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The paradigm of paraglacial megafans of the San Juan river basin, Central Andes, Argentina

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ABSTRACT

The spatial distribution and several morphometric characteristics of the Quaternary alluvial fans of the San Juan River, in the province of San Juan, at the Central and Western part of Argentina, have been studied to classify them as paraglacial megafans, as well to ratify its depositional environmental conditions. The high sedimentary load exported by San Juan river from the Central Andes to the foreland depressions is estimated about 3,682,200 hm^3. The large alluvial fans of Ullum-Zonda and Tulum valleys were deposited into deep tectonic depressions, during the Upper Pleistocene deglaciation stages. The outcome of collecting remotely sensed data, map and DEM data, geophysical data and much fieldwork gave access to morphometric, morphographic and morphogenetic data of these alluvial fans. The main drainage network was mapped on processed images using QGis (vers.2.0.1). Several fan morphometric parameters were measured, such as the size, the shape, the thickness, the surface areas and the sedimentary volume of exported load. The analyzed fans were accumulated in deep tectonic depressions, where the alluvium fill reaches 700 to 1200 m thick. Such fans do not reach the large size that other world megafans have, and this is due to tectonic obstacles, although the sedimentary fill average volume surpasses 514,000 hm^3. The author proposes to consider Ullum-Zonda and Tulum alluvial fans as paraglacial megafans. According to the stratigraphic relationships of the tropical South American Rivers, the author considers that the San Juan paraglacial megafans would have occurred in the period before 24 ka BP , possibly corresponding to Middle Pleniglacial (ca 65–24ka BP). They record colder and more humid conditions compared with the present arid and dry conditions.

1. Introduction

All Andean rivers have sustained human civilizations foreland for more than 5000 years and have provided fertile oasis for agriculture. The oasis in the San Juan and Mendoza valleys are good examples where water management strategies were quite advanced along with the flood protection measures. The studied area lies within the Western Argentine Arid Zone which is a part of the “South American Arid Diagonal.” The Andes are an important barrier to moisture coming in from the Pacific Ocean, consequently, the adjacent region is recorded with low precipitation, arid conditions and sparse vegetation are predominant. An alluvial fan is a deposit whose surface forms a segment of a cone that radiates downslope from the point where the stream leaves the source area (Bull, 1977). Alluvial fans have greatly diverse sizes, slopes, types of deposits, and source area characteristics which are widespread in the dryer parts of the world (Bull, 1977, 1991). The alluvial fan environment is important to man. Crops are grown on fans and water is pumped from fan deposits. In contrast, a megafan is a fan-shaped sedimentary system covering an area of several hundreds to thousands of square kilometers (Bull, 1991). Its features are quite different from the same so-called depositions developed in the piedmonts or in the perimountainous environments. The longitudinal slope is extremely low in comparison with the classic small piedmont fans. Its development indicates an absence of obstacles and this situation facilitates its longitudinal development. The study of alluvial fans has many practical applications. In this study case, they are the areas with free aquifers in the basin (LLoret and Suvires, 2006). Several mega-fans may be cited such as the Kosi mega-fan that covers large areas in North Bihhar, India and Nepal (Gohain and Parkash, 1987) with a radius greater than 60 km. The Kosi river, in the Indo Gangetic plain, builds a mega-fan as a result

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of the high rainfalls (1500 mm year) of the reception basin; much unlike the fans in arid regions where the annual rainfall is low (Singh et al., 1993). In this case of study, the mega-fans are an important source of water to recharge the ground water reservoir. Some of them are located throughout the territories of Ecuador, Peru, Bolivia and Argentina (Iriondo, 2010). These were formed by the accumulation of sediments carried by the river networks from the Andes. The collectors of these networks cross the mountain ranges and deposits fans from the piedmonts to long distances towards the east (Iriondo, 1988). The mega-fan of Paraná covers half of the northwest of the province of Corrientes in Argentina and the south of Eastern Paraguay. These large reliefs would have been formed in the Pliocene but remain active until the present (Iriondo, 2007). In the northern part of Argentina, different mega-fans have been identified, such as: the Salado River (650 km long by 150 km wide) and the Bermejo, Pilcomayo, Parapetí and Grande rivers which extend to the countries of Paraguay and Bolivia. On the other hand, Andes foreland region present large landforms fill with thick alluvium deposits resulting in glacial smelting (Dorn, 1994). In the area under study, Ortiz et al. (1977) describes the great alluvial fans of the Mendoza and Tunuyán rivers which lie to south of San Juan basin. Rocca (1969) carried out an important hydrogeological study of the Ullum-Zonda (U:Z) and Tulum (T) valleys. This author found two large aquifers coincident with the alluvial fans of San Juan river. These fans constitute the most important ground water reservoir of San Juan province (Lloret and Suvires, 2006). The paper presents the location, shapes, morphometric data and the Digital Elevation Models (DEM) of the alluvial fans of the San Juan River. The morphometric characteristics of width, length, surface, basin and fan areas as well as the values of the thickness of the sedimentary fill of the U-Z and T fans are published herein. In conclusion to label them as paraglacial megafans, due to their size, thickness, sedimentary fill and genesis at the time they were formed.

2. Characteristics of the study area

The area is located in the Province of San Juan, which is at the central-western part of Argentina, between 31° S and 32° S latitude and 67°–70° 30′ W longitude, from 800 to 600 m a.s.l. altitude. Fig. 1. The climate is arid to desertic (Bwk, Koeppen) where daily and seasonal temperatures vary greatly. The extreme absolute temperatures reached 45 °C and −4 °C. The annual mean temperature ranges from 14 °C to 19 °C. The annual rainfall values range within 100–124 mm. The moist winds blowing from the Atlantic Ocean are stopped by the eastern extreme of Pampean Ranges. The prevailing winds are from the S, while others, far less frequent or intense, blow from the W, NW and NE. The Tulum valley contains the main irrigated oasis in the province of San Juan and therefore is densely populated with about 700,000 inhabitants. This territory contains four large regional morphostructural units which coincide with four geological provinces (from W to E): Principal Cordillera, Frontal Cordillera, Precordillera and Pampean ranges, Fig. 1.

These mountainous areas are separated from each other by longitudinal block basins occupied by intermountain alluvial plains, great alluvial fans and fertile valleys. The geometry of the subduction of the Nazca plate below the South American plate controls the Quaternary deformations and the topography of the Andean Ranges which extend for more than 8000 km along the edge of South America between 4° S and 46° 30' S (Costa et al., 2006). The considered area is found on a subduction section of a very low angle between 5° and 10°, located between 27° S and 33° S. In the Fig. 1, we can see the Precordillera range, that is an Andean thrust and fold belt with a typical thin skin structural style developed in an Early Paleozoic carbonate platform and overlying Paleozoic rocks (Ramos, 1996). The structural vergence is located to the east in the Front Range, Western and Central Precordillera, while the vergence in the Eastern Precordillera is to the west (Ramos et al., 2002). The Chica de Zonda and Marquezado ranges belong to Eastern Precordillera while the Alta de Zonda range, the Cerro Blanco and Cerro de la Sal belong to Central Precordillera (Fig. 1). The Desaguadero river is the main fluvial collector of the Central Andes that, in the last century, drained to the Atlantic Ocean. Presently, however, and due to greater dryness conditions and increased water use and consumption, it has become an endorreic system. It has a length of 1498 km; it is born around

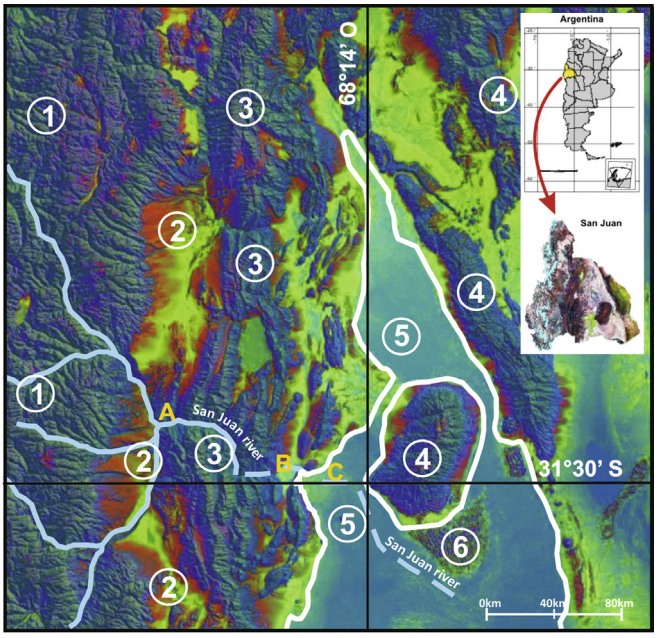

Fig. 1. Study area located of Central Andes foreland basin, San Juan Province, Argentina. San Juan river basin drains major morpho-structural units of geological provinces of Central Andes, which are presented from west to east: 1 Frontal Cordillera, 2 longitudinal tectonical depression of Iglesia-Calingasta-Barreal valleys; 3 Precordillera; 4 Pampean ranges; 5 longitudinal tectonical depression of Bermejo and Tulum valleys; 6 Structural high of Medanos Grandes sand sea. Sites: A: Las Juntas, B: Ullum-Zonda valley; C: Tulum valley.

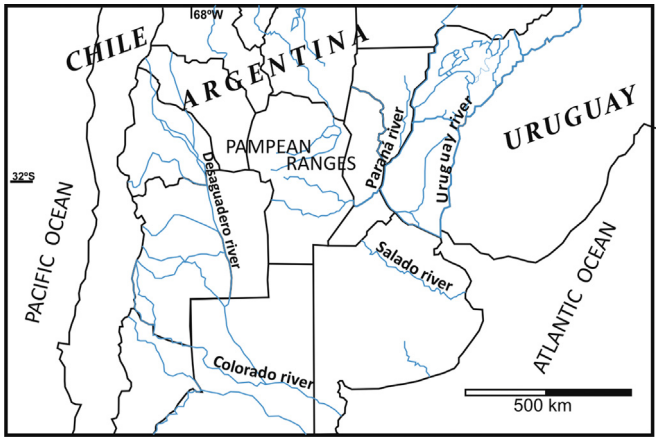

Fig. 2. Large rivers in Central Andean and Tropical regions of Argentina. These rivers drain a diverse geological and climatic regime. The Desaguadero – Colorado river forms the most important river system in this region. The Ullum-Zonda and Tulum basins are drained by San Juan river. These basins have been filled with thick alluvium sediments derived from Andean chain during most of the Upper Pleistocene event. The Desaguadero-colorado river debouched in the Atlantic Ocean years ago.