Palaeogeography, Palaeoclimatology, Palaeoecology 417 (2015) 220–235

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Late Pennsylvanian aridification on the southwestern margin of Gondwana (Paganzo Basin, NW Argentina): A regional expression of a global climate perturbation

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ARTICLE INFO

Article history:
Received 8 May 2014
Received in revised form 10 October 2014
Accepted 21 October 2014
Available online 27 October 2014

Keywords:
Paleosol
Pennsylvanian
Paleoclimate
Late Paleozoic
Ice age
Gondwana

ABSTRACT

Paleosols of the Paganzo Group preserve a shift from the cool climate of the glaciated high-latitudes of Gondwana to a long-term aridification punctuated by shorter-term fluctuations in moisture regime in the late Carboniferous. A quantitative reconstruction of paleoclimate inferred from the major element chemistry of paleosol horizons and the stable isotope geochemistry of soil-formed minerals and organic matter indicates that the climate varied substantially during deglaciation along the southwestern margin of Gondwana in the Middle Pennsylvanian including two geologically abrupt shifts to notably drier conditions. This dynamic climate terminates in a dry subhumid moisture regime characterized by steppe/dry scrub floral provinces. Quantitative estimates of net primary production during the post-glacial interval inferred from paleosol major element geochemistry are consistent with a mesic soil temperature regime, in agreement with paleotemperatures inferred from pedogenic goethite δD and $\delta^{18}O$. Contemporaneous aridification is well expressed in paleotropical continental records with Middle to Late Pennsylvanian aridification coincident with an abrupt evolutionary change in many marine and terrestrial species. The synchrony of aridification between the high and low paleo-latitudes and concomitant major restructuring of some ecosystems suggests that a paleoclimate change of global nature occurred during the Moscovian and Kasimovian.

1. Introduction

The Middle to Upper Pennsylvanian stratigraphy of Euramerica records a well-known shift in terrestrial floral communities (Phillips et al., 1974, 1985; DiMichele et al., 1996), marked by enhanced extinction rates of land plants (Cascales-Miñana and Cleal, 2014) and a restructuring of ecosystems referred to as the "collapse of the rainforests" (DiMichele et al., 2009; Cleal et al., 2010; Sahney et al., 2010). Some of the earliest studies of Late Pennsylvanian plant macrofossils suggested a climatic driver for this change due to a near extinction of lycopsids and rapid development of tree ferns with leaf morphologic adaptations suggestive of prolonged dry seasons (White and Thiessen, 1913). An alternative explanation of this Late Pennsylvanian shift in plant communities is that this is a record of a prolonged erosion leading to an unconformity traceable between the U.S. midcontinent, Appalachian Basin, and European floral records (Wagner and Lyons, 1997; the "Wagner Gap"). Detailed stratigraphic correlations and palynologic investigations, however, illustrate that unconformities in these areas were relatively short-lived and are not contemporaneous over such large spatial scales (Falcon-Lang et al., 2011).

Moreover, analysis of plant succession within and between coal beds in refugia suggests that plant communities displayed long-term (>10 kyr) persistence, patterns that are observable from several coal fields across the Middle to Late Pennsylvanian transition throughout the U.S. midcontinent (Willard et al., 2007; DiMichele et al., 2010), which further suggests that continuity of time, rather than a stratigraphic gap, is represented by these successions. At present, what remains unresolved is whether this type of floral reorganization is a result of some series of environmental disturbances that in turn influenced global climate, or if the terrestrial ecosystem upheavals of the Late Pennsylvanian paleotropics reflect a response to global-scale changes in paleoclimate (DiMichele et al., 2009; Tabor et al., 2013).

Paleoclimate reconstructions during the Middle to Late Pennsylvanian indicate pronounced shifts in atmospheric circulation (Tabor and Montañez, 2002; Loope et al., 2004), and numerical climate simulations display a high degree of sensitivity of low-latitude moisture regimes to the presence of continental ice on Gondwana (Poulsen et al., 2007;

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http://dx.doi.org/10.1016/j.palaeo.2014.10.029
0031-0182/

Horton et al., 2010; Montañez and Poulsen, 2013). However, there is a marked lack of direct comparison of high- to low-paleolatitude paleoclimate and terrestrial paleoecologic records in time equivalent successions. Such direct comparisons are critical for refining our understanding of the global significance of reconstructed regional climate variation (Yang et al., 2014).

Here, we present a study of mid-latitude paleoenvironments and paleoclimate change during the Pennsylvanian in order to assess the potential to resolve a global climate driver for the major restructuring in paleotropical terrestrial ecosystems, or a global climate response to tropical vegetation reorganization. This analysis is possible now due to ongoing high-precision chronostratigraphic reconstructions (Bangert et al., 1999; Fielding et al., 2008; Stollhofen et al., 2008; Gulbranson et al., 2010; Césari et al., 2011; Mori et al., 2012; López-Gamundí et al., 2013) for Gondwana that permit direct comparison of high- and low-paleolatitude successions at sub-million year resolution. This study integrates the morphology and geochemistry of radiometrically-calibrated paleosols and their soil-formed minerals from the Paganzo Group of the Paganzo and Río Blanco basins of northwest Argentina (Fig. 1) to make qualitative inferences of landscape dynamics and quantitative reconstructions of temperature, precipitation, and climatic seasonality during a transition from glacial to non-glacial conditions towards the close of the Carboniferous.

2. Paleogeographic and tectonic setting and stratigraphic framework

The Paganzo and Río Blanco basins developed on the active southwestern margin of Gondwana during the late Paleozoic of what is now the modern day Andes and Andean Precordillera region (Fig. 1A). Both sedimentary basins were positioned at ~45°S latitude for much of the Carboniferous (Scotese et al., 1999; Torsvik and Cocks, 2004) with northward migration beginning in the Early Permian (Van der Voo and Torsvik, 2001).

The Río Blanco Basin initially formed as a foreland basin (Scalabrini Ortiz, 1973) *via* thrusting of the Cuyania Terrane during the Devonian Chañic Orogeny (Ramos, 2004; Limarino and Spalletti, 2006). The sedimentary succession that records this foreland basin phase consists of mixed terrestrial and marine siliciclastic sedimentary rocks of the Angualasto Group, culminating with deposition of glacial diamictites of Visean age (Perez Loinaze, 2007; Gulbranson et al., 2010). Subsidence style and basin geometry of the Río Blanco Basin shifted from a foreland-style basin to a back-arc basin during accretion of the disputed "Chilenia" Terrane during the late Paleozoic Río Blanco tectonic event (López Gamundí, 1997; Limarino and Spalletti, 2006). Paganzo Group sedimentary strata were deposited in the Río Blanco back-arc basin during the latest Mississippian (Serpukhovian) through the latest Pennsylvanian (Gulbranson et al., 2010). Sedimentary strata of the Paganzo Group in this basin record the inception of mid-Carboniferous glaciation on the southwestern margin of Gondwana followed by post-glacial transgressive facies and a long-lived sequence of paralic sedimentary facies (Limarino et al., 2002; Limarino and Spalletti, 2006; Gulbranson et al., 2010).

The Paganzo Basin developed as a foreland basin during the late Paleozoic Río Blanco tectonic event as evidenced by significant regional unconformities separating mid-Carboniferous strata of the Paganzo Basin from Ordovician strata and metamorphosed igneous intrusions (Limarino and Spalletti, 2006). This basin is defined to the west by the Protoprecordillera (near the modern Andean Precordillera), which was a prominent paleotopographic feature of the region (Fig. 1A). To the north and east the basin is surrounded by I-type and S-type granites

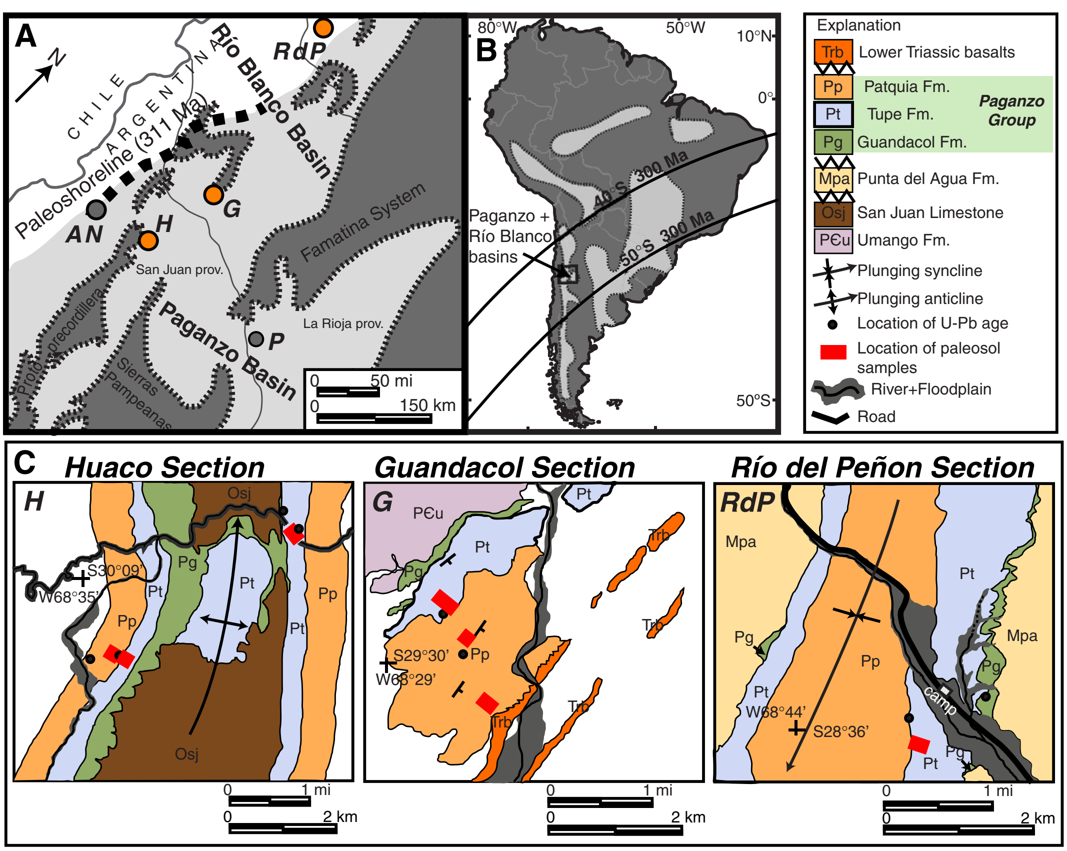

Fig. 1. Paleogeography and modern geology of the study area. A) Map of the Paganzo and Río Blanco basin and surrounding areas, positive relief is shaded in gray, filled circles indicate field localities. H = Huaco, G = Guandacol, RdP = Río del Peñon, and P = Paganzo. Map rotated to reflect the late Carboniferous orientation (*i.e.*, arrow is present-day north); dashed line delineates paleoshoreline. B) Late Paleozoic basins in light gray and paleolatitudes for 300 Ma. C) Geologic maps of the Huaco, Guandacol, and Río del Peñon field localities. Zigzag line delineates unconformities between stratigraphic units.