Sedimentary Geology 289 (2013) 194–209

Contents lists available at SciVerse ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Reworked pyroclastic beds in the early Miocene of Patagonia: Reaction in response to high sediment supply during explosive volcanic events

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ARTICLE INFO

Article history:
Received 31 May 2012
Received in revised form 25 February 2013
Accepted 3 March 2013
Available online 13 March 2013

Editor: J. Knight

Keywords:
Pyroclastic deposits
Explosive volcanism
Hyperpycnal flows
Fluvial deposits
Patagonia

ABSTRACT

Two meter-scale pyroclastic levels are interbedded within the early Miocene succession of the Estancia 25 de Mayo (*Patagoniense transgression*) and Santa Cruz formations in the foreland Austral (or Magallanes) Basin, Argentina. The Lower Pyroclastic Level (LPL) is a tabular body interbedded within offshore marine deposits, laterally continuous for 30 km and varying in thickness from few centimeters to around 4 m. Grain-size grades from coarse to extremely fine ash with upward-fining along with a northeastern-fining trends. Structureless fine to very fine tuffs dominate and rare parallel laminations are the only tractive sedimentary structures. The Upper Pyroclastic Level (UPL) lies within low energy fluvial deposits and is laterally discontinuous, and it is composed by lenticular bodies reaching a maximum of 15 m thick and 100 m wide, with a concave-up base and a plane top. Grain-size range is similar to the LPL but it coarsens upward. The lower portion of the UPL shows parallel lamination, current ripple lamination and mud drapes with large pumice lapilli and plant debris, whereas the upper portion shows parallel lamination and trough cross-stratification. Both pyroclastic levels are composed mainly of pumice grains and glass shards with minor proportions of quartz and plagioclase crystals and lithic fragments. The LPL shows no mixing with epiclastic material whereas the UPL shows an upward increase in epiclastic material, and an upward increment in the scale of cross-bedding.

The large thickness in relation to the possible emission center and the content of plant debris of the LPL does not suggest a direct, submarine, ash-fallout origin. The LPL is interpreted as a deposit of hyperpycnal-flows generated at the coastal zone when tephra-laden rivers plunged into the ocean. Large amounts of well preserved plant debris support the hypothesis of a terrestrial source of the sediments. The UPL is entirely composed of tractive deposits, so an ash fallout origin is disregarded. This, together with the lenticular shape and the alluvial plain origin of the encasing sediments, suggests accumulation within fluvial channels. Cycles of upper-flow-regime parallel lamination, current-ripple lamination and mud drapes at the lower portion, suggest short-lived turbulent flows that initially filled semi-abandoned channels. They were followed by sheet floods and channel reactivation, expressed by large-scale cross-bedding. The low degree of particle mixing observed in both levels is explained by the inability of streams to erode the substrate as they are suddenly over-saturated with pyroclastic sediments during and after the eruption. The grain-size distribution of the LPL and geochemical data indicate a contemporaneous volcanic source located to the west/southwest in the Andean ranges, where the South Patagonian Batholith is presently located.

1. Introduction

Volcanically-influenced sedimentary settings are complex systems which reflect the addition of volcanic ejecta, succeeding transport and deposition in a wide range of environments, from top of mountain chains to the bathyal ocean (Fisher and Smith, 1991; McPhie et al., 1993; Manville et al., 2009). A unique feature of these systems is that sediment supply is not limited by rates of weathering, erosion, or production of biogenic material, but can be introduced instantaneously and in enormous volumes by volcanic eruptions, overwhelming pre-existing transport systems (Fisher and Smith, 1991; Newhall and Punongbayan, 1996; Manville et al., 2005, 2009).

The stratigraphic record of volcanic regions comprises both syn- and post-eruptive volcaniclastic deposits that result from the immediate or subsequent reworking of this material by surface processes (Smith, 1991; Orton, 1996; Manville et al., 2009). These deposits, accumulated in various and markedly different sedimentary environments, leave a complex stratigraphic and sedimentologic record that

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http://dx.doi.org/10.1016/j.sedgeo.2013.03.004

varies from proximal coarse volcanic facies (e.g., Smith, 1991) to distal fine-grained volcanic facies (Kataoka, 2005; Kataoka et al., 2009), recording the processes that acted at high altitude subaerial settings (cf., Fisher and Smith, 1991; Smith, 1991) as well as in shallow and deep marine settings (Sigurdsson et al., 1980; Wright and Mutti, 1981; Carey, 2000).

Smith (1991) subdivided volcaniclastic sequences into: i) syn-eruptive units, formed coevally with volcanic activity through the immediate reworking of pyroclastic material, and extending through the period where the landscape is still responding to the hydrological and sedimentary-yield consequences of the eruption; and ii) inter-eruptive sequences, where normal background sedimentary processes occur without a direct volcanic influence.

Most models of syn- or inter-eruptive terrestrial deposits deal with coarse grained material proximal to the volcanic source, reworked by fluvial processes and debris flows (Kuenzi et al., 1979; Smith, 1988, 1991; McPhie et al., 1993; Newhall and Punongbayan, 1996; Zernack et al., 2011). On the contrary, less is known about distal sand-to-mud sized pyroclastic material interacting with fluvial and marine processes (Kataoka, 2005; Manville et al., 2005, 2009; Kataoka et al., 2009).

Meter-thick-scale submarine pyroclast-rich deposits were mostly interpreted as the result of submarine or delta slope failures, or related to submarine or subaerial pyroclastic flows (Sigurdsson et al., 1980; Wright and Mutti, 1981; McPhie et al., 1993). However, during subaerial explosive eruptions a large amount of sediment is supplied by ash fallout to the drainage basins which finally is carried to the ocean resulting in underflows or quasi-steady hyperpycnal flows (Mulder and Syvitski, 1995).

The Cenozoic stratigraphic record of extra-Andean Patagonia is characterized by large amounts of pyroclastic material preserved within many sedimentary units. Particularly, the lower Miocene marine deposits known as the "*Patagoniense transgression*", widely distributed over eastern Patagonia (Fig. 1), present numerous intercalated fine-grained pyroclastic beds and variable proportions of pyroclastic material mixed within other epiclastic sediments (Di Paola and Marchese, 1973; Riggi, 1978; Bellosi, 1995; Crawford et al., 2008). Little is known about their age, source and modes of deposition and preservation, and most of them were interpreted as pyroclastic ash fallout deposits (Di Paola and Marchese, 1973; Riggi, 1978; Crawford et al., 2008). This paper present a detailed facies analysis of two early Miocene thick, distal fine-grained pyroclastic deposits preserved within offshore marine and low energy fluvial environments, and accounts for the processes of reworking, deposition, and preservation that fluvial channel, shorelines and offshore settings imprint on the volcanic-sourced particles, as well as how each sedimentary system reacts against the supply of pyroclastic particles.

2. Geologic framework

The pyroclastic beds studied here are part of the Burdigalian infill of the Austral (or Magallanes) Basin (Cuitiño et al., 2012). This basin is located in the southern portion of the South American Plate, and limited by its west side by the Patagonian–Fueguian Andes (Fig. 2A). This rift-sag to foreland basin contains deep-marine to continental sedimentary units of early Cretaceous to middle Miocene age (Biddle et al., 1986; Arbe, 2002). During the Miocene the succession was thrusted and inverted due to Andean tectonics (Fosdick et al., 2011). In the study area, between Lago Argentino to the north and Sierra Baguales to the south, only the late Cretaceous to Miocene foreland deposits are present (Fig. 2), covered in part by a thick pile of late Cenozoic volcanic lava flows and modern glaciogenic deposits. The pyroclast-rich succession studied herein is composed of the shallow marine Estancia 25 de Mayo Formation (Cuitiño and Scasso, 2010; formerly called the Centinela Formation of Furque and Camacho, 1972), transitionally overlain by the continental Santa Cruz Formation (Fig. 2B; Table 1). The Oligocene fluvial sediments

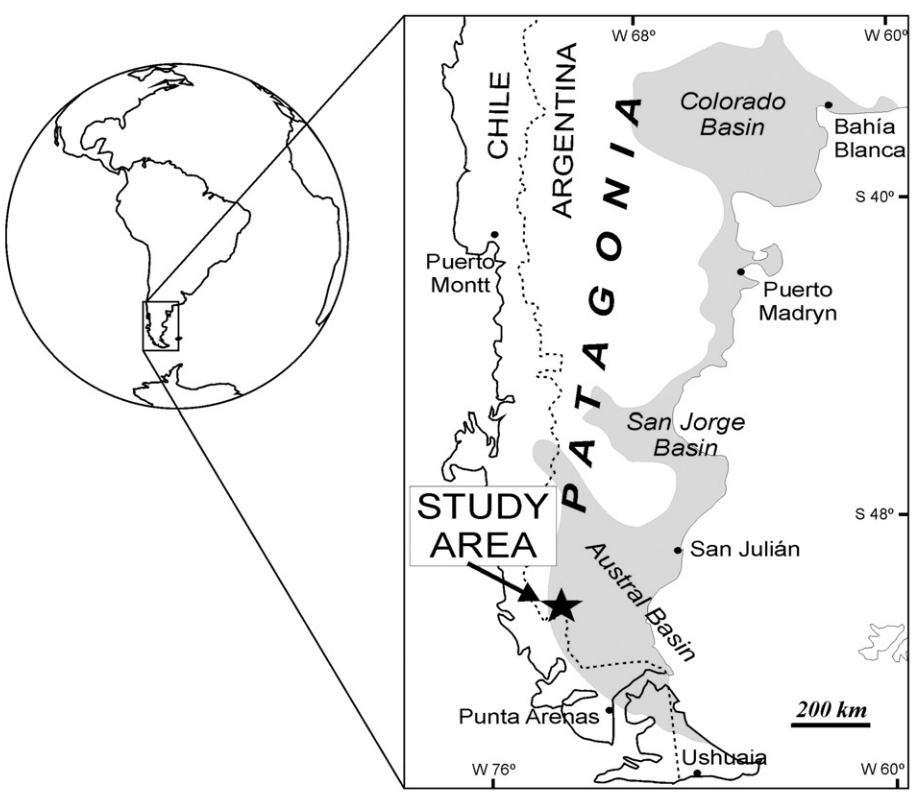

Fig. 1. Location of the study area. The gray area in eastern Patagonia corresponds to the surface inundated by the early Miocene "Patagoniense" transgression. After Malumián et al. (1999).