Middle-Upper Triassic successions in the eastern Iberian Chain (Alt Palància and Manzanera areas): Stratigraphic precisions.

Sucesiones del Triásico Medio-Superior en la Cadena Ibérica oriental (áreas de Alt Palància y Manzanera): Precisiones estratigráficas.

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Abstract: *Cartographic, stratigraphic and structural studies in the Alt Palància and Manzanera areas indicate that the Middle-Upper Triassic successions entirely belong to the 'Mediterranean type of Triassic'. The two carbonate units of the Muschelkalk facies have carbonate-marl alternations both at the base and at the top. The palynological study of claystones and marls allows dating the Röt facies and the three Mus-chelkalk units. The isotopic study of gypsum samples allows distinguishing the middle Muschelkalk unit from the Keuper unit despite the facies similarity and tectonic disruption.*

Keywords: *Triassic. Stratigraphy. Palynology. Sulfate isotopy. Iberian Chain.*

Resumen: Los estudios cartográficos, estratigráficos y estructurales muestran que las sucesiones del Triásico Me-dio-Superior en las áreas de Alt Palància y Manzanera pertenecen en su totalidad al 'tipo Mediterráneo' de Triásico. Las dos unidades carbonatadas de la facies Muschelkalk presentan alternancias de margas y carbonatos en la base y en el techo. El estudio palinológico de la arcillas y margas permite datar la facies Röt y las tres unidades del Muschelkalk. El estudio isotópico de los yesos permite distinguir la unidad del Muschelkalk medio de la del Keuper, a pesar de la similitud de facies y la distorsión tectónica.

INTRODUCTION

In the 'Mediterranean type' of the Triassic Iberian basin, the evaporite units of the middle Muschelkalk and the Keuper facies are very similar, and difficulties arise to distinguish them when the stratigraphic successions have been affected by tectonism or diapirism. Difficulties also appear to differentiate be-tween the two carbonate Muschelkalk units in disrupted outcrops. In the eastern Iberian Chain, confu-sions concerning the middle Muschelkalk and the Keuper facies were documented by Boulouard and Viallard (1981) in the Serranía de Cuenca, and by Doubinger et al. (1990) in the Cuenca-to-Manzanera area. Regarding the carbonate Muschelkalk units, stratigraphic assignments of the units (López-Gómez et al., 1992) followed by re-assignments are recorded (Escudero-Mozo et al., 2015).

This paper provides new information on the Middle-Upper Triassic successions in specific areas of the eastern Iberian Chain, i.e. the Alt Palància (Castelló de la Plana province) and the Manzanera (Teruel province) areas, where these stratigraphic controversies remain. The Triassic outcrops in these areas (Fig. 1) were mapped at 1:10,000 scale and geological cross-sections were constructed. Twenty stratigraphic sections of the Middle-Upper Triassic succession were studied, whose results are summarized in Fig. 2. Samples were taken for petrographic studies, palynological dating, and isotopic determination of sulfates. The results concerning the Alt Palància area were taken from Ortí et al. (2020). A summary of new results obtained by us in the Manzanera area (Benedicto et al., in prep.) are included in this paper.

CARTOGRAPHIC RESULTS

In the Alt Palància area, the major Espina-Espadà Fault separates a southwestern Triassic domain char-acterized by block faulting (Andilla-Bejís, Almarja, Torás, and Caudiel outcrops) from a northeastern one (Montán outcrop) characterized by thrusting and folding. In a large portion of the southern domain (Almarja and Torás outcrops, and a large portion of the Andilla-Bejís outcrop) the Middle-Upper Triassic succession is found variably eroded, and angular unconformities occur between the Triassic rocks and the overlying Mesozoic rocks (Jurassic carbonates of different ages, or siliciclastics of the Lower Cretaceous). In the Caudiel outcrop and also in the Montán outcrop, only an unconformable contact between the Imón Fm. and the Lower Jurassic carbonates (Cortes de Tajuña Fm.) is observed. In the Manzanera area, a unique, antiformal Triassic outcrop is present. The nucleus of this structure, however, is characterized by intense thrusting and folding. Here again, the Middle-Upper Triassic succession is unconformably covered by the Cortes de Tajuña Fm., and the Imón Fm. is found variably eroded. Locally,

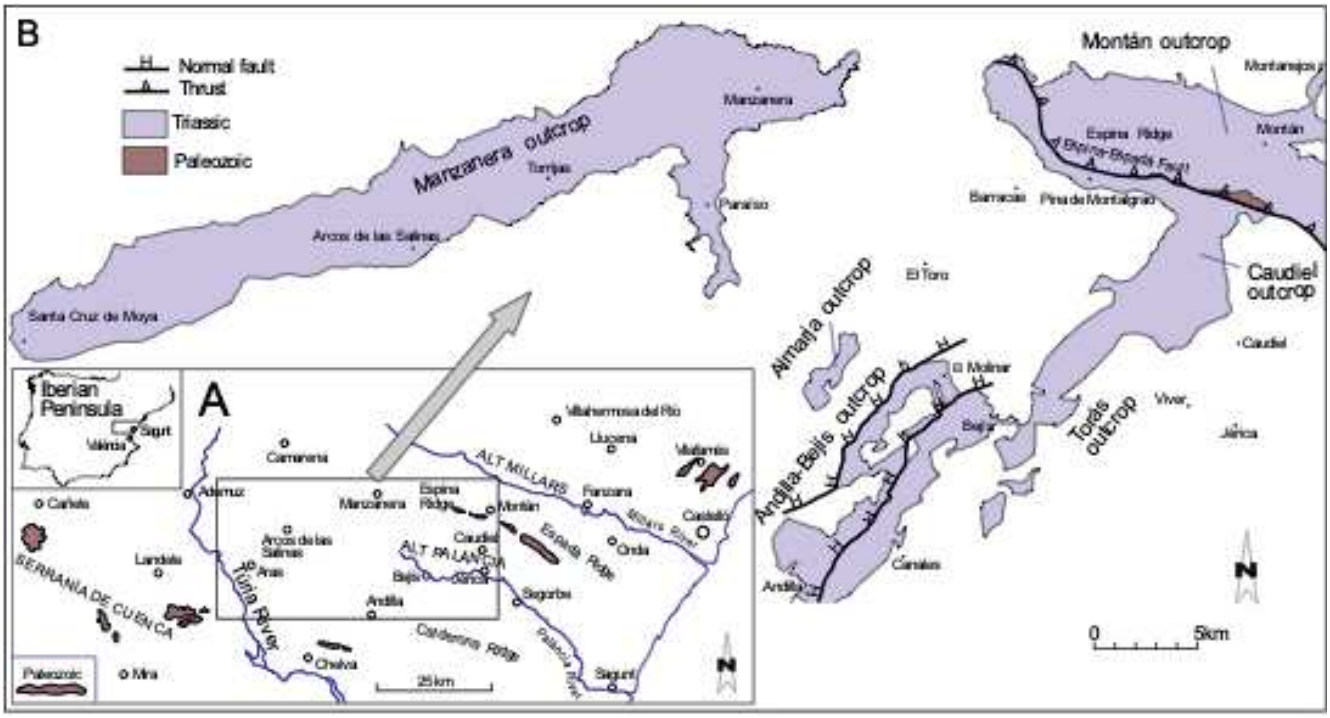

FIGURE 1. (A) Location map of the study area. (B) Map of the Triassic outcrops studied.

also Lower Cretaceous materials rest unconformably onto the Triassic materials.

STRATIGRAPHIC RESULTS

Virgili et al. (1977), Sopeña et al. (1983) and López-Gómez et al. (1998) assigned the Triassic rocks in the València sector of the eastern Iberian Chain to the 'Mediterranean type' of Triassic, in which the presence of two carbonate Muschelkalk units separated by a siliciclastic-evaporitic unit is recorded. In this sector, however, the lithostratigraphic terminology for the Middle Triassic succession is not consistent. Initially, López-Gómez and Arche (1992) used the terms Landete Fm. (lower Muschelkalk), Mas Fm. (middle Muschelkalk), and Cañete Fm. (upper Muschelkalk). Later, the terms Oronet Fm. (lower Muschelkalk), Azúebar Fm. (middle Muschelkalk), and Cirat Fm. and Pina de Montalgrao Fm. (upper Muschelkalk) were introduced by Garay Martín (2001, 2005) in the Calderona and Espadà ridges, which are adjacent to the Alt Palància area. To avoid this terminological duality, here we use the classic terms 'lower Mus-chelkalk unit', 'middle Muschelkalk unit', and 'upper Muschelkalk unit' for the Landete Fm., the Mas Fm., and the Cañete Fm. of López-Gómez and Arche (1992), respectively.

In the Alt Palància area, the Middle-Upper Triassic succession comprises the following units from base to top (Ortí and Guimerà, 2015): Röt evaporites (uppermost Buntsandstein facies), lower Muschelkalk carbonates, middle Muschelkalk evaporites, upper Muschelkalk carbonates, Keuper evaporites, Imón Fm., and Canales Claystone unit (only in the Andilla-Bejís outcrop). The same succession, excluding the Canales unit, is present in the Manzanera Triassic outcrop.

As regards the carbonate Muschelkalk units, three types of sub-units were distinguished in both the Alt Palància and Manzanera areas: lower carbonate-marl alternation, (intermediate) carbonate sub-unit, and upper carbonate-marl alternation. The carbonate sub-unit is present in all the section of the two study areas, but regarding the carbonate-marl alternations, some precisions should be highlighted (Fig. 2). In the Alt Palància area: the lower alternation of the lower Muschelkalk was found in all the outcrops; the upper alternation of the lower Muschelkalk was observed only in the Caudiel outcrop; the lower alternation of the upper Muschelkalk was observed only in the Montán outcrop; and the upper alternation of the upper Muschelkalk was present in all the outcrops. In the Manzanera outcrop: the lower alternation of the lower Muschelkalk does not crops out; ii) the upper alternation of the lower Muschelkalk is present in the Parai-so Bajo section; and both the lower and the upper alternations of the upper Muschelkalk are present in several sections. The local absence of these alternations in some sections is a structural feature.

In the Alt Palància area, the thickness of the units are as follows (Fig. 2). Only small variations (20-25 m) were observed in the Röt unit in all the outcrops. The thickness variation of the lower Muschelkalk unit (70-115 m) is of great paleogeographic relevance given that it has remained uneroded in all the outcrops. The original thickness of the middle Muschelkalk unit is difficult to estimate due to the tectonic migration of its plastic materials. Minimum

values of 80 m were estimated in the Andilla-Bejís outcrop, and 100-200 m in the Montán outcrop. The thickness variation of the upper Muschelkalk unit is also difficult to estimate because of local erosion, but a thickness up to 190 m was estimated in the composite section of the Montán outcrop. The original thickness of the Keuper unit probably varies between 50 and 100 m. The thickness variation of the Imón Fm. (15-40 m) suggests partial erosion below the Jurassic-Cretaceous cover. Its maximum thickness is found in the Montán outcrop (Pina de Montalgrao village). The Canales Claystone unit has a thickness of about 40 m near the Canales village (Andilla-Bejís outcrop). As a whole, the thickest succession is exposed in the Montán outcrop (about 290 m accumulated for the two Muschelkalk carbonate units, and more than 300 m for the assemblage of the Keuper and the middle Muschelkalk units) indicating a synsedimentary control of the Espina-Espadà Fault. Values similar to these in the Montán outcrop were also found in the Manzanera outcrop (Fig. 2).

PALYNOLOGICAL RESULTS

Palynological analyses of clayey, marly and carbonatic lithologies were done. Most of the samples were taken in

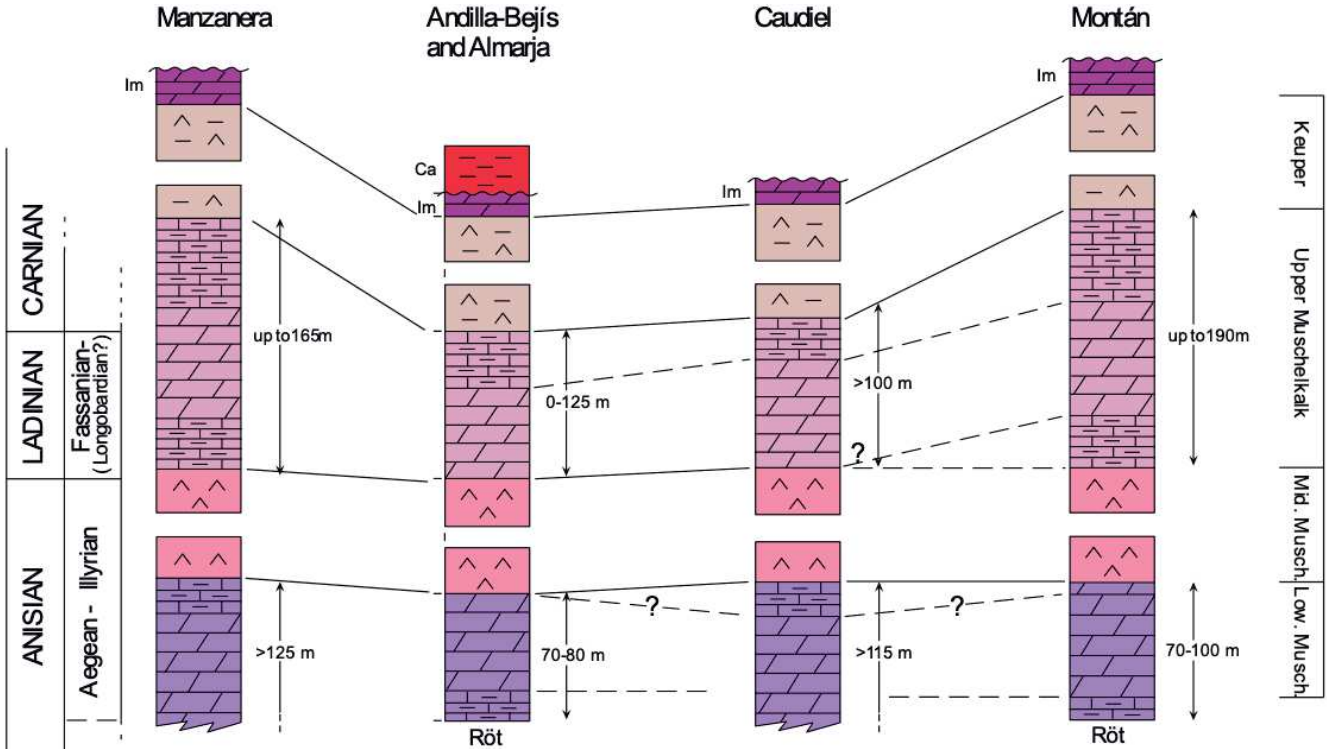

FIGURE 2. Compilation of representative stratigraphic sections of the Middle-Upper Triassic exposed in the Manzanera and Alt Palància outcrops. For location see Fig. 1. Im: Imón Formation. Ca: Canales Claystone unit.

the lower and upper carbonate-marl alternations of the two carbonate Muschelkalk units. In the Alt Palància area, 49 samples were collected and from them 32 were productive. The results can be found in Ortí et al. (2020). In the Manzanera outcrop, 24 samples were collected and from them 13 were pro-ductive. In the two cases, the palynological determinations were done by A. Götz (School of Earth and Environmental Sciences, Portsmouth University, U.K.). The assemblage of the results indicates that the ages of the units and sub-units are as follows: the Röt unit is Anisian; in the lower Muschelkalk unit, the lower carbonate-marl alternation is Anisian or early Anisian (Aegean/Bithynian) and the upper alterna-tion is Anisian (Bithynian-Pelsonian); the middle Muschelkalk is Anisian (mainly Illyrian); in the upper Muschelkalk unit, the samples of the lower carbonate-marl alternation are Ladinian (undetermined), although all the samples of the upper alternation are early Ladinian (Fassanian). The presence of Longo-bardian (late Ladinian) could not be proved palynologically.

ISOTOPIC RESULTS

Sulfur and oxygen isotopes (δ34SV-CDT and δ18OV-SMOW) of gypsum samples were analyzed. In the Alt Palància area 22 samples were studied, and for comparative purposes also 22 samples coming from other adjacent Triassic outcrops (Segorbe, Villahermosa del Río, Fanzara, Chelva) were analyzed (Ortí et al. (2020). For the present paper, 30 additional gypsum samples coming from the Manzanera outcrop were studied. In the assemblage of results, the δ34SV-CDT values revealed fundamental for distinguishing be-tween the middle Muschelkalk and the Keuper evaporites. In the Alt Palància area, the gypsum samples of the middle Muschelkalk unit yielded δ34S values ranging from 15.6 to 17.8‰ with a mean of 16.4‰

(δ18O values 12.8-18.0‰), and those of the Keuper unit from 14.0 to 15.5‰ with a mean of 14.4‰ (δ18O values 11.5-16.4‰). In the other Triassic outcrops, the assemblage of samples of the middle Muschelkalk unit yielded δ34S values ranging from 15.7 to 16.7‰, and those of the Keuper unit from 13.3 to 15.6‰ (Ortí et al., 2020). In the additional samples studied for the present paper in the Manzanera outcrop, the samples of the middle Muschelkalk unit yielded δ34S values ranging from 15.7 to 17.4‰ with a mean of 16.4‰ (δ18O values 15.7-17.4‰), and those of the Keuper unit from 13.8 to 15.5‰ with a mean of 14.4‰. (δ18O values 12.3-17.9‰). According to all these results, δ34S values of 15.7‰ or higher correspond to the middle Muschelkalk unit and values of 15.5‰ or lower correspond to the Keuper unit. Some δ34S values of 15.6‰ were found indistinctly in the two units.

CONCLUSIONS

The stratigraphic and isotopic results indicate that the Alt Palància and adjacent Triassic areas (Espadà Ridge, Millars Valley, Villahermosa del Río) belong to the Mediterranean Triassic. All these areas cannot be assigned to the Levantine-Balearic Triassic of Escudero-Mozo et al. (2015).

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REFERENCIAS

Boulouard, Ch., Viallard, P., 1981. *Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine*, 5, 1, 31-42.

Doubinger, J., López-Gómez, J., Arche, A., 1990. *Review Palaeobotany Palynology,* 66, 25-45.

Escudero-Mozo, M.J., Márquez-Aliaga, A., Goy, A., Martín-Chivelet, J., López-Gómez, J., Márquez, L., Arche, A., Plasencia, P., Pla, C., Sánchez-Fernández, D., 2015. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 417, 236-260.

Garay Martín, P., 2001. Ph.D. Thesis, Universitat de València, 692 pp. Microfiche edition.

Garay Martín, P., 2005. *Geo-Temas*, 8, 159-162.

López-Gómez, J., Arche, A., 1992. *Estudios Geológicos*, 48, 123-143.

López-Gómez, J., Arche, A., Calvet, F., Goy, A., 1998. *Zentralblatt für Geologie und Paläontologie*, 1 (9-10), 1033-1084. Stuttgart.

Ortí, F., Guimerà, J., 2015. *Teófilo Sanfeliu Montolio, más allá de la geología.* Libro homenaje. Publicacions de la Universitat Jaume I, Homenatges 2015 (4), 109-112. Castelló de la Plana.

Ortí, F., Guimerà, J., Götz, A., 2020. *Geologica Acta,* 18.4, 1-26. doi: 10.1344/GeologicaActa2020.18.4.

Sopeña, A., Virgili, C., Arche, A., Ramos, A., Hernando, S., 1983. In: Comba, J. (ed.). Madrid, Instituto Geologico y Minero de España (IGME), *Geología de España*, 2, 47-64.

Virgili, C., Sopeña, A., Ramos, A., Hernando, S., 1977. *Cuadernos Geología*, 4, 57-88.