First report of sponge rhaxes in the Picún Leufú Formation (Tithonian–Berriasian), Neuquén Basin, Argentina

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Göttingen Contributions to Geosciences
www.gzg.uni-goettingen.de

77: 49-56, 5 figs. 2014

The Picún Leufú Formation (Tithonian-Berriasian, Neuquén Basin, Argentina) comprises mixed carbonate-siliciclastic rocks. Here we report the occurrence of rhaxes (microscleres of the sponge genus *Rhaxella* Hinde, 1890) in the Picún Leufú Formation, which have formerly been misinterpreted as calcispheres. Furthermore, the meaning of the microscleres with respect to sedimentary environments and diagenesis in the Picún Leufú Formation is briefly evaluated. The rhaxes in the Picún Leufú Formation are highly abundant (up to 80–90 % of the components) and occur in various facies ranging from the proximal lagoon to the outer inner ramp, all representing shallow water environments. Diagenetic processes linked to the rhaxes probably have a significant impact on reservoir qualities in different parts of the Picún Leufú Formation.

Received: 03 January 2013

Accepted: 01 August 2013

Subject Areas: Palaeontology, Sedimentology

Keywords: Porifera, Demospongea, Geodiidae, Jurassic, Tithonian, Cretaceous, Berriasian, Argentina, Neuquén Basin, palaeoecology, diagenesis

Introduction

The Neuquén Basin is located on the eastern side of the Andes and is the most important hydrocarbon-producing province in southern South America (Howell et al. 2005) (Fig. 1). The Basin was characterised by a back-arc extension during the late Jurassic to early Cretaceous (e.g., Legarreta & Uliana 1991). Stratigraphical units in the south-eastern margin of the basin were deposited on a ramp system (Legarreta & Uliana 1991; Schwarz & Buatois 2012) with a steeper depth gradient in the western part of the basin (Schwarz & Buatois 2012) and are characterised by multiple carbonate, clastic and evaporite intervals (e.g., Uliana & Legarreta 1993; Vergani et al. 1995; Howell et al. 2005).

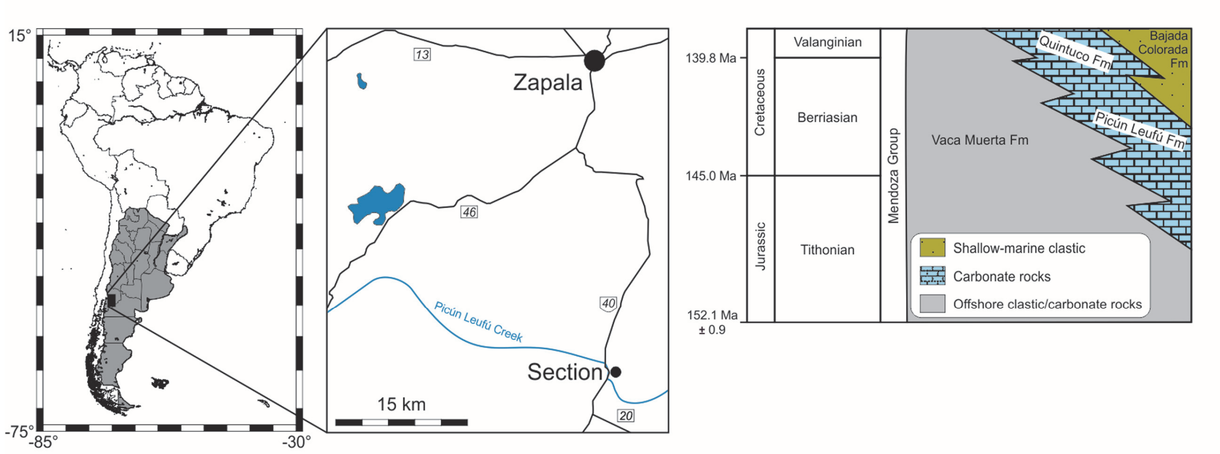

Fig. 1: Location of the study area and stratigraphy of the Tithonian–Valanginian strata in the Neuquén Basin (stratigraphy after Howell et al. 2005, modified).

In the study area the Tithonian to middle Valanginian interval is represented by the two marine lithostratigraphic Formations of the lower Mendoza Group, i.e. (from base to top) the Vaca Muerta Formation and the Picún Leufú Formation (Weaver 1931) (Fig. 1), with the Vaca Muerta Formation being the basinal equivalent to the shelf deposits of the Quintuco and Picún Leufú Formations.
Thin section analysis of mixed siliciclastic-carbonate rocks of the Picún Leufú Formation revealed highly abundant kidney-shaped microscleres ("*rhaxes*": Fig. 3.3., 3.4.), being characteristic for the genus *Rhaxella* Hinde, 1890. However, these components have been interpreted as calcispheres (Armella et al. 2007). Aim of this paper is the reinterpretation of these fossils in the Picún Leufú Formation. Furthermore, the meaning of the rhaxes with respect to sedimentary environments and diagenesis in the Picún Leufú Formation is briefly evaluated.

Methods

One section exposed along the Picún Leufú Creek in the southern part of the Neuquén Basin (Figs. 1–2) was documented and sampled. 75 thin sections were prepared for microfacies analyses. The microfacies was classified based on Dunham (1962). Field emission scanning electron microscopy (Fe-SEM) was conducted on selected samples, using a ZEISS Gemini Supra TM 40. For elemental analyses, an energy dispersive X-ray spectrometer (EDX) Oxford Inca 400 coupled to the SEM was used. The carbonate content was measured using the gas volumetric "Scheibler" method (cf. Kenter et al. 1997). For the identification of mineral phases a Philips PW1800 diffractometer (XRD) equipped with a Cu-tube (kα 1.541, 40 kV, 30 mA) was used. Based on these results, the weight-percent of stable carbonate minerals (dolomite and low-mg calcite) were calculated for each sample. The ratio between calcite and dolomite was calculated based on Royse et al. (1971).

Results and discussion

Rhaxes in the Picún Leufú Formation

Rhaxes observed in the Picún Leufú Formation have spherical and reniform shapes. The taxonomic interpretation of rhaxes is still controversially discussed since reniform shapes are characteristics of both selenaster- and sterraster-type microscleres (e.g., Reitner 1992; Wiedenmayer 1994; Pisera 1997; Rützler 2002; Reid 2004). But, selenasters are characteristic for the family Placospongiidae Gray, 1867 (Rützler 2002) while sterrasters are typical for the Geodiidae Gray, 1867 (Uriz 2002). However, the discussion of this taxonomic problem is not possible based on the investigated material and lies beyond the scope of this paper. For this reason, we will use the term "*rhaxes*" in the following.

The rhaxes observed in the Picún Leufú Formation occur abundantly in some samples (up to 80–90 % of the components: Fig. 3.1). Similar occurrences are e.g. known from the Portlandian of Dorset, were *Rhaxella* spicules make up to 70 % of the rocks (Townson 1975). The length of the spicules of the Picún Leufú Formation ranges between 103–127 μm, while the width ranges between 72–96 μm. This is comparable to the size range of *Rhaxella* spicules in the Portlandian of Dorset, which range between ~50–230 μm in length and ~50–170 μm in width (cf. Haslett 1992) (Fig. 4). The rhaxes in the Picún Leufú Formation are characterised by a clear rim which appears dark under transmitted light and spar cemented inner parts (Fig. 3.3.). EDX measurements show that the rim of the rhaxes is siliceous, while the core is made up of $CaCO_3$ (Fig. 5). In some samples, the rhaxes occur as nuclei of ooids (Fig. 3.4.).

Despite these characteristics, the rhaxes in the Picún Leufú Formation have been misinterpreted as calcispheres (Armella et al. 2007). Calcispheres are characterised by differentiated calcitic walls with or without openings and

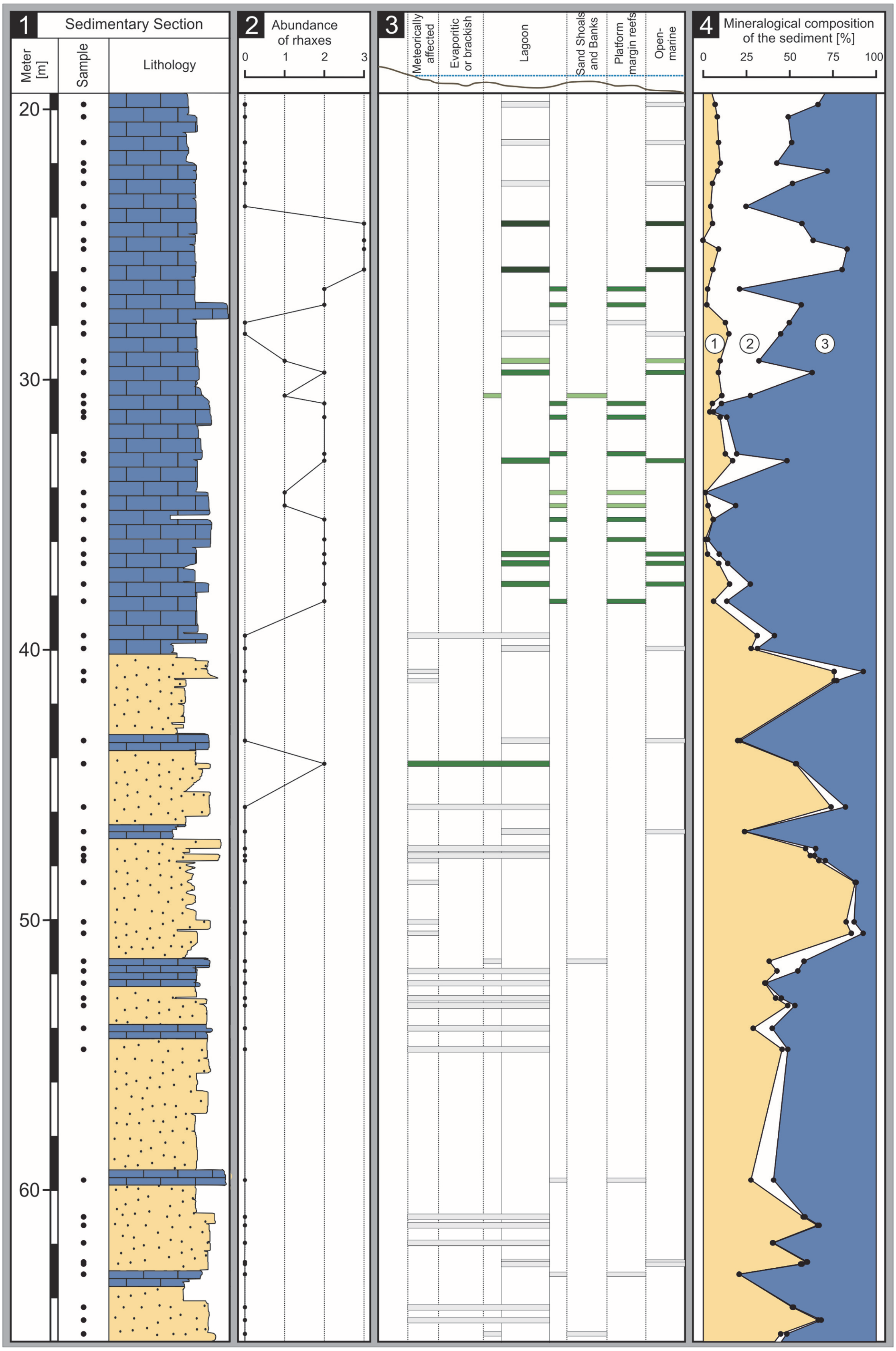

Fig. 2: Sedimentary section. **(A)** Lithology; **(B)** Estimated abundances of rhaxes in thin sections (0 = absent, 1 = rare, 2 = common, 3 = abundant); **(C)** Distribution of rhaxes in different palaeoenvironments of the Picún Leufú Formation, colours of bars indicate the petrographically estimated abundance of rhaxes in the respective facies (white bar = absent, light green bar = rare, middle green bar = common, dark green bar = abundant); **(D)** Mineralogical composition of the sediment (in %; 1 = silica, 2 = dolomite, 3 = low-magnesium calcite).

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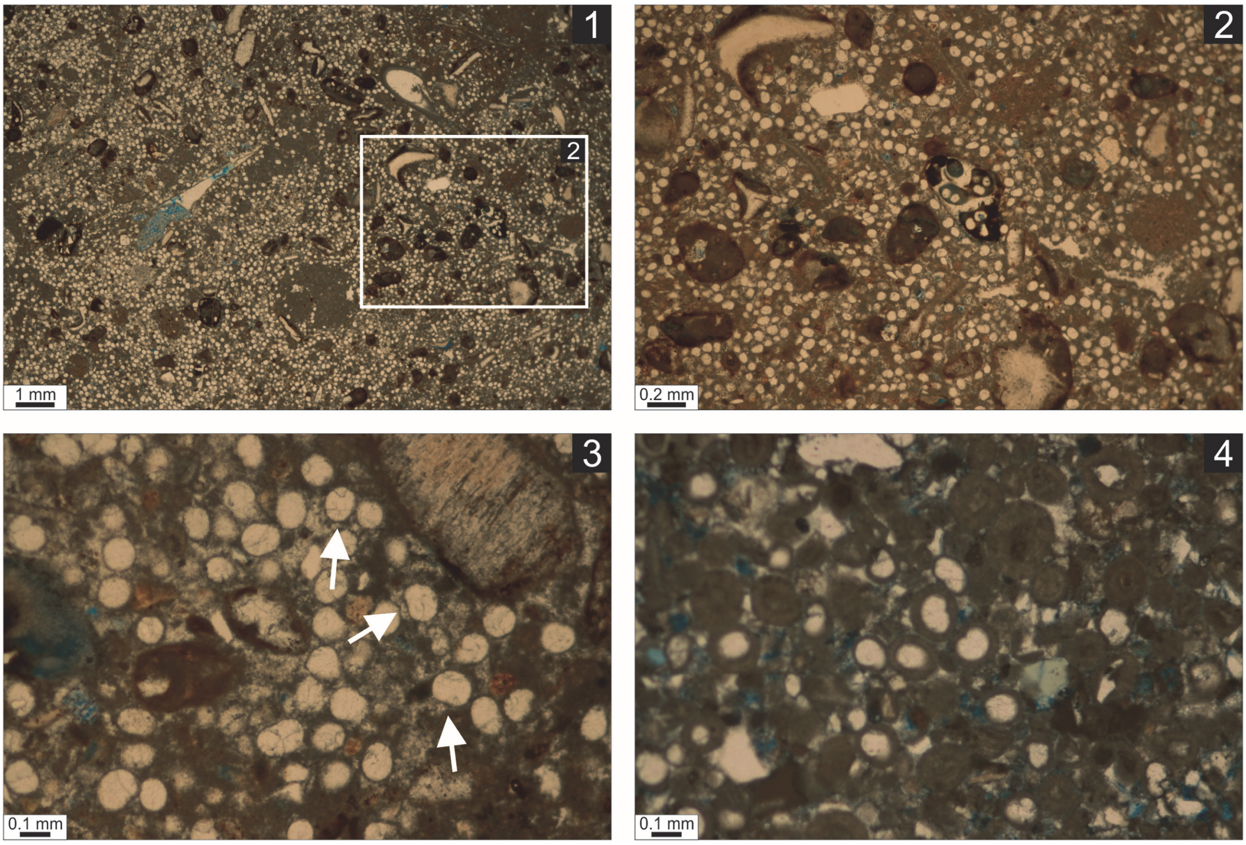

Fig. 3: **(1–4)** Thin sections photographs of sponge rhaxes – *Rhaxella* sp. **(1)** Example of sample with highly abundant rhaxes; **(2)** Detail of (1), note the spherical and reniform shapes of the rhaxes; **(3)** Rhaxes with a clear micritic rim (white arrows); **(4)** Rhaxes as nuclei of ooids. All from the Picún Leufú Fm. (Tithonian–Valanginian), south of Zapala, Neuquén Basin, Argentina.

pores (e.g., Keupp 1991; Flügel 2004; and references therein). But, transmitted light and scanning electron microscopy reveals that the objects do not exhibit typical wall structures of calcispheres (Figs. 3, 5) and, neither openings nor pores have been observed. These findings clearly support the interpretation as sponge rhaxes.

Palaeoenvironment and diagenesis

Sedimentary rocks of the Picún Leufú Formation were deposited on a tidally dominated, mixed carbonate-siliciclastic ramp (Spalletti et al. 2000). The studied interval of the Picún Leufú Formation, which is merely a small part of the whole Formation, can roughly be subdivided into two lithological intervals and range from siliciclastic rocks with intercalated carbonate beds to pure carbonates (Fig. 2). Six facies groups (FGs) have been distinguished (Fig. 2). The observed rhaxes occur in different facies ranging from the proximal lagoon to the outer inner ramp, with pure sandstones in the lower part of the section being the only exception (Fig. 2). And, the number of rhaxes increases with decreasing amounts of siliciclastic material (Fig. 2). This implies that the distribution of *Rhaxella* was strongly affected by impact of siliciclastic material.

In the Portlandian of Dorset, *Rhaxella* throve in low-to medium energy environments of the outer part of the carbonate shelf (i.e., seaward of the high energy ooid shoal), were facies transitionally changed downslope into open marine conditions (Townson 1975; Haslett 1992). This is in good accordance with the situation observed in the Picún Leufú Formation, since the rhaxes-bearing facies clearly represent shallow water environments. And, they are partly also abundant in relative deeper facies like lagoonal or marginal ramp facies (Fig. 2). Moreover, a close spatial association of environments with rhaxes and ooid shoals is evident in the Picún Leufú Formation as well, since rhaxes commonly occur as nuclei of ooids. Since rhaxes within ooids are commonly well-preserved (Fig. 3.4.), it appears that they have not been significantly transported or even reworked before ooid genesis. This observation further underlines the close spatial relationship between environments inhabited by *Rhaxella* and ooid shoals.

However, it appears that deep water depths were critical for *Rhaxella* as well. In the lower Oxfordian of north Yorkshire, the extensive development of *Rhaxella* generally went along with the establishment of shallow water marine conditions (i.e., the transition from Oxford Clay into the Lower Calcareous Grit; Wright 1983). In case of the Neuquén Basin, the Los Catutos Member (middle Tithonian) of the Vaca Muerta Formation could help to evaluate this problem. In contrast to the Picún Leufú Formation, the Los Catutos Member was situated in the more distal part of the Neuquén Basin, representing deeper open marine parts of the ramp (e.g., Scasso et al. 2005). And, rhaxes also have been described in this Member though they are not abundant as in the Picún Leufú Formation (only 4–20 % rhaxes and radiolarians; Scasso et al. 2005). Furthermore, the preservation seems to be worse than in the Picún Leufú Formation, since the rhaxes are flattened or fragmented, only rarely preserved, and show other diagenetic features which could not be observed in the Picún Leufú Formation (e.g., syntaxial overgrowths; Scasso et al. 2005). And, they can easily be confused with spumellarian radiolarians (Scasso et al. 2005*)*, implying that the preservation of the rhaxes is not very good. For these reasons it appears much more probable that environments inhabited by *Rhaxella* were closer to the ones represented by the Picún Leufú Formation than to the environments represented by the Los Catutos Member.

This raises the question whether the shallow marine Picún Leufú Formation even directly represents the environment inhabited by *Rhaxella*. In some cases it is assumed that *Rhaxella* lived epifaunally attached to a fine sand substrate supported by a lime mud matrix (Townson 1975; Haslett 1992). Wholly preserved body fossils of *Rhaxella* have not been found in the Picún Leufú Formation so far. And, the rhaxes are not restricted to a muddy to fine sandy facies, but also occur within different types of coarser grained grainstones and packstones. Furthermore, the preservation of the rhaxes ranges from clearly recognisable (i.e., with well-defined silicified rims) to poorly recognisable shapes (i.e., with strongly alterated rims). In sum this implies that the observed rhaxes are not entirely autochthonous, and that the environments inhabited by *Rhaxella* are not directly represented by the sedimentary facies of the Picún Leufú Formation. Thus, the respective environments have been very close to the ones represented by the Picún Leufú Formation or may just have been constantly reworked. However, both would imply that the environments inhabited by *Rhaxella* may have not been stable over a relative long time once they had been established, but rather changed dynamically on short term.

The preservation style of the investigated rhaxes has implications for diagenetic processes in the Picún Leufú Formation, particularly with regard to desilification- and silification-processes. In the Portlandian of Dorset (Portland Limestone Formation) e.g., spicules of *Rhaxella* are usually only preserved as casts and moulds, with the silica replaced by calcite (Townson 1975). The dissolution of the silica gives rise to thinly bedded chert horizons, which preserved these spicules in their original siliceous form (Wilson 1966). Similar processes are described for the Lower Calcareous Grit, were thin beds of cherts were secondarily formed because of *Rhaxella* (Powell 2010). This is in line with a proposed relation between presence of rhaxes and diagenetic quartz cementation during shallow burial, being important in hydrocarbon provinces with highly variable reservoir qualities such as e.g. the South Viking Graben (Williams et al. 1985; Hendry & Trewin 1995; Maast et al. 2011). Thus, the occurrence and distribution of rhaxes could have implications for reservoir qualities in different settings of the Picún Leufú Formation.

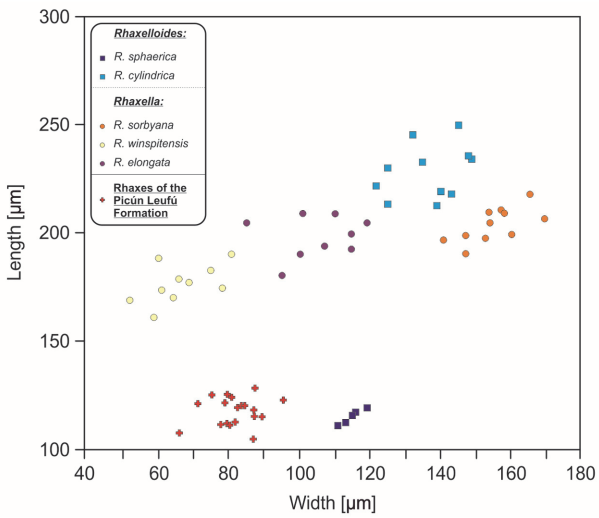

Fig. 4: Dimension of rhaxes in the Picún Leufú Formation compared to spicules of *Rhaxella sorbyana*, *R. winspitensis*, *R. elongata*, *Rhaxelloides sphaerica* and *R. cylindrica* (after Haslett 1992, modified). Note that the rhaxes in the Picún Leufú Formation are smaller than those of other species.

Conclusions

Rhaxes in the Picún Leufú Formation have formerly been misinterpreted as calcispheres (Armella et al. 2007). They are locally highly abundant in some samples (up to 80–90 % of the components). Dimensions of the rhaxes are comparable to the size range of *Rhaxella* spicules in the Portlandian of Dorset, while they are smaller than ones in the Ardassie limestone of Brora and in the Alness Spiculite of the Moray Firth (both Oxfordian Stage). Rhaxes in the Picún Leufú Formation occur in a wide range of facies ranging from the proximal lagoon to the outer inner ramp, all clearly representing shallow water environments. Although they are not originally preserved, they are commonly clearly recognisable due to the presence of a well-defined silicified rim. The rim could be explained by the depositional and diagenetic environments in which early diagenetic solution and re-precipitation of silica was temporarily favoured. This could be important with respect to reservoir qualities in different parts of the Picún Leufú Formation.

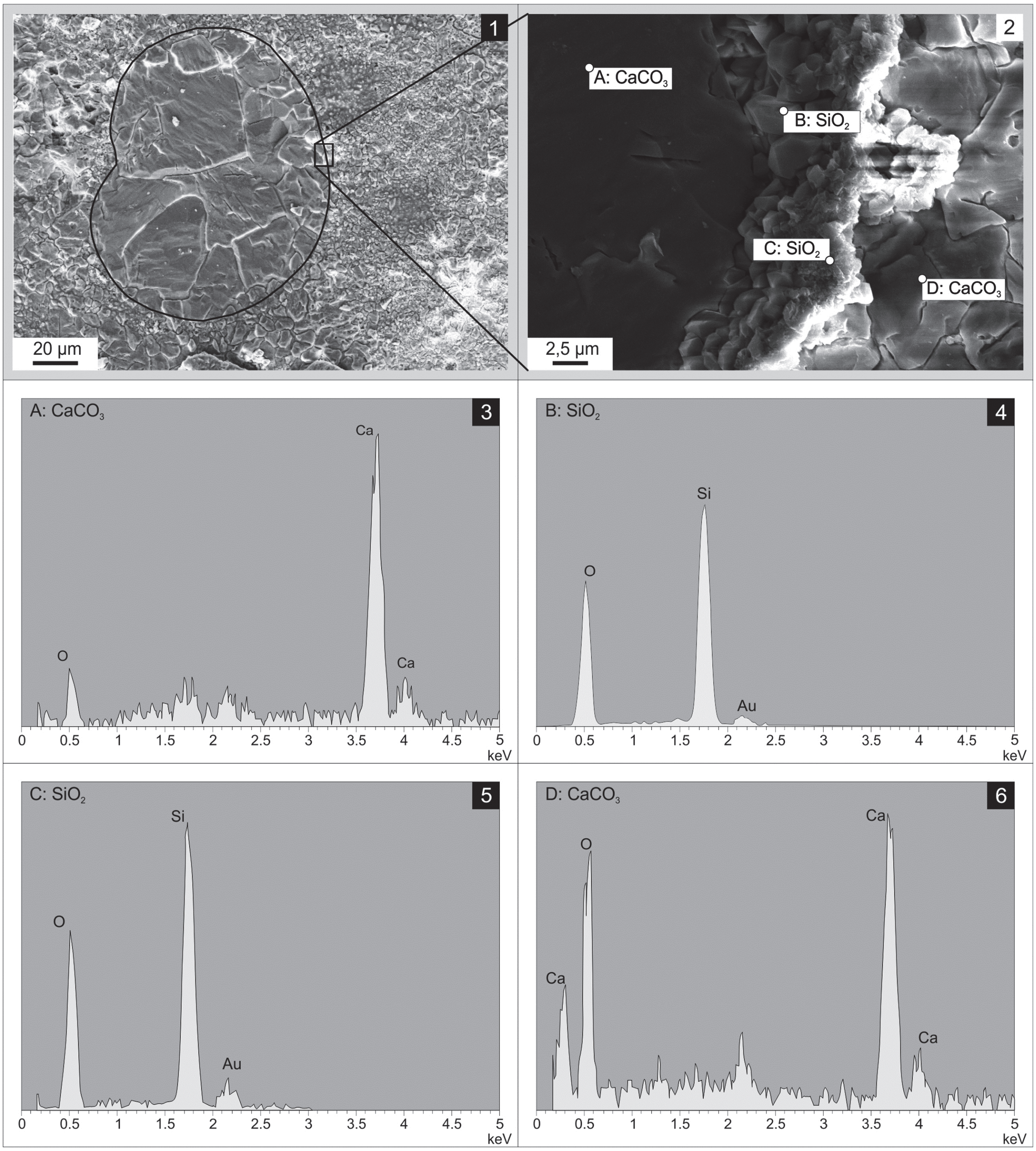

Fig. 5: **(1–6)** SEM pictures and respective EDX data of a *Rhaxella* rhax from the Picún Leufú Formation. **(1)** Rhax with clear reniform shape; **(2)** Detail of (1), the silicified rim is clearly distinguishable from the calcite because of etching; **(3–6)** EDX data [see (2) for positions]; $CaCO_3$ spar cemented inner part of the rhax]; **(4–5)** SiO_2 rim of the same rhax; **(6)** $CaCO_3$ matrix surrounding the rhax.

Acknowledgements

We thank Professor Dr Luis A. Spalletti, Dr Ernesto Schwarz (Universidad Nacional and Centro de Investigaciones Geológicas, La Plata) and Dr José Luis Massaferro (Gerencia Geología y Estudios Integrados, Buenos Aires) for a good introduction into the regional geology. Dr Juan Francisco Sánchez Beristáin (Universidad Nacional Autónoma de México, México City) and an anonymous reviewer are greatly acknowledged for their constructive criticism and advice which helped to improve the quality of the paper. Sebastian Flotow (Bremen University) is acknowledged for the preparation of thin sections and Petra Witte (Bremen University) for help with EDX and SEM analyses. We also thank the research groups Historical Geology / Palaeontology (Professor Dr Helmut Willems, Bremen University) and Crystallography (Professor Dr Reinhard X. Fischer, Bremen University) for providing analytical support.

References

Armella, C.; Cabaleri, N. & Leanza, H. A. (2007): Tidally dominated, rimmed-shelf facies of the Picún Leufú Formation (Jurassic/Cretaceous boundary) in southwest Gondwana, Neuquén Basin, Argentina. *Cretaceous Research* **28** (6): 961-979. http://dx.doi.org/10.1016/j.cretres.2007.01.001

Dunham, R. J. (1962): Classification of carbonate rocks according to depositional texture. In: Ham, W. E. (ed.): Classification of carbonate rocks. *The American Association of Petroleum Geologists, Memoirs* **1**: 108-171.

Flügel, E. (2004): *Microfacies of Carbonate Rocks: Analysis, Interpretation and Application.* Berlin etc. (Springer): xix + 976 pp.

Gray, J. E. (1867): Notes on the Arrangement of Sponges, with the Descriptions of some New Genera. *Proceedings of the Zoological Society of London* **35** (2): 492-558.

Haslett, S. K. (1992): Rhaxellid sponge microscleres from the Portlandian of Dorset, UK. *Geological Journal* **27** (4): 339-347. http://dx.doi.org/10.1002/gj.3350270404

Hendry, J. P. & Trewin, N. H. (1995): Authigenic quartz microfabrics in Cretaceous turbidites: evidence for silica transformation processes in sandstones. *Journal of Sedimentary Research (A: Sedimentary Petrology and Processes)* **65** (2): 380-392. http://dx.doi.org/10.1306/D42680CC-2B26-11D7-8648000102C1865D

Hinde, G. J. (1890): On a new Genus of Siliceous Sponges from the Lower Calcareous Grit of Yorkshire. *Quarterly Journal of the Geological Society* **46** (1-4): 54-61. http://dx.doi.org/10.1144/GSL.JGS.1890.046.01-04.06

Howell, J. A.; Schwarz, E.; Spalletti, L. A. & Veiga, G. D. (2005): The Neuquén Basin: an overview. In: Veiga, G. D.; Spalletti, L. A.; Howell, J. A. & Schwarz, E. (eds.): The Neuquén Basin, Argentina: A Case Study in Sequence Stratigraphy and Basin Dynamics. *Geological Society London Special Publications* **252**: 1-14.

Kenter, J. A. M.; Podladchikov, F. F.; Reinders, M.; Van der Gaast, S. J.; Fouke, B. W. & Sonnenfeld, M. D. (1997): Parameters controlling sonic velocities in a mixed carbonate-siliciclastics Permian shelf-margin (upper San Andres formation, Last Chance Canyon, New Mexico). *Geophysics* **62** (2): 505-520. http://dx.doi.org/10.1190/1.1444161

Keupp, H. (1991): Fossil Calcareous Dinoflagellate Cysts. In: Riding, R. (ed.): *Calcareous Algae and Stromatolites.* Berlin & Heidelberg (Springer): 267-286.

Legarreta, L. & Uliana, M. A. (1991): Jurassic–Cretaceous marine oscillations and geometry of back-arc basin fill, central Argentine Andes. In: Macdonald, D. I. M. (ed.): Sedimentation, Tectonics, and Eustasy. Sea-level Changes at Active Margins. *Special Publication of the International Association of Sedimentologists* **12**: 429-450.

Maast, T. E.; Jahren, J. & Bjørlykke, K. (2011): Diagenetic controls on reservoir quality in Middle to Upper Jurassic sandstones in the South Viking Graben, North Sea. *AAPG Bulletin* **95** (11): 1937-1958. http://dx.doi.org/10.1306/03071110122

Pisera, A. (1997): Upper Jurassic Siliceous Sponges from the Swabian Alb: Taxonomy and Paleoecology. *Palaeontologia Polonica* **57**: 3-216.

Powell, J. H. (2010): Jurassic sedimentation in the Cleveland Basin: a review. *Proceedings of the Yorkshire Geological Society* **58** (1): 21-72. http://dx.doi.org/10.1144/pygs.58.1.278

Reid, R. E. H. (2004): Mesozoic and Cenozoic Choristid Demosponges. In: Finks, R.; Reid, R. E. H. & Rigby, J. K.: Porifera (Demospongea, Hexactinellida, Heteractinida, Calcarea). *Treatise on Invertebrate Paleontology, Part E: Porifera (Revised)* ***3***. Boulder, Colo. (The Geological Society of America) & Lawrence, Kans. (The University of Kansas): 175-198.

Reitner, J. (1992): 'Coralline Spongien'. Der Versuch einer phylogenetisch-taxonomischen Analyse. *Berliner Geowissenschaftliche Abhandlungen (E: Paläobiologie)* **1:** 1-352.

Royse, C. F.; Wadell, J. S. & Petersen, L. E. (1971): X-ray Determination of Calcite-Dolomite: an Evaluation. *Journal of Sedimentary Petrology* **41** (2): 483-488. http://dx.doi.org/10.1306/74D722A7-2B21-11D7-8648000102C1865D

Rützler, K. (2002): Family Placospongiidae Gray, 1867. In: Hooper, J. N. A. & Soest, R. W. M. van (eds.): *Systema Porifera: A Guide to the Classification of Sponges.* New York, N.Y. (Kluwer Academic/Plenum Publishers): 196-200.

Scasso, R. A.; Alonso, M. S.; Lanés, S.; Villar, H. J. & Laffitte, G. (2005): Geochemistry and petrology of a Middle Tithonian limestone-marl rhythmite in the Neuquén Basin, Argentina: depositional and burial history. In: Veiga, G. D.; Spalletti, L. A.; Howell, J. A. & Schwarz, E. (eds.): The Neuquén Basin, Argentina: A Case Study in Sequence Stratigraphy and Basin Dynamics. *Geological Society London Special Publications* **252**: 207-229.

Schwarz, E. & Buatois, L. A. (2012): Substrate-controlled ichnofacies along a marine sequence boundary: The Intra-Valanginian Discontinuity in central Neuquén Basin (Argentina). *Sedimentary Geology* **277-278**: 72-87. http://dx.doi.org/10.1016/j.sedgeo.2012.07.014

Spalletti, L. A.; Franzese, J. R.; Matheos, S. D. & Schwarz E. (2000): Sequence stratigraphy of a tidally dominated carbonate–siliciclastic ramp; the Tithonian–Early Berriasian of the Southern Neuquén Basin, Argentina. *Journal of the Geological Society*, London **157** (2): 433-446. http://dx.doi.org/10.1144/jgs.157.2.433

Townson, W. G. (1975): Lithostratigraphy and deposition of the type Portlandian. *Journal of the Geological Society* **131** (6): 619-638. http://dx.doi.org/10.1144/gsjgs.131.6.0619

Uliana, M. A. & Legarreta, L. (1993): Hydrocarbons habitat in a Triassic-to-Cretaceous sub-Andean setting: Neuquén Basin, Argentina. *Journal of Petroleum Geology* **16** (4): 397-420. http://dx.doi.org/10.1111/j.1747-5457.1993.tb00350.x

Uriz, M. J. (2002): Family Geodiidae Gray, 1867. In: Hooper, J. N. A. & Soest, R. W. M. van (eds.): *Systema Porifera: A Guide to the Classification of Sponges.* New York, N.Y. (Kluwer Academic/Plenum Publishers): 134-140.

Vergani, G. D.; Tankard, A. J.; Belotti, H. J. & Welsink, H. J. (1995): Tectonic Evolution and Paleogeography of the Neuquén Basin, Argentina. In: Tankard, A. J.; Suárez S., R. & Welsink, H. J. (eds.): Petroleum Basins of South America. *American Association of Petroleum Geologists Memoir* **62**: 383-402.

Weaver, C. E. (1931): Paleontology of the Jurassic and Cretaceous of West Central Argentina. *Memoirs of the University of Washington* **1**: 1-469.

Wiedenmayer, F. (1994): Contributions to the knowledge of post-Palaeozoic neritic and archibenthal sponges (Porifera). The stratigraphic record, ecology and global distribution of intermediate and higher taxa. *Schweizerische Paläontologische Abhandlungen* **116**: 1-147.

Williams, L. A.; Parks, G. A. & Crerar, D. A. (1985): Silica diagenesis, I. Solubility controls. *Journal of Sedimentary Research* **55** (3): 301-311. http://dx.doi.org/10.1306/212F86AC-2B24-11D7-8648000102C1865D

Wilson, R. C. L. (1966): Silica diagenesis in Upper Jurassic Limestones of Southern England. *Journal of Sedimentary Petrology* **36** (4): 1036-1049. http://dx.doi.org/10.1306/74D715F0-2B21-11D7-8648000102C1865D

Wright, J. K. (1983): The Lower Oxfordian (Upper Jurassic) of North Yorkshire. *Proceedings of the Yorkshire Geological Society* **44** (3): 249-281. http://dx.doi.org/10.1144/pygs.44.3.249

Cite this article: Afşar, F.; Duda, J.-P.; Zeller, M.; Verwer, K.; Westphal, H. & Eberli, G. P. (2014): First report of sponge rhaxes in the Picún Leufú Formation (Tithonian–Berriasian), Neuquén Basin, Argentina. *In:* Wiese, F.; Reich, M. & Arp, G. (eds.): "Spongy, slimy, cosy & more…". Commemorative volume in celebration of the 60th birthday of Joachim Reitner. *Göttingen Contributions to Geosciences* **77**: 49–56.

http://dx.doi. org/10.3249/webdoc-3916

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