ELSEVIER

Sedimentary Geology 133 (2000) 175–184

Sedimentary Geology

www.elsevier.nl/locate/sedgeo

Discussion

Late Miocene Mediterranean desiccation: topography and significance of the 'Salinity Crisis' erosion surface on-land in southeast Spain: Reply

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Received 2 February 2000; accepted 21 February 2000

1. Introduction

We welcome this opportunity to amplify the results of our studies of the Late Miocene Messinian sequence in the Sorbas Basin of southeast Spain. The Salinity Crisis concept has captured geological imagination and found its way into textbooks, but scrutiny reveals its details to be disturbingly elusive. Our approach has been to read the history of this important episode in Neogene history in well-exposed on-land sections at Sorbas, Almería, near the western end of the Mediterranean. The Salinity Crisis concept, as it was first proposed (Hsü et al., 1973, 1977) and has largely survived (Cita, 1991), is of deep-desiccation and reflooding of the Mediterranean near the close of the Miocene. Marine downdraw resulted in marginal erosion; evaporites accumulated in depressions; and final marine reflooding completed the cycle. Our rationale is that if these principal tenets of the concept are correct, then one or more of their effects should be recorded throughout the region, both on the deep Mediterranean floor and in marginal basins that were contemporaneously connected to the Mediterranean, including the Sorbas Basin. This emphasis on the widespread effects of the Salinity Crisis does not exclude the possibility that they were overprinted by local conditions, which probably differed considerably over a region as extensive and diverse as the Mediterranean basins. Indeed, we have interpreted the evaporites of the Sorbas Basin to be local products of basin barring, related to the Salinity Crisis but not coeval with deep Mediterranean evaporites. At the same time, we have taken the view that the regional result of the Salinity Crisis in all marginal basins should be an erosion surface on the scale of the massive sea-level fall implied by the concept. It is our recognition of this erosion surface in the Sorbas Basin that has drawn most criticism from Fortuin et al. (2000). Here we provide further details of critical localities so that our observations can be accurately assessed.

2. Sorbas Basin

We identified a major late Messinian erosion surface in the Sorbas Basin, and suggested that it represents Mediterranean evaporative drawdown (Riding et al., 1998, 1999). This surface incises underlying rocks that include the basin-margin Fringing Reef Unit and the laterally equivalent upper part of the basin-centre Abad Marls. Locally it also cuts the Bioherm Unit, which underlies the Fringing Reef Unit and is also laterally equivalent to part of the Abad

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PII: S0037-0738(00)00039-7

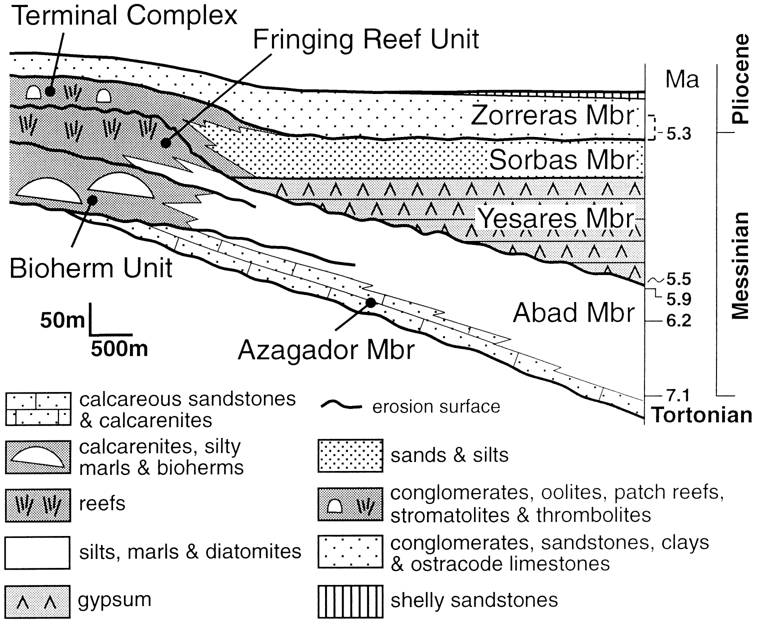

Fig. 1. Messinian–Pliocene stratigraphy of the Sorbas Basin, Almería, showing the erosion surface below the Terminal Complex and Yesares Member which we suggest represents “Salinity Crisis” sea-level fall (after Riding et al., 1999). Fortuin et al. infer a late Abad sea-level fall of about 100 m affecting the Fringing Reef. We agree that Braga and Martín (1996) recognized a 100 m sea-level fall in the Fringing Reef Unit. However, this predated the larger sub-Yesares sea-level fall and did not conclude the Fringing Reef development. Following the 100 m fall, the Fringing Reef prograded in response to renewed sea-level rise, but was then abruptly interrupted in an ascending phase (Braga and Martín, 1996). The Fringing Reef Unit does not, therefore, descend step-by-step in its final stages, as suggested by the stratigraphic scheme in Fortuin et al., 2000 (their Fig. 1). Note that the lower part of the Abad Marls are the lateral equivalent of the Azagador Member (Riding et al., 1991; Martín and Braga, 1994), and not of the Azagador Member plus the Bioherm Unit as depicted by Fortuin et al. (Fig. 1 “current interpretation”). In fact, the coiling change of *Neogloboquadrina acostaensis* (dated at 6.2 Ma, Berggren et al., 1995) occurs within the Bioherm Unit (Braga and Martín, 1996).

Marls (Fig. 1). The surface had a minimum original relief of 240 m, and we estimated its age to be between 5.9 and ~5.5 Ma (the Messinian stage is dated 7.1–5.3 Ma, Berggren et al., 1995). The amount of erosion recorded by this surface far exceeds that observed at any other break in the Sorbas Messinian sequence, and we therefore concluded that it represents the Mediterranean Salinity Crisis erosion surface. We suggested that when seawater reflooded the area the Sorbas Basin was connected by a sill to the adjacent Mediterranean. This local effect temporarily led to barred-basin conditions, and as a result the first reflooding sediments in the basin were evaporites of the Yesares gypsum Member. However, conditions soon became normal marine, and marls, sands and limestones of the Sorbas Member, and laterally equivalent Terminal Complex, formed before the close of the Messinian.

The significance of our recognition of this erosion surface is not only that it identifies and dates Salinity Crisis erosion on-land, but also that it provides concrete evidence for marked sea-level fall. This supports the central tenet of the Salinity Crisis hypothesis—evaporative drawdown. This is a significant observation because, of the many remaining questions concerning the Salinity Crisis, one of them is still—surprisingly—whether the Mediterranean really desiccated and, if so, by how much.

Fortuin et al. (2000) make four principal comments: (i) the surface that we recognize below the Yesares gypsum is not erosional; (ii) the Sorbas Member overlying the Yesares gypsum was deposited under conditions of raised salinity, not near-normal marine salinity as we deduced; (iii) the most likely horizon representing the Salinity Crisis erosion surface in the Sorbas sequence occurs higher in the Messinian,

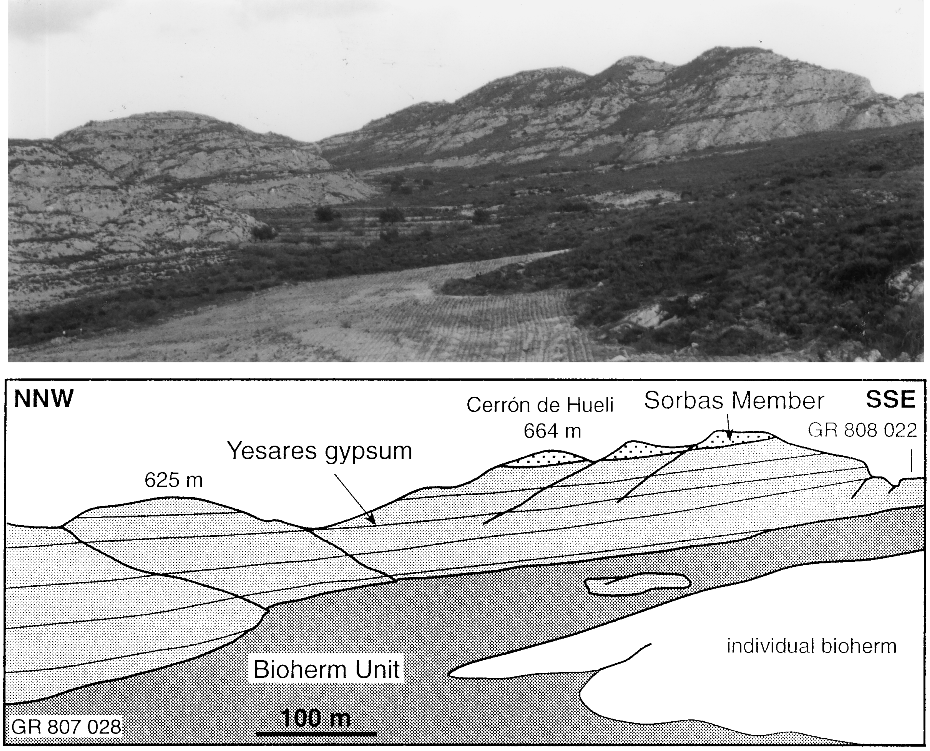

Fig. 2. Panoramic view of Cerrón de Hueli from the west (section B–B′ in Fig. 4), showing the erosional contact between the Yesares gypsum and the underlying Bioherm Unit. Bedding, clearly represented by pelite–gypsum alternations, indicates southerly onlap of the Yesares gypsum over the Bioherm Unit. Grid references refer to Sheet 24-42, Mapa Militar España, 1:50.000.

below the non-marine Zorreras Member; and (iv) our Sorbas interpretation has implications that conflict with wider regional cyclostratigraphic correlations (Krijgsman et al., 1999, 2000) and are therefore unlikely to be correct.

2.1. Base of the Yesares gypsum

The starting point for our reconstruction of Salinity Crisis events in the Sorbas Basin is recognition of the erosional nature of the sub-Yesares gypsum surface. Fortuin et al., (2000) dispute this on the grounds that: (a) the erosion surface cannot be traced from basin margin to basin centre; (b) in the Hueli area the contact between the Yesares gypsum and the underlying Abad Marls and Bioherm Unit is complicated by dissolution effects; (c) the number of cycles in the Abad Marls below the gypsum appears to be constant at basin centre locations; (d) erosional features below the gypsum, for example near El Tesoro, can be better explained by local faulting and mass wasting effects; (e) at Los Yesos, west of Sorbas, the Yesares–Abad contact appears conformable; (f) the erosion surface above the Fringing Reef Unit is due to interregional sea-level fall “in the order of 100m”.

(a) *Tracing the erosion surface.* The erosive contact of the top of the Fringing Reef Unit can be traced into the sub-Yesares surface at Hueli (from GR 799 020 to GR 815 021, Sheet 24-42, Mapa Militar España, 1:50.000) and at the eastern end of Cerro Cantera (from GR 652 033 to GR 652 034, Sheet 23-42, Mapa Militar España, 1:50.000). This supports our conclusion that the sub-Terminal Complex erosional surface is traceable into, and laterally equivalent to, the sub-Yesares surface (see Riding et al., 1999, Fig. 2).

(b) *Hueli area.* Slumping locally complicates the contact between the Yesares gypsum and underlying units (Riding et al., 1999, p. 6). This does not, however, account for the erosive downcutting at the

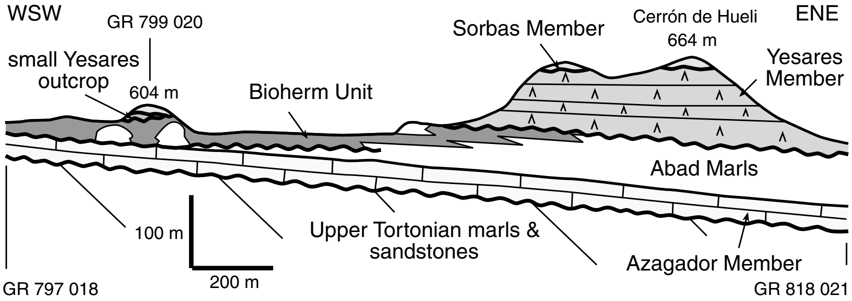

Fig. 3. Stratigraphy at Cuesta Encantada near Hueli, 5 km SE of Sorbas town, viewed from the south (section A–A′ in Fig. 4). Westward, the upper Abad Marls pass laterally into the Bioherm Unit, which erosively cuts part of the lower Abad Marls. The Yesares gypsum unconformably overlies both the Abad Marls and the Bioherm Unit. Note the small outcrop of Yesares gypsum below the Sorbas Member and directly on top of the Bioherm Unit at GR 799 020. Symbols and lithologies as in Fig. 1. Grid References refer to Sheet 24-42, Mapa Militar España, 1:50.000.

base of this unit, traceable over distances of 6 km from, for example, Los Perales to Hueli. Our schematic illustration (Riding et al., 1999, Fig. 3) is generalized, but correct. This can be verified by tracing the base of the Yesares gypsum laterally and observing it cutting down through the Abad Marls to the Bioherm Unit. The Bioherm Unit is normally directly overlain by the Fringing Reef or by the Abad Marls, but locally—as at Hueli—the gypsum erosively overlies the Bioherm Unit. This can be seen in the small hill west of Cuesta Encantada (GR 799 020, Sheet 24-42, Mapa Militar España, 1:50.000) and is shown in the map of the area by Martín et al. (1997). It provides definitive evidence of sub-Yesares erosion.

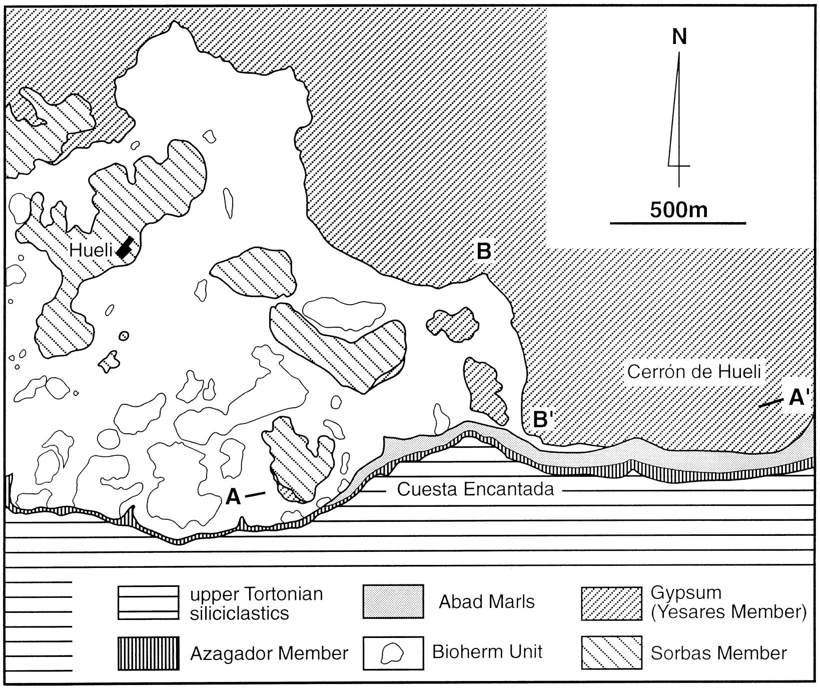

Fig. 4. Geological map of the Hueli area, 4 km SSE of Sorbas town. The Bioherm Unit and the Abad Marls are unconformably overlain by the Yesares gypsum Member. The WSW–ENE Cuesta Encantada section (A–A′) is shown in Fig. 3, and the NNW–SSE Cerrón de Hueli panorama (B–B′) in Fig. 2.

The onlap geometries in the basal part of the Yesares gypsum are clearly seen on the northwestern side of Cerrón de Hueli (GR 807 028–808 022, Sheet 24-42, Mapa Militar España, 1:50.000) (Fig. 2) demonstrating that the Yesares was deposited unconformably on underlying units.

(c) *Number of cycles.* Lateral changes in cycle numbers can be observed. For example, towards the northwest from Los Molinos del Río Aguas (from GR 827 055 to GR 824 058, Sheet 24-42, Mapa Militar España, 1:50.000) the number of cycles in the Abad Marls increases along the section due to angular unconformity between the Abad Marls (dipping 12°N310E) and the Yesares Member (the sub-Yesares erosion surface dips 9°N17E). To the southwest, progressive reduction of Abad cycles to zero as the Abad Marls are cut by the sub-Yesares erosion surface can be observed in the exposures at Cuesta Encantada (GR 797 018–818 021). The upper part of the Abad Marls passes laterally into the reefs and calcarenites of the Bioherm Unit, while at the same time, the base of Bioherm Unit erosively cuts into the Lower Abad Marls (Figs. 1 and 3). Overlying them, the sub-Yesares surface erodes both the Abad Marls and, at this location, the Bioherm Unit (Fig. 3). Only about 12 cycles remain in the eroded Abad Marls below the Yesares gypsum at the western end of Cerrón de Hueli. This is reduced to six cycles at the small col further west (GR 803 021). Continuing to the west, the Abad Marls disappear and the Yesares gypsum directly overlies the Bioherm Unit (GR 799 020) (Figs. 3 and 4). This lateral thinning and disappearance of the Abad Marls at Cuesta Encantada is shown in numerous geological maps of the area (Spanish Geological Survey, IGME, Sheet 24-42, Sorbas, 1973; Dronkert, 1977; Ott d'Estevou, 1980; Montenat, 1990; Martín et al., 1997) (Fig. 4).

(d) *Erosional features below the gypsum.* The irregular nature of the erosion surface is seen at its greatest on a basin-wide scale, with a vertical relief of at least 240 m between the basin centre and the basin margin (Riding et al., 1998). The maximum relief that we have observed at a single locality is 30 m at Molino del Río Aguas (Riding et al., 1999, Fig. 5). In contrast to what Fortuin et al. state, this exposure does show lateral pinching out of the lowermost gypsum horizon and onlap of the subsequent gypsum bed on the top surface of the marls. The fact that the gypsum–Abad contact is parallel at some individual localities does not negate the erosive nature of the contact between these essentially flat-lying units; the overall cross-cutting relationship is clear on a larger scale. With regard to El Tesoro, one of the areas that we used to illustrate the base of the gypsum (Riding et al., 1999, Fig. 6), the exposure we described and figured is 1 km northeast of El Tesoro (GR 840 062–843 066, Sheet 24-42, Mapa Militar España, 1:50.000) and supports our interpretation of the existence of original 10 m-scale gullies incised in the Abad Marls. However, Fortuin et al. (2000, Fig. 2) confuse this exposure with a location west of El Tesoro (GR 831 056) where faulting is evident. Incidentally, although they describe the faulting as reverse, they actually illustrate a normal fault.

(e) *Los Yesos.* As we note in (d), the Abad–Yesares gypsum contact can locally appear conformable, especially in small exposures such as Los Yesos. Two significant points to note at Los Yesos are: (i) there are only four gypsum cycles below the Sorbas Member (Goubert et al. 1999). This is to be expected due to the onlap architecture of the Yesares (fewer beds as the basin margin is approached); and (ii) beds within the Yesares Member, but between the gypsum horizons, contain marine fossils, including foraminifers, bivalves and echinoids (Goubert et al., 1999). This new information adds further support to the view that the later gypsum cycles developed in progressively more normal marine conditions (Riding et al., 1998, p. 8).

With regard to the onlap architecture, the Yesares gypsum was the first deposit to form when the sea reflooded the Sorbas Basin area following Mediterranean downdraw, and the basal units of the gypsum onlap the underlying eroded surface (Riding et al., 1998, p. 7). However, Fortuin et al. (2000) state: “onlap … implies a general transgressive trend, whereas the overall tendency of the Yesares is shallowing up”. Although it is difficult to ascertain, it is certainly possible that the Yesares gypsum shallows-up, but this does not mean that it did not also have an onlapping relationship. Onlap indicates net sea-level rise. Coincidence of onlap and shallowing of facies during relative sea-level rise is commonplace and depends on the relative sea-level rise and sedimentation rates (Curray, 1964).

(f) *Erosion above the Fringing Reef and sea-level fall.* We agree that a sea-level fall of ~100 m affected the Fringing Reef. This was documented by Braga and Martín (1996). However, this fall predated, and was less than, the sub-Yesares sea-level fall that reflects the Salinity Crisis. Subsequent to the 100 m sea-level fall, the Fringing Reef Unit recovered and continued to grow and its further progradation was finally abruptly interrupted in an ascending phase (Braga and Martín, 1996). The Fringing Reef Unit does not, therefore, descend step-by-step in its final stages, as suggested by Fortuin et al. (2000) (Fig. 1).

2.2. Sorbas Member

2.2.1. Yesares–Sorbas contact

The Yesares–Sorbas contact is conformable and gradational (Roep et al., 1979)—as seen at the Río Aguas section near Sorbas town. However, Fortuin et al. (2000) are overstating the case when they say that "all Sorbas Basin investigators agree" on this point. For example, Clauzon et al. (1996) place an erosion surface between these units. In our view, both Yesares and Sorbas units belong to the same sequence. They are conformable in the centre of the basin, but tectonic activity near the southern basin margin resulted in them locally being unconformable (Riding et al., 1999) (Figs. 2 and 3).

2.2.2. Sorbas Member salinity

Fortuin et al. state that many parts of the Sorbas Member were "deposited under raised salinities, as shown by the total lack of bioturbation in the laminitic basinal and lagoonal muds and the presence of halite pseudomorphs in the latter". Absence of bioturbation can be caused by a variety of environmental factors, such as dysaerobic/anoxic bottom conditions, and does not necessarily indicate increased salinity. The halite pseudomorphs referred to by Fortuin et al. (2000) occur in lagoonal muds together with birdfoot prints (Roep et al., 1979, 1998); in this very shallow marginal environment they cannot, therefore, be taken as representative of the general marine salinity in the basin. In contrast with the view of Fortuin et al. (2000) both micro- and macrofaunal assemblages indicate normal marine salinities for most, if not all, of the Sorbas Member. The raised salinities invoked by Fortuin et al. (2000) are required by their view that the Sorbas Member equates with Lower Evaporite deposition in the deep Mediterranean (see Section 3), the only sea to which the Sorbas Basin was connected. But this is inconsistent with the biotic evidence for near-normal marine salinities that can be found throughout the basin in the Sorbas Member and the laterally equivalent Terminal Complex. Fine-grained basin centre sediments contain marine ostracodes (Nachite, 1993), unreworked planktonic and benthic foraminifers (Riding et al., 1998; Sánchez-Almazo et al., 1999), and calcareous nannoplankton (Sánchez-Almazo et al., 1999). The foraminifer assemblage recorded in the Sorbas Member is widespread in Mediterranean post-evaporitic marine sediments (Iaccarino et al., 1999a,b). The coeval Terminal Complex contains *Porites* coral reefs (Dabrio et al., 1985; Dabrio and Polo, 1995; Roep et al., 1998) and marine bivalves, red algae, *Halimeda*, and echinoids (Martín et al., 1993).

2.3. Zorreras Member

We have provided specific locality evidence showing that the sub-Yesares surface is a major erosion and unconformity surface (Riding et al., 1998, 1999). Because they disagree with this, and because acceptance of our interpretation would result in "too many precession-controlled cycles", Fortuin et al. (2000) are forced to seek the Salinity Crisis erosion surface elsewhere in the Sorbas sequence. Apparently the only candidate is the sub-Zorreras surface, proposed by Roep et al. (1998). We have already outlined the problems with this interpretation (Riding et al., 1998, 1999). The change from coastal Sorbas sediments to fluviatile and lacustrine Zorreras facies is, as Fortuin et al. (2000) admit, only locally and weakly erosive and it is not incised (Montenat and Ott d'Estevou, 1977, p. 211). At the type-section 1.5 km northeast of Sorbas town the "Sorbas/Zorreras transition is abrupt but not erosional" (Krijgsman et al., 2000). It appears simply to reflect the progradation of the continental Zorreras deposits over the coastal Sorbas sediments (Riding et al., 1998, pp. 13–14).

2.3.1. Age

We did not state that the Zorreras Member is of Pliocene age. We wrote 'the Zorreras Member is generally believed to be Pliocene, but we cannot rule out a late Messinian age for its lower part. Definite Pliocene biotas have only been recorded from the marine upper Zorreras' (Riding et al., 1998, pp. 8–9). We also show this on our figure—that Fortuin et al. (2000) (Fig. 1) reproduce—by using a bracketed date for the lower part of the Zorreras (Riding et al., 1999, Fig. 2).

It is pertinent to note that Fortuin et al. (2000) assume that the continental sequence of the Zorreras is Messinian because it has reversed polarity and is overlain in the adjacent Níjar Basin by deposits of the *Globorotalia margaritae* Zone. Even so, a possible early Pliocene age for part of the continental deposits cannot be discounted because reversed polarity (Chron C3r) continues into the Pliocene for more than 0.1 Ma (Berggren et al., 1995), which is a time span similar to that obtained by Krijgsman et al. (2000) for the Zorreras continental deposits, based on the assumption that it includes eight precession cycles (see Section 2.4). The overlying marine Zorreras is currently dated as Early Pliocene in the Sorbas Basin, but with no further precision (Civis et al., 1977; Montenat and Ott d'Estevou, 1977). In the case of the Níjar Basin, if the overlying deposits belong to the *G. margaritae* Zone (MPL2) then they have an age younger than 5.1 Ma, and the implication would be that a substantial part of the continental Zorreras might be Pliocene.

2.4. Cyclostratigraphy

In the Sorbas sequence, cyclostratigraphy (Krijgsman et al., 1999, 2000) relies on recognition of cycles in four contrasting units: Abad Marls, Yesares gypsum, Sorbas Member (marine sands and marls), Zorreras Member (fluviatile and lacustrine deposits). There are several areas of uncertainty: (i) Upper Abad erosion (see (c), Section 2.1) casts doubt on correlations based on counting Abad cycles. (ii) The number of Yesares gypsum–pelite cycles in the Sorbas Basin is debatable: 12 cycles were recognized by Dronkert (1977), and 13 by Rosell et al. (1998). How confident, then, should Fortuin et al. (2000) be in recognizing 14 Yesares cycles? (iii) In the Sorbas Member, Krijgsman et al. (2000) admit they cannot confidently recognize precessional cycles; nonetheless, they count three of these. (iv) The non-marine Zorreras succession consists of fluviatile and lacustrine sands, silts and limestones. Krijgsman et al. (2000) recognize eight red silt (dry climate)–yellow sand (wet climate) cycles. Alternations of clay and sand in fluviatile systems can reflect channel migration, and thus be autocyclic in origin. How faithfully then do such sand–silt alternations and localized (1 m thick and ~3 km in extent) lake deposits in fluviatile systems reflect orbital precession? Despite these uncertainties, Fortuin et al. (2000) report a total of 25 precessional cycles: Yesares (14), Sorbas (3), Zorreras (8). Assuming an average periodicity for Neogene precession of 21.7 kyr, this gives a total of 542,500 years from which timings are calculated. The resulting ages and correlations that underpin the approach of Fortuin et al. (2000) to the Sorbas succession must be evaluated in the light of the uncertainties outlined above.

Incidentally, we did not suggest a tectonic "yo-yo" mechanism for the Yesares gypsum cycles. In our opinion, these cycles could be precession forced. What we did say is that they formed during generally rising sea level in a tectonically barred basin. It is possible, therefore that, in addition to climate, the gypsum–pelite cycles could reflect local tectonic effects on the fluctuating connections between the Sorbas Basin and the main Western Mediterranean.

In the case of the Abad Marls, in addition to problems caused by overlooking the erosional break below the Yesares gypsum, uncertainties arise in the correlations attempted with Sicily and Gavdos in Crete (Krijgsman et al., 1999). "Minor misfits" in cycle correlation appear rather to be the rule than the exception. Krijgsman et al. (1999, Fig. 1) reveals discrepancies in the number of laminites (sapropels and diatomites, assumed to correspond to insolation maxima) present in the different sections. For example, between Events 1 and 2 there are three laminites in Sorbas compared with six in Sicily; between Events 3 and 4, there are five laminites in Sorbas, but four in Crete and Sicily; between Events 7 and 8 there are 11 laminites in Sorbas, nine in Crete; between Events 8 and 9 there are two laminites in Sorbas, one in Crete. Furthermore, several of the "confirmed" biostratigraphic links, based on planktionic foraminiferal bioevents, are questionable. For example, location of Event 7 (sinistral/dextral coiling change in *Neoglobo-quadrina acostaensis*) has separately been described as "not easy to determine, because in some places there are several sinistral–dextral oscillations", (Sierro et al.,

1993) and the same is true of Events 8 and 9. Overall, 59 beds representing insolation maxima in Sorbas compare with 55 in Crete. This $4 \times 21.7\ \mathrm{Ka} = 0.087\ \mathrm{Ma}$ age discrepancy contrasts with the ± 0.02 Ma precision ascribed to the astrochronological age estimates (Krijgsman et al., 1999). These uncertainties suggest that the correlations proposed between Sorbas, Sicily and Crete are less than direct, straightforward and accurate.

3. The Yesares gypsum

Although our work has emphasized the succession of a single marginal Mediterranean Basin, its broad regional context cannot be overlooked. We have not equated the Yesares and Sorbas members with the Upper Evaporites of Sicily and the deep Mediterranean. We wrote that the Yesares evaporites 'post-date deep desiccation and represent evaporite silled basin conditions beside a refilled Mediterranean brimming with normal salinity seawater' (Riding et al., 1998, p. 12). To convey the significance of this clarification it is necessary to explain a key piece of Salinity Crisis lore. The lower halite and upper gypsum deposits reported below the deep Mediterranean floor have long been equated with the Lower and Upper Evaporites of central Sicily (Hsü et al., 1977) (although this has been opposed by Butler et al. (1995) who argued that these Sicilian evaporites do not represent uplifted Mediterranean floor). Fortuin et al., 2000, appear to adhere to the classic (Hsü et al., 1977) view that correlates Messinian evaporite units throughout the Mediterranean. We agree with the logic that Mediterranean deep-desiccation should have left its mark at widely separated locations throughout the region. Indeed, we expect that the erosion surface resulting from downdraw should be the key regional indicator of this remarkable event. But this does not also imply that all Mediterranean evaporites would have formed at exactly the same time, and we have specifically argued against the view that evaporites in marginal basins should be contemporaneous with those of the deep ocean floor (see Riding et al., 1998, pp. 4–6, Fig. 6). According to Fortuin et al., 2000, the Yesares gypsum of the Sorbas Basin must be equated with either the Lower or Upper Evaporite unit of the deep Mediterranean (in fact they link it with the Lower Evaporite: Fortuin et al., 2000, Fig. 1). In contrast, we consider it most likely that the Yesares gypsum corresponds neither with the Lower nor with the Upper Evaporite of the deep Mediterranean, and that it post-dates both of them. However, if the interpretation of Butler et al. (1995) that the Sicilian sequence does not represent deep Mediterranean floor deposits is correct, then it could be that the Yesares gypsum corresponds with the Upper Evaporite of Sicily, but this would not support the view of Fortuin et al. (2000).

4. Conclusions

The Sorbas succession records: (a) intense erosion consistent with substantial marine drawdown (sub-Yesares gypsum surface), (b) marine reflooding and evaporite deposition (Yesares gypsum) passing conformably up into near-normal marine Messinian sediments (Sorbas Member and Terminal Complex), followed by (c) abrupt transition to (d) non-marine conditions (Zorreras Member). We have no doubt that the cyclostratigraphic and other field observations of the Sorbas Messinian succession will, ultimately, be mutually consistent and complementary; but this is not yet the case, as this comment and reply demonstrate.

Field evidence does indicate major erosion below the Yesares Member, and we provide map coordinates of key exposures that demonstrate this. These allow our statements concerning the erosional base of the Yesares gypsum Member to be readily checked in the field. The Sorbas Member, and laterally equivalent Terminal Complex, contain planktonic and benthic fossils, including echinoids and coral reefs, that demonstrate near-normal marine conditions. The sub-Zorreras surface, which is generally agreed (including by Fortuin et al., (2000)) to be only locally and weakly erosive, is unlikely to reflect sea-level fall on the scale of Mediterranean desiccation. Finally, the regional correlations advocated by Fortuin et al. (2000) are based on cycles whose recognition in the Sorbas sequences is questionable. Future cyclostratigraphic work needs, in particular, to take account of the removal of Abad Marl cycles by sub-Yesares erosion and the difficulty of cycle recognition in the disparate units of the Yesares–Sorbas–Zorreras sequence.

Acknowledgements

Isabel Sánchez-Almazo kindly allowed us to quote unpublished data on Sorbas nannofossils. We thank A.R. Fortuin, F.G. Hilgen and W. Krijgsman for generously providing pre-prints of papers in press. This research was supported by an Acciones Integradas award from the British Council and Ministerio de Educación y Ciencia, and by Fundación Ramón Areces project "Cambios climáticos en el sur de España durante el Neógeno" to J.C.B. and J.M.M.

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