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first order watercourses that function as ephemeral streams. These streams are especially common on the east side of Loma Pelada in the central area of the valley.

The objectives of this research paper are: (a) to present a geomorphological map and describe the main Holocene sedimentary records generated by alternated aggradational/degradational dynamics involving the fluvial coupled system of a large set of ephemeral streams; (b) to identify the archaeological features involved in the sedimentary processes and past human settlements; (c) to reconstruct the geomorphological processes produced as responses to local, regional, and global climatic changes, and anthropogenic impacts; and (d) to construct a Holocene evolutionary geomorphological model that helps understand the complexity of these basins.

1.1. Study area

The Tafí Valley is an intermountain elongated basin oriented south/north, forming part of the Sierras Pampeanas of NW Argentina. It is bordered to the east by the Cumbres Calchaquíes (4600 masl) and the Sierras de Mala Mala (2800 masl); to the west by the Sierra de Aconquija (4600 masl); and to the south by the Cerro Ñuñorco (3320 masl) (Fig. 1). The valley bottom is between 1800 and 2500 masl in height. In the centre of the valley there is a hill known as Loma Pelada (2680 masl), which is surrounded by the Tafí River and its tributaries. From La Angostura Dam, located to the south, this river flows to the Tucumán plain where it becomes part of the Salí River basin.

The climate is semiarid with summer rains and marked thermal amplitude. The annual average temperature is 13.1 °C. Annual rain average in the low areas is 400 mm and in the uplands it reaches from 500 to 550 mm. These values are favoured by the south/north orientation of the valley, which allows wet winds to enter from the SE. Precipitation is seasonal with most rain falling in the summer between November and March (Sesma et al., 1998). The development of different kinds of vegetation in the valley varies according to microclimate conditions as well as different substrates and soil compositions. Low lying areas contain grasslands while slopes and ravines contain alder (*Alnus acuminata*) and queñoa (*Polylepis australis*) woodlands (Cabrera, 1976).

From a geological point of view, this valley is a tectonic depression bordered to the NE by the Tafí del Valle fault. This fault is accompanied by other parallel faults located in the E and W borders of the valley and Loma Pelada (Gutiérrez and Mon, 2004). In this relief, dominant lithologies are metamorphic rocks (banded schists, biotitic and mocovite schists, and phyllite) together with quartz dikes and pegmatites (Ruiz Huidobro, 1972) belonging to the Precambrian and Lower Paleozoic.

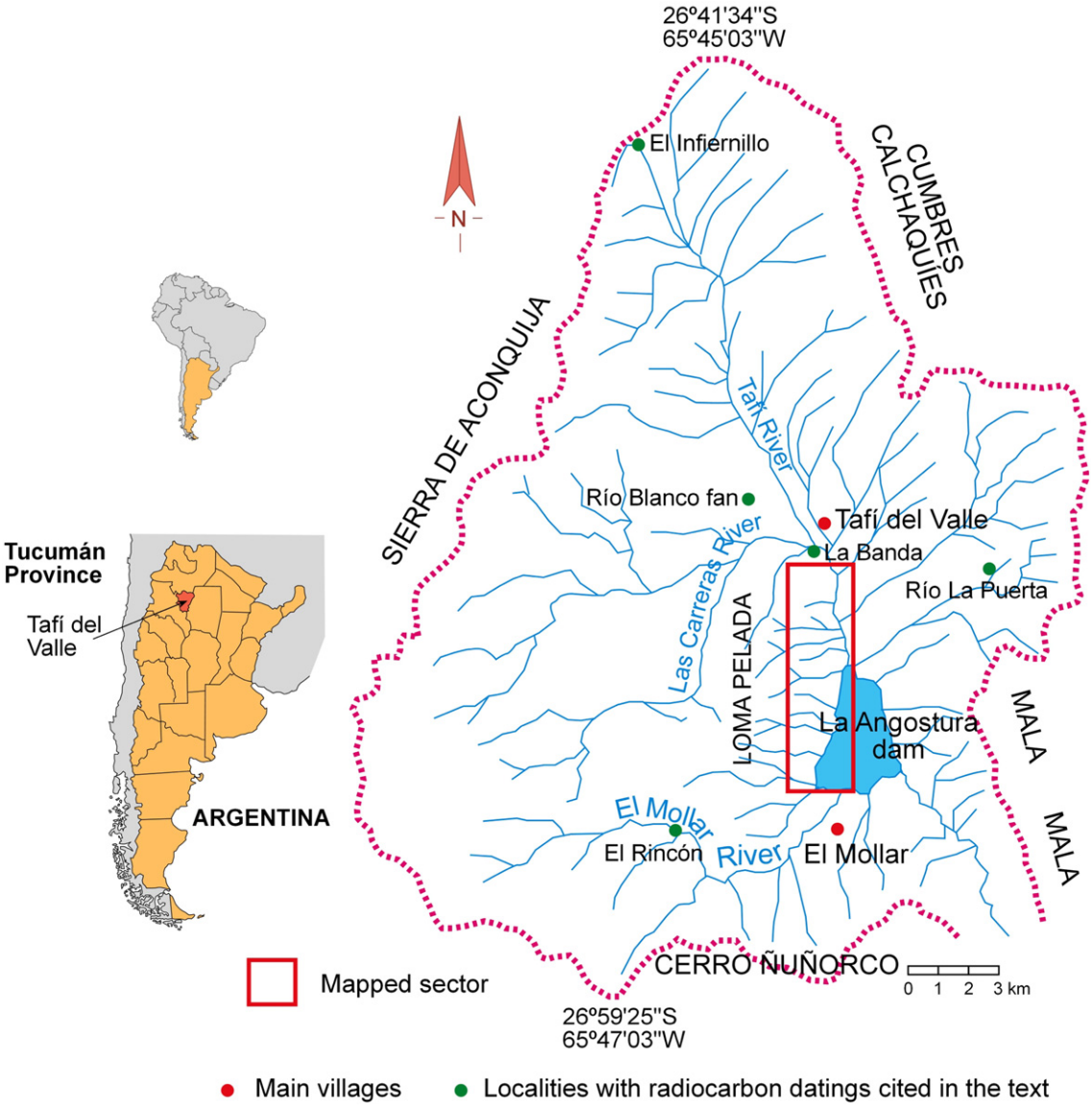

Fig. 1. Study area location and localities with radiocarbon datings cited in the text.