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EARLY SYN-RIFT EVOLUTION IN THE WEST CAMEROS BASIN (UPPER JURASSIC, NW IBERIAN RANGE), SPAIN and PEDOGENETIC CALCRETES IN EARLY SYN-RIFT ALLUVIAL SYSTEMS (UPPER JURASSIC, WEST CAMEROS BASIN), NORTHERN SPAIN—REPLY

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First, we would like to highlight our appreciation of Dr. Platt's and Dr. Wright's comments and the opportunity they give us to discuss some aspects of our papers (Sacristan-Horcajada et al. 2015, 2016) improving the final state of our work.

Knowledge about sedimentology of alluvial systems has had an important development in recent years, with new proposals for models in rift basins where tectonics play a predominant role (Nichols and Fisher 2007; Hartley et al. 2010; Weismann et al. 2010; Fielding et al. 2012). The differential behavior of the extensional structures during the earliest syn-rift stage (Tithonian) in the West Cameros Basin played a key role in the architecture of the various alluvial systems (Sacristan-Horcajada et al. 2015) as well as the distribution of various calcrete sequences (Sacristan-Hocajada et al. 2016).

We discuss the points raised Drs. Platt and Wright in the same order they established.

CONCERNING THE SECTION THAT PLATT AND WRIGHT HAVE TITLED "ALLUVIAL FANS"

With respect to this section of the discussion, we consider it important to emphasize several points:

1) The Types of Early Syn-Rift Alluvial Systems Studied.—From our point of view, in the case of the Nuestra Señora de Brezales Formation, it would be an oversimplification to refer only to "alluvial fans." The Brezales Fm (abbreviation of Nuestra Señora de Brezales Fm, see below) has been interpreted as the result of clastic sedimentation in alluvial systems (alluvial and fluvial fans) developed in generally small half-grabens. Specifically in our recent studies, detailed facies analysis, stratigraphic framework, and paleogeographic reconstructions have proved that the arrangement of the depositional system was complex and heterogeneous, due to the differential behavior of the extensional structures that controlled each halfgraben (Sacristán-Horcajada et al. 2012b; Sacristán-Horcajada et al. 2013; Sacristán-Horcajada et al. 2015). This different tectonic activity produced that each halfgraben basin displayed different sedimentary architectures and alluvial records, although they were developed under similar climatic conditions. Sacristán-Horcajada et al. (2015) classified these halfgraben alluvial infills in three types of alluvial systems: A) the poorly channelized alluvial-fan systems (PCAF) should be considered as true alluvial fans (*sensu* Blair and McPherson 1994a, 1994b); B) the highly channelized alluvial-fan system (HCAF) should be considered as "relatively small fluvial distributary fan system" (*sensu* Nichols and Fisher 2007) or even "small to very small distributive fluvial fan system" (DFS *sensu* Hartley et al. 2010 and Weissmann et al. 2010); C) the distributive fluvial fan system (braided channels) changing downstream to an axial tributary fluvial system (braided river) (DFF-F), developed during Stage 2 in the Vizcaínos halfgraben basin, shows a fan-shaped distributary system of braided channels, which downstream join a tributary braided river.

2) Original Name of the Studied Unit.—Regarding the original name of the studied unit, Sacristán-Horcajada et al. (2015, 2016) refer initially to it with the complete name: "Nuestra Señora de Brezales Formation." However, in these articles, the authors clarify that, for brevity, the unit is referred to as Brezales Formation "(Brezales Fm hereafter)." That is, Sacristán-Horcajada et al. (2015, 2016) consider and keep the original name of this Formation.

3) The Role of the Pre-Rift Marine Jurassic Substrate as Source Area.—The Brezales Fm overlies a major unconformity that developed on pre-rift marine Callovian to Kimmeridgian sandstones and limestones. In the north and central sectors of the study area (West Cameros Basin), this unconformity developed over the Callovian limestones and sandy limestones (Pozalmuro Fm, defined by Wilde 1990), and corresponds to a paleokarst that modified up to 20 m of the top of the pre-rift marine record. In the south sector of the study area, the unconformity developed over the Middle–Upper Jurassic sandstones and conglomerates. Specifically, in this southern sector, the Brezales Fm lies unconformably on the following units, from NW to SE: the Callovian red sandstone of the Pozalmuro Fm (e.g., Mamolar–La Gallega–Nuestra Señora de Brezales Hermitage area), the Oxfordian ocher-yellowish sandstone of the Aldealpozo Fm, defined by Alonso and Mas (1990) (San Leonardo–Casarejos area), and the lower Kimmeridgian sandstone with interbedded thin coralline limestone of the Torrecilla en Cameros Fm, defined by Alonso and Mas (1990) (e.g., Talveila–Cubilla area). Otherwise, as noted by Miall (1981), it is obvious that sediments in small halfgraben basins related to extensional tectonic settings are usually locally derived and so reflect the local lithological variation of the substrate. Arribas et al. (2003)

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studied the provenance of the detrital sediments in the West Cameros Basin and concluded that the composition of the alluvial Brezales Fm indicated that the underlying marine pre-rift Jurassic sediments were the main source rocks for this formation and that the lithological composition and grain-size characteristics of the clastic sediments reflect the lithological variation of this pre-rift Jurassic substrate. These conclusions are consistent with the lithological and grain-size differences observed in Sacristán-Horcajada et al. (2015). In the north sector, the predominance of carbonate clasts in the coarser facies and the quartzolithic composition of most of the sandstone facies reflect the erosion of the marine pre-rift Callovian limestones and sandy limestones. However, the limited amounts of carbonate rock fragments, the higher content of clastic lithic fragments and quartz grains, and the generally finer grain size in the south sector reflect the predominance of sandy siliciclastic deposits in the underlying pre-rift Jurassic sediments.

Therefore, it is very important to clarify that when Sacristán-Horcajada et al. (2015) suggest that "source-area lithology can be considered a constant factor" they refer to the fact that during the deposition of the Brezales Fm the source area of the various alluvial systems (both alluvial fans and fluvial fans) was always the marine Jurassic substrate with a constant sediment-lithic character, i.e., "progressive erosion and unroofing of the underlying marine Jurassic substrate and varying subcrop beneath the basal unconformity" as Platt and Wright point out in their Discussion.

4) Faulting as a Key Control on Sedimentation at Various Scales.—Sacristan-Horcajada et al. (2015) consider that faulting plays a fundamental role in controlling sedimentation at various scales. Therefore, they conclude that both tectonics and catchment sizes where the main control on sedimentary characteristics of the associated alluvial systems in this type of extensional setting, and that care must be taken when making climatic and tectonic interpretations using the sedimentary record of these alluvial systems. For example, on a larger scale, Sacristán-Horcajada et al. (2015) note the Jaramillo–Covarrubias Fault (Platt 1990) as one of several NE–SW transfer faults dividing the basin into major depocenters, but at the same time they also highlight the role of small-scale faulting in controlling sedimentation. In fact, if Figures 3B, 7, and 15A of Sacristán-Horcajada et al. (2015) show that in the sections of San Martin (SM) and Hortigüela (HO) the Brezales Fm is absent (represented by crosses "X" in Figs. 3B and 7, and white circles "O" in Fig. 15), and that in both cases this occurs just west of the Jaramillo–Covarrubias Fault. However, in the Jaramillo Quemado (JQ) section, just to the east of the same fault, the Brezales Fm reaches 102 m in thickness. The distance of the aforementioned sections from the Jaramillo–Covarrubias Fault is less than 1 km and during the deposition of the Brezales Fm the Marine Jurassic limestones were exposed and subjected to karstification in the San Martin (SM) and Hortigüela (HO) sections, whereas in the Jaramillo Quemado (JQ) section a thickness of up to 102 m of the Brezales Fm was deposited.

5) Confusion between Stratigraphic Sections.—In their Discussion, Platt and Wright indicate that "at Espejón, where the Brezales Formation is not absent as suggested by Sacristán-Horcajada et al. (2015), but features a basal sandy section overlain by a spectacular conglomerate channel complex which was described in detail by Platt (1995)." We consider that this interpretation is not correct. In the southern sector of the West Cameros Basin, Sacristán-Horcajada et al. (2015) logged 11 detailed sections (see Figs. 1C, 3B, C, D, and 5 of Sacristán-Horcajada et al. 2015). We consider that Platt and Wright confuse the section we call Espejón (ES) with the section logged by Platt next to the chapel of Nuestra Señora de Brezales (see Fig. 3 in Platt 1995), which actually corresponds to the section that we logged in the same place, and which we call Brezales (BR), as shown in Figures 3 and 4 of Sacristán-Horcajada et al. (2015). As it can be seen in our section Brezales (BR), the Brezales Fm is obviously present there. Specifically, our section Brezales (BR) is 2.5 km north of the Espejón village, whereas our section Espejón (ES) is only about 500 meters from this locality.

6) The Sedimentary Record of the Brezales Fm in the Southern Part of the Basin.—In their Discussion, Platt and Wright consider the section logged next to the chapel of Nuestra Señora de Brezales as a representative example of the sedimentary record of the Brezales Fm in the southern part of the basin. From our point of view, the stratigraphic record of the Brezales Formation proposed by those authors (Fig. 3 in Platt 1995) is not stratigraphically accurate. As noted above, in the southern sector of the study area, the Brezales Fm unconformably overlies Callovian–Kimmeridgian units of the marine pre-rift deposits. However, Platt (1995, Fig. 3) and Wright et al. (1995, Fig. 2) consider that the Brezales Formation lies unconformably directly over the north-dipping Marine Jurassic limestone cropping out in the morphological elevation on which the chapel is built, which corresponds to a marine Bajocian–Bathonian succession. But this stratigraphic succession interpreted by Platt and Wright is not correct, because between the top of the Bajocian–Bathonian limestone outcrop of the chapel and the base of the Brezales Fm, there is an outcrop of at least ten meters of Callovian red sandstone (Pozalmuro Fm), which can be observed in a small valley near the chapel and north of it. It is this red sandstone unit on which the Brezales Fm lies unconformably and, in our opinion, Platt and Wright have inaccurately considered the Callovian red sandstone (Pozalmuro Fm) as the lower part of the Tithonian Brezales Formation.

Finally, concerning this section we wish to express our sincere apologies for not having cited Platt (1995) or Wright et al. (1995). However, despite the efforts of these authors to highlight contrasting ideas, particularly in relation to the role of the lithology of the source areas and tectonics, we consider that the explanations we have given here show that our interpretations about these issues have more agreements than disagreements with the aforementioned articles.

CONCERNING THE SECTION THAT DR. PLATT AND DR. WRIGHT HAVE TITLED "LAMINAR CALCRETES"

Platt and Wright raise three critical issues that we discuss below: 1) the interpretation of the laminar calcretes as analogous to those from the late stages of some calcrete chronosequences, 2) their failure to cite earlier studies and different interpretations, and 3) their confusion over the term alveolar septal fabric.

1) Interpretation of Laminar Calcrete Facies.—Sacristán-Horcajada et al. (2016) interpret various calcrete facies, analyzing in each case the pedogenic elements and processes. Facies analysis was performed rigorously, both at macroscale (facies) and microscale (microfabric), relying on the most significant publications about pedogenesis and subaerial exposure (see references in Sacristán-Horcajada et al. 2016). Laminar calcrete facies is one of the latest and more complex stages of development in calcrete deposits in the Brezales Fm, and it is a characteristic pedogenetic term, similar to those reported by Gile et al. (1966), Esteban and Klappa (1983), Machete (1985), and Alonso-Zarza et al. (1998). Laminar calcretes are related to other calcrete facies (nodular, brecciated-pisolithic, etc.) in pedogenetic calcrete sequences (see Fig. 9B in Sacristán-Horcajada et al. 2016). In any case, the laminar calcrete facies is included in calcrete sequences and corresponds to a progressive calcretization process. In our study, we have found a spatial relationship between laminar calcretes and other pedogenetic calcrete facies depending on the type of host sediment grain size (see Discussion in Sacristan-Horcajada et al. 2016, Drainage Area: Lithology and Size, and Fig. 10).

2) Not-Cited References.—In relation to the references that Platt and Wright indicate that we have not cited (Wright et al. 1988, Platt 1989, and Wright et al. 1995), we must note that all these works are reviewed, discussed, and cited in Alonso-Zarza and Wright (2010), an article that we do cite in Sacristán-Horcajada et al. (2016). Thus, in our article we selected only those publications we considered most significant for the aim of our research, avoiding further repetitions. Besides, the scientific contribution of Platt (1989) is focused in a younger stratigraphic unit (Berriasian in age), in which the author described calcified root mats as a pedogenetic feature developed above other types of substrate, such as palustrine carbonates. We must indicate that the Brezales Fm is Tithonian in age (Arribas et al. 2003) and that our study focuses exclusively on pedogenetic calcretes developed in this siliciclastic unit. On the other hand, to understand our contribution correctly (Sacristán-Horcajada et al. 2016) it is necessary to previously understand the stratigraphic framework of Depositional Sequence 1 (Brezales Fm and Boleras Fm; Arribas et al. 2003) in the West Cameros Basin (see section "Geological Setting" and Figure 1 in Sacristán-Horcajada et al. 2016, p. 269–270), as well as the various types of alluvial systems that were active during sedimentation of the Brezales Fm (Sacristan-Horcajada et al. 2015). Although we are aware of the development of calcretes in the upper part of lacustrine–palustrine carbonate sequences (Sacristán-Horcajada et al. 2012a, 2012b, 2012c, 2013, 2015), in this work (Sacristán-Horcajada et al. 2016) we considered only the pedogenetic calcretes associated with the alluvial systems of the Brezales Fm (Sacristan-Horcajada et al. 2015).

3) Confusion with the term alveolar septal fabric.—We would like to clarify that we are not confused with the term alveolar septal fabric. Alveolar structures are very common in laminar calcrete facies of the Brezales Fm, and sometimes it is possible to recognize thin walls of micritic calcite separated by pore spaces, similar to those described by Esteban and Klappa (1983) and Wright (1986). It is possible that Figure 5E is not a good example of this structure, because this image shows exclusively an alveolar structure. However, this rhizocretion feature is present in laminar calcrete facies.

Finally, we want reiterate our thanks to Dr. Platt and Dr. Wright for the opportunity they have given us to discuss all the comments they made, and we hope this reply enhances the comprehension of our work.

REFERENCES

Alonso, A., and Mas, R., 1990, El Jurásico Superior marino en el sector Demanda–Cameros (La Rioja–Soria): Cuadernos de Geología Ibérica, v. 14, p. 173–198.

Alonso-Zarza, A.M., and Wright, V.P., 2010, Calcretes, *in* Alonso-Zarza, A.M., and Tanner, L.H., eds., Carbonates in Continental Settings: Facies, Environments and Processes: Amsterdam, Elsevier, p. 225–267.

Alonso-Zarza, A.M., Silva, P., Goy, J.L., and Zazo, C., 1998, Fan-surface dynamics and biogenic calcrete development: interactions during ultimate phases of fan evolution in the semiarid SE Spain (Murcia): Geomorphology, v. 24, p. 147–167.

Arribas, J., Alonso, A., Mas, R., Tortosa, A., Rodas, M., Barrenechea, J.F., Alonso-Azcarate, J., and Artigas, R., 2003, Sandstone petrography of continental depositional sequences of an intraplate rift basin: western Cameros Basin (North Spain): Journal of Sedimentary Research, v. 73, p. 309–327.

Blair, T.C., and McPherson, J.G., 1994a, Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages: Journal of Sedimentary Research, v. 64, p. 450–489.

Blair, T.C., and McPherson, J.G., 1994b, Alluvial fan processes and forms, *in* Abrahams, A.D., and Parsons, A.J., eds., Geomorphology of Desert Environments: London, Chapman and Hall, p. 354–402.

Esteban, M., and Klappa, C.F., 1983, Subaerial exposure environment, *in* Scholle, P.A., Bebout, D.G., and Moore, C.H., eds., Carbonate Depositional Environments: American Association of Petroleum Geologists, Memoir 33, 54 p.

Gile, L.H., Peterson, F.F., and Grossman, J.B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347–360.

Hartley, A.J., Weissmann, G.S., Nichols, G.J., and Warwick, G.L., 2010, Large distributive fluvial systems: characteristics, distribution, and controls on development: Journal of Sedimentary Research, v. 80, p. 167–183.

Machete, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., ed., Soils and Quaternary Geology of the Southwest United States: Geological Society of America, Special Paper 203, p. 1–21.

Miall, A.D., 1981, Alluvial sedimentary basins: tectonic setting and basin architecture, *in* Miall, A.D., ed., Sedimentation and Tectonics in Alluvial Basins: Geological Association of Canada, Special Paper 23, p. 1–33.

Nichols, G.J., and Fisher, J.A., 2007, Processes, facies and architecture of fluvial distributary system deposits: Sedimentary Geology, v. 195, p. 75–90.

Platt, N.H., 1989, Lacustrine carbonates and pedogenesis: sedimentology and origin of palustrine deposits from the Early Cretaceous Rupelo Formation, W Cameros Basin, N Spain: Sedimentology, v. 36, p. 665–684.

Platt, N.H., 1990, Basin evolution and fault reactivation in the western Cameros Basin, Northern Spain: Geological Society of London, Journal, v. 147, p. 165–175.

Platt, N.H., 1995, Sedimentation and tectonics of a syn-rift succession: Upper Jurassic alluvial fans and palaeokarst at the late Cimmerian unconformity, Western Cameros Basin, northern Spain, *in* Plint, G., ed., Sedimentary Facies Analysis: International Association of Sedimentologists, Special Publication 22, p. 219–236.

Sacristán-Horcajada, S., Mas, R., and Arribas, M.E., 2012a, Evolución de los sistemas lacustres asociados al estadio temprano de rift en el Semigraben de Rupelo (NO de la Cuenca de Cameros, España): subsidencia e influencia marina: Geotemas, v. 13, p. 89.

Sacristán-Horcajada, S., Mas, R., and Arribas, M.E., 2012b, Tectonic subsidence and transfer zones as controls over halfgraben sedimentation during the beginning of a rift system: the NW area of the Cameros Basin North Spain: International Association of Sedimentologists, 29th Meeting, Schladming, Austria, 515 p.

Sacristán-Horcajada, S., Mas, R., and Arribas, M.E., 2012c, Marine influence in the third depositional sequence (lower–middle Berriasian) of the mainly continental synrift sedimentary record in the western Cameros Basin, (N Spain): International Association of Sedimentologists, 29th Meeting, Schladming, Austria, 515 p.

Sacristán-Horcajada, S., Mas, R., and Arribas, M.E., 2013, Alluvial fan characteristics and distribution at the beginning of a rifting-phase (latest Jurassic record, Western Cameros Basin, N Spain), *in* Parsons, D.R., Ashworth, P.J., Best, J.L., and Simpson, C.J., eds., 10th International Conference on Fluvial Sedimentology, Conference Programme and Abstract Volume, p. 408–409.

Sacristán-Horcajada, S., Mas, R., and Arribas, M.E., 2015, Early syn-rift evolution in the Wesst Cameros Basin (Upper Jurassic, NW Iberian Range) Spain: Journal of Sedimentary Research, v. 85, p. 794–819.

Sacristán-Horcajada, S., Arribas, M.E., and Mas, R., 2016, Pedogenetic calcretes in early syn-rift alluvial systems (Upper Jurassic, West Cameros Basin), Northern Spain: Journal of Sedimentary Research, v. 86, p. 794–819.

Weissmann, G.S., Hartley, A.J., Nichols, G.J., Scuderi, L.A., Olson, M., Buehler, H., and Banteah, R., 2010, Fluvial form in modern continental sedimentary basins: distributive fluvial systems: Geology, v. 38, p. 39–42.

Wilde, S., 1990, The Bathonian and Callovian of the Northwest Iberian Range: stages of facial paleogeographical differentiation on an epicontinental platform: Cuadernos de Geología Ibérica, v. 14, p. 113–142.

Wright, V.P., 1986, The role of fungal biomineralization in the formation of early Carboniferous soil fabrics: Sedimentology, v. 33, p. 831–838.

Wright, V.P., Platt, N.H., and Wimbledon, W.A., 1988, Biogenic laminar calcretes: evidence of calcified root-mat horizons in paleosols: Sedimentology, v. 35, p. 603–620.

Wright, V.P., Platt, N.H., Marriott, S.B., and Beck, V.H., 1995, A classification of rhizogenic (root-formed) calcretes with examples from the Upper Jurassic–Lower Cretaceous of Spain and Upper Cretaceous of southern France: Sedimentary Geology, v. 100, p. 143–158.

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