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Metre-scale cyclicity in Permian ramp carbonates of equatorial Pangea (Venezuelan Andes): Implications for sedimentation under tropical Pangea conditions

Juan Carlos Laya [a,b,*], Maurice E. Tucker [c,d], Alberto Perez-Huerta [e]

[a] Berg-Hughes Center and Department of Geology and Geophysics, Texas A&M University, College Station, TX, United States
[b] Grupo de investigaciones de ciencias de la tierra "TERRA" Escuela de Ing. Geologica. Fac. de Ing. Universidad de Los Andes, Merida, Venezuela
[c] Department of Earth Sciences, Durham University, UK
[d] School of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, UK
[e] Department of Geological Sciences, University of Alabama, USA

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ABSTRACT

Palmarito strata in the mid-Permian of the Venezuelan Andes show three different types of metre-scale cycle: Type A cycles are mixed clastic-carbonate, shallowing-upward peritidal cycles. The upper boundaries of the cycles are exposure surfaces with calcrete. This kind of cycle shows a significant degree of randomness in its thickness pattern and this is attributed to an autocyclic origin through tidal-flat progradation, and variations in carbonate productivity and clastic input to the depositional area. Type B cycles consist entirely of shallow subtidal facies with a shallowing-upward arrangement and an alternation between heterozoan and photozoan assemblages. Type C cycles were deposited in a middle to outer ramp setting and are characterized by a heterozoan assemblage and shallowing-upward trends that includes spiculitic wackestone–packstone passing up into neomorphic bioclastic wackestone or bioclastic crinoidal–bryozoan wackestone–packstone. All cycles are interpreted as 4th–5th order (10^4 to 10^5 years duration) and some can be linked to Milankovitch orbital rhythms, notably short eccentricity (~100,000 years). Overall, the origin of the Palmarito cycles was a complex combination of autocyclic and allocyclic controls; however, the evidence suggests that cycles in the lower part of the succession were dominated more by autocyclic processes whereas those in the upper part were more the result of allocyclic controls. Climate-driven processes, such as migration of the intertropical convergence one and the waxing and waning of polar ice-caps, had significant effects on deposition of the Palmarito succession and the cycles therein, controlling the clastic sediment supply, nutrient availability and thus carbonate production, and sea-level change, and these factors determined the vertical stacking pattern of the cycles.

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1. Introduction

The origin of metre-scale cycles in carbonate successions has been a controversial topic for the last few decades with three major controls generally considered: orbital forcing, tectonics and sedimentary processes (autocyclicity). The first two external (allocyclic) controls may give rise to well-ordered through to random patterns of cycle thickness, but any trends may well be overprinted by noise generated by irregular autocyclic processes. Statistical tools can be useful to identify order (and disorder) in the stratigraphic record of cyclic carbonates (e.g. Lehrmann and Goldhammer, 1999; Sadler et al., 1993; Burgess, 2006). Some authors have shown that cyclic successions are the result of long-term eustatic variations in sea-level so that the cycle thickness trends can be correlated on a near-global scale (e.g. Grötsch, 1996). In reality, it is likely that many cyclic successions are the product of both allocyclic and autocyclic processes operating at the same time (e.g. Bosence et al., 2009).

In addition to the traditional variation of sea level and/or tectonics as an allocyclic explanation for metre-scale cycles, this paper suggests that climatic changes were also very important in generating cycles. Arid–humid climatic fluctuations affect rainfall, continental run-off and terrigenous input, as well as nutrient supply, and these factors are important in terms of carbonate productivity. In addition, variations in the position of the intertropical convergence zone, driven by expansion–contraction of polar ice-caps, have a major influence on carbonate deposition, including the type of biotic community, photozoan or heterozoan. Carbonate ramps show a broad variety of facies and their features are the key to understanding changes in environmental conditions, which at the same time are the product of changes of local and regional tectonic, climatic and oceanographic processes. In the Permian strata of northern Venezuela discussed here, the facies mostly show a vertical repetition in an ordered stacking pattern which can be used to define the cycles; these occur on different scales from several 10s of centimetres to a few metres in thickness.

* Corresponding author at: Berg-Hughes Center and Department of Geology and Geophysics, Texas A&M University, College Station, TX, United States.
E-mail address: layajc@geos.tamu.edu (J.C. Laya).

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Permian times were important on the global scene with the formation of Pangea which led to significant tectonic, sedimentary and stratigraphic developments, global changes in climate, and biotic evolutionary events. At least partly for these reasons, the Palmarito strata consist of well-developed metre-scale cycles, influenced by climatic and tectonic factors in the low-latitude region where Venezuela was located at the time. The dominant humid conditions gave way to a more arid climate in the uppermost part of the succession and this took place under a compressive tectonic regime that was dominant during the Permian collision between Gondwana and Laurentia.

The aim of this research article is to discuss the metre-scale cycles in the context of Permian equatorial Pangea and provide possible explanations of the mechanisms causing their repetition. The fieldwork data and analyses of facies have been augmented by geochemical data (stable isotopes and trace elements).

South of Merida city, there are six localities for the Palmarito Formation which are the best for cycle studies in the Venezuelan Andes (Fig. 1). First, *Santa Cruz de Palmarito (S1)*, where the Palmarito Formation was first described by Christ (1927) and defined as the stratotype, is located '100 m towards the south from a small chapel called Santa Cruz de Palmarito along a mule trail'. The 100 m-thick succession shows fossiliferous massive and nodular limestones that can be ascribed to the middle to upper part of the formation (Laya and Tucker, 2012).

Second, *Quebrada de Portachuelo 2* (*S2*) shows outcrops from the head of the stream towards the west, which are on the eastern side of a synclinal structure. The middle and upper parts of the Palmarito Formation is exposed showing massive grey-bluish, highly fossiliferous limestones and crystalline dolomite, dipping westwards. The section has been described by Arnold (1966) as Quebrada Quevada

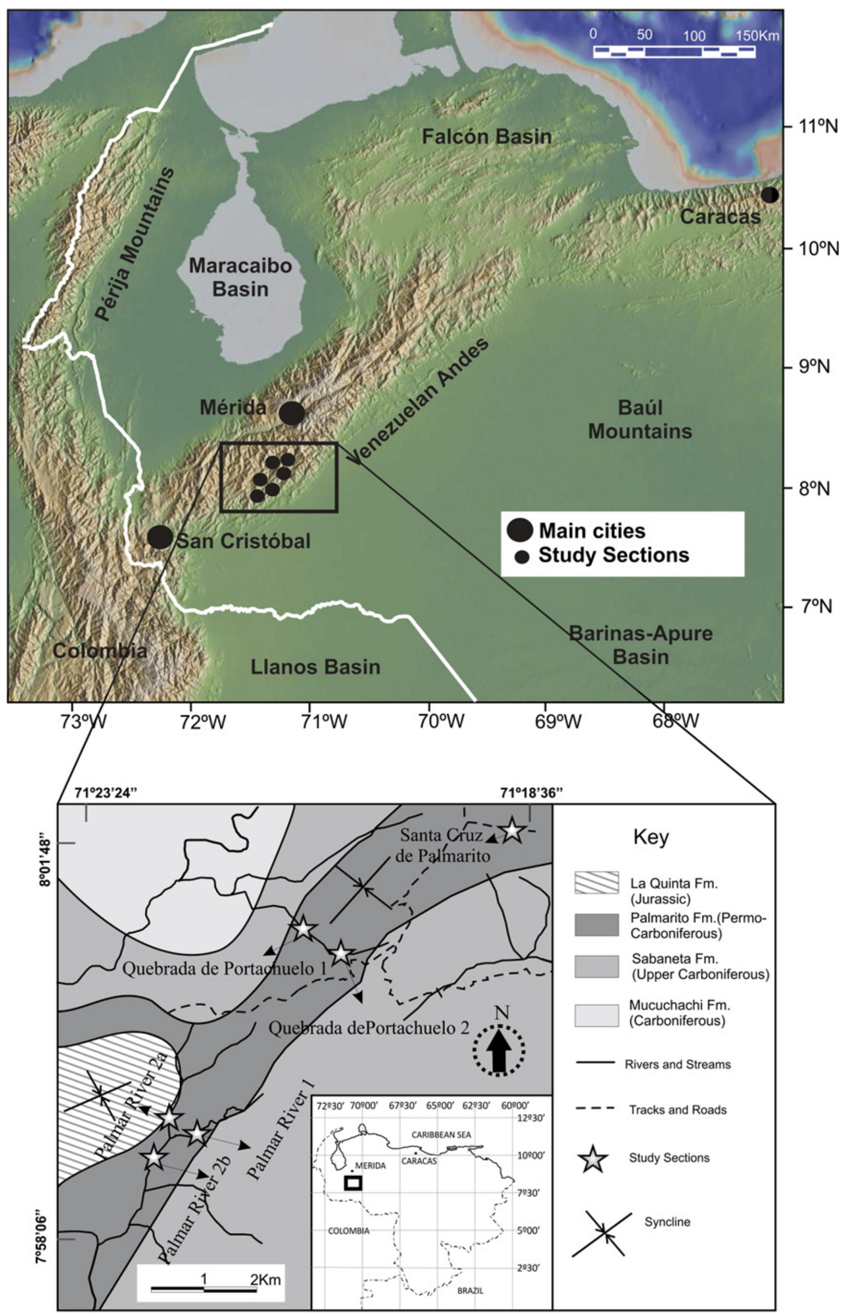

Fig. 1. Digital relief image of western Venezuela (above) modified from Ryan et al. (2009), also available in http://www.geomapapp.org and detail map of study area (below) showing the location of the main sections of study Laya and Tucker (2012).

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