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Discussion of the paper by Godet et al. 2011, entitled "Reconciling strontium-isotope and K–Ar ages with biostratigraphy: the case of the Urgonian platform, Early Cretaceous of the Jura Mountains, Western Switzerland" (Swiss Journal of Geosciences, 104, 147–160)

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1 Introduction

For decades, the age of the Urgonian deposits, in Switzerland and in the southeast of France in particular, has been addressed and disputed in several articles, by authors belonging to two opposing groups of researchers. For Arnaud-Vanneau and Arnaud (1990) and a number of other workers (e.g. Adatte et al. 2005; Godet et al. 2010, 2011, 2012, and references therein), the Urgonian deposits found in the Canton Vaud, in the western part of the Swiss Jura, and the lower member of the Urgonian limestones, in the French Subalpine Chains, are Late Barremian in age. These authors rely on a certain approach to sequence stratigraphy, combined with chemostratigraphical and geochronological data and selected palaeontological data (rejecting or neglecting some fossil groups that might support alternative interpretations). For instance, Godet et al. (2012) state that "The orbitolinid biostratigraphy fide Conrad et al. (2012) is questionable". This is in contrast to Clavel et al. (1987) and a number of other researchers, such as the present authors (see Clavel et al. 2007; Conrad et al. 2012 and references therein) who maintain that foraminifers provide reliable biostratigraphical information, particularly in depositional environments where the classical markers such as ammonites, planktonic foraminifers, and nannofossils are lacking. In our stratigraphical interpretation, all Urgonian deposits are Late Hauterivian in age in the western Swiss Jura, whereas in the French Subalpine Chains the lower member of the Urgonian limestones dates from the Late Hauterivian, the Early Barremian or the Late Barremian, depending on its paleogeographic location (Clavel et al. 2012). This interpretation relies on a wider set of palaeontological data and different approach to sequence stratigraphy. However, according to Godet et al. (2012), "The sequence-stratigraphic interpretation forwarded by Conrad et al. (2012) is not consistent with modern sequence-stratigraphic interpretation of platform carbonates". Since we understand from this statement that there will be no agreement on the best practice in sequence stratigraphy, we will not discuss the topic further. We focus here of the western Swiss Jura and on the difference in age between the interpretation of the first group (represented by the paper by Godet et al. 2011) and our interpretation. The difference between these two interpretations is significant, because it covers a full stage, with implications that go far beyond the study area, referring to the whole of the northwestern Tethyan domain. In particular it is whether,

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globally, the onset of the rudist limestone (Urgonian limestones sensu stricto) is not older than the Late Barremian or conversely takes already place in the Late Hauterivian, subsequently in the Early Barremian.

Recently, while defending their views on the ages ascribed to one of their key Urgonian sections, Godet et al. (2012) referred to the contents of the paper which is the focus of the present discussion stating that "New $^{87}Sr/^{86}Sr$ age data obtained on rhynchonellid brachiopods and K/Ar data on selected glauconite grains corroborate a Late Barremian age for the onset of the Urgonian in the Swiss Jura Mountains". Hence, in addition to a discussion of the biostratigraphical data and its interpretation (Sect. 2 below), we will also review these points (Sr-isotope data in Sect. 3 and K/Ar data on glauconite in Sect. 4) and show that there is no difficulty in reconciling their geochronological data with our interpretation of the biostratigraphy of the western Swiss Jura.

2 Interpretation of biostratigraphical data

Godet et al. (2011) provide a schematic representation of the Late Valanginian to Late Barremian deposits in the western Swiss Jura (op. cit. Fig. 1). A simplified version of the lithostratigraphical column from this figure, with the erosional profile, is shown to the left in our Fig. 1. On the right-hand side of their figure, they list "fossils of biostratigraphical importance" establishing or confirming the Late Barremian age of the "Urgonien Jaune" (UJ) and the "Urgonien Blanc" (UB) in the Swiss Jura, based on the work of Remane et al. (1989), Blanc-Alétru (1995) and Godet (2006). On our Fig. 1, their biostratigraphical interpretation is shown in colour, alongside the lithostratigraphical column, for ease of comparison. The remaining part of our Fig. 1, on the right-hand side, shows the stratigraphic ranges of nine fossil groups and our overall conclusion with regard to the biostratigraphy of the western Swiss Jura. The basis of our interpretation, and the reasons why we disagree with the interpretation of Godet et al. (2011), are outlined below, firstly with regard to ammonites, and then with regard to other fossil groups.

2.1 Ammonites

Because there is no consensus on the biostratigraphical use of several fossil groups, and also because there is no agreement on the significance of the nannofossil assemblage found in the UJ, the sole biostratigraphical constraints which we share with Godet et al. (2011) are the ammonite finds.

According to Godet et al. (2011), the Lower–Upper Hauterivian boundary is located in the "Marnes d'Uttins"

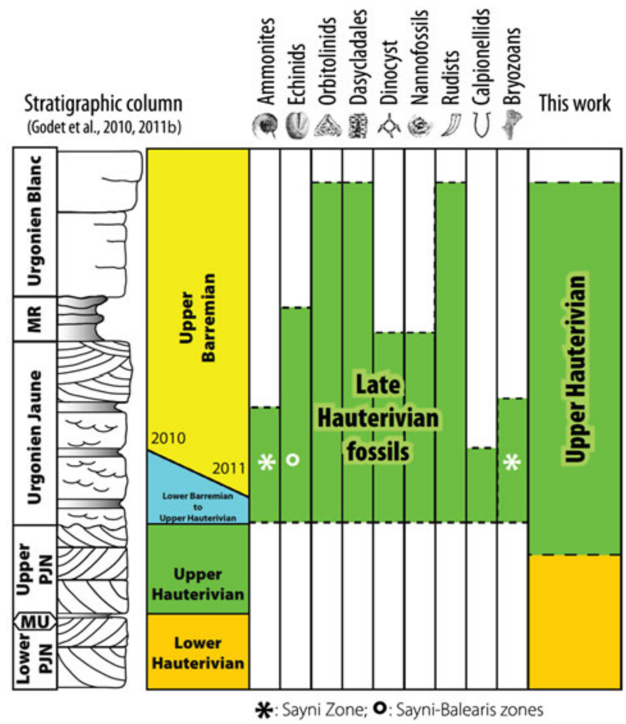

Fig. 1 Palaeontological dating of the "Pierre Jaune de Neuchâtel" and Urgonian limestones ("Urgonien Jaune" and "Urgonien Blanc") in the Swiss and French Jura. The column to the *left* with the formation names and erosional profile is after Godet et al. (2010, 2011) the *adjacent column* shows the biostratigraphical interpretation of Godet et al. (2011). The column on the *extreme right* shows our biostratigraphical interpretation, based on the nine fossil groups shown in between. All the fossils above the "Marnes d'Uttins" are Late Hauterivian or younger in age, including all long-ranging taxa, the last occurrence of which is Hauterivian. The palaeontological data base is as follows: ammonites (Mouty 1966; Busnardo and Thieuloy in Remane et al. 1989; Clavel et al. 2007); echinids (Clavel in Remane et al. 1989); orbitolinids (Clavel et al. 1987, 2007, 2010 and references therein); dasycladalean algae (Conrad and Masse in Remane et al. 1989; Clavel et al. 2007, 2010 and references therein); dinocysts (R. Jan du Chêne in Clavel et al. 2007; P. Hochuli in Godet 2006); nannofossils (S. Gardin and E. Erba in Godet 2006); rudists (Masse 1976, 1995; Masse et al. 1998, in Remane et al. 1989, 1998); calpionellids (Granier et al. 1995); bryozoans (Walter 1993)

(MU) member (Fig. 1), i.e. the small medial subunit of the "Pierre Jaune de Neuchâtel" (PJN) formation, which helps divide the latter into a Lower PJN and an Upper PJN. From the MU, Godet et al. (2011, Fig. 1) report the occurrence of *Lyticoceras nodosoplicatum* and of *Acanthodiscus subhystricoides* (actually another representative of *Lyticoceras*). It is worth mentioning that a specimen of *Lyticoceras claveli* was collected at Mont de Musièges (southern Jura collection B.C. Faculty of Sciences, University of Lyon, FSL No. 108129) in the upper part of the PJN (Busnardo and Thieuloy in Remane et al. 1989). Because the genus *Lyticoceras* is strictly limited to the Nodosoplicatum Zone (Thieuloy et al. 1983; Busnardo and Thieuloy in Remane et al. 1989; Bulot 1995), the

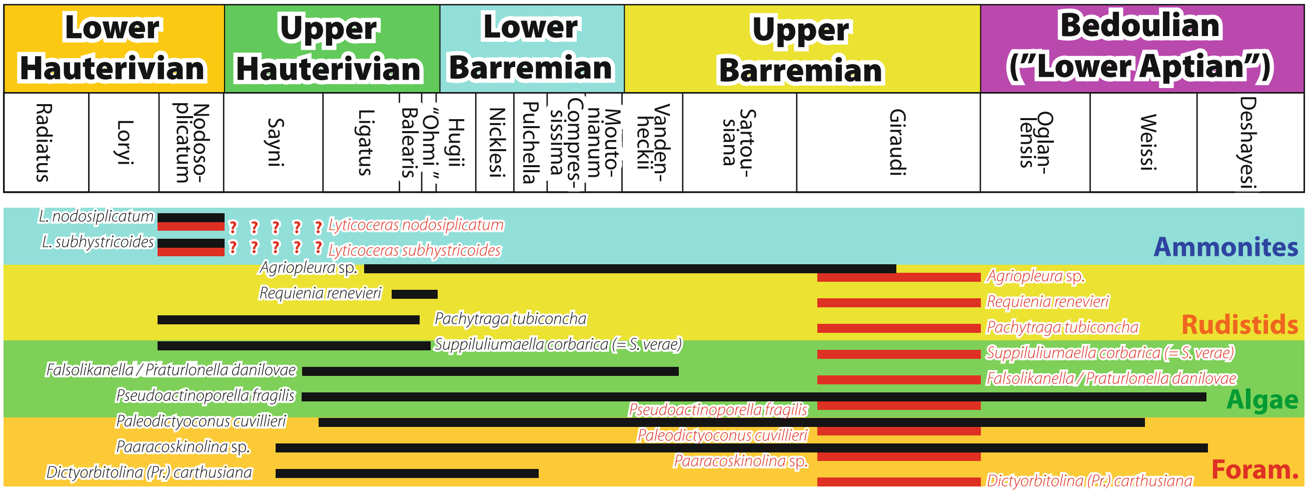

Fig. 2 Established ammonite zonation for the Hauterivian, Barremian and "Lower Aptian". Stratigraphic ranges of the "Fossils of biostratigraphical importance" according to Godet et al. (2011, Fig. 1) are coloured in *red*; the ranges documented in the literature cited in Fig. 1 are shown in *black*. The original list is supplemented by *Pachytraga tubiconcha* (UB) and *Dissocladella hauteriviana* (UB), not cited by Godet et al. (2011), but by Blanc-Alétru (1995)

Lower–Upper Hauterivian boundary must therefore be located above the MU in the upper part of the PJN, not within MU itself (Fig. 1).

Few ammonites have been found higher, in younger stratigraphic units. In the French Southern Jura, in lateral equivalents of the Swiss UJ, i.e. above the PJN and below the rudist-bearing UB, there are records of:

- *Cruasiceras cruasense* (FSL 89951): at Col de l'Épine (Savoy, det. Busnardo in Guyomard 2002)
- cf. *Cruasiceras cruasense* and *Crioceratites* cf. *nolani*: at Mont Clergeon (la Chambotte, Savoy, det. Busnardo in Clavel and Charollais in Remane et al. 1989)
- *Lyticoceras* sp. (FSL 89933): a specimen was "found by A. Mouty at top of the Pierre Jaune at Confort" (Geneva area Jura; Busnardo and Thieuloy in Remane et al. 1989). Re-determined as "gr. *Lyticoceras*/*Cruasiceras* sp.", this ammonite dates the lowermost part of the UJ either from the top of the Early Hauterivian or the bottom of the Late Hauterivian (Cruasense Subzone of the Sayni Zone; Clavel et al. 2007)

Each of these genera and species characterize the Hauterivian, the genus *Cruasiceras* being strictly confined to the base of the Sayni Zone, i.e. Late Hauterivian

2.2 Other fossil groups

Other biostratigraphical markers can be duly calibrated in outcrops in which they occur together with ammonites: the stratotypes in the Vocontian Trough for dinocysts and calcareous nannofossils, the outer platform and slope for the orbitolinids, dasycladalean algae and echinids (Busnardo et al. 1991; Clavel et al. 2007, 2010). Among the main species of orbitolinids found in the UB, Godet et al. (2011) quote *Paleodictyoconus cuvillieri*, a species ranging from the Hauterivian to the Aptian (i.e. not significant), and *Praedictyorbitolina carthusiana*, which has been dated by ammonites from the Late Hauterivian Sayni Zone to the Early Barremian Pulchella Zone, excluding the Late Barremian (Clavel et al. 2007, 2010), a fact negated by Adatte et al. (2005).

The "divergences and problems in orbitolinid biostratigraphy" (Godet et al. 2012) led them to reject most remaining groups (echinids, dasycladalean algae, dinocysts, rudists, calpionellids, bryozoans), except for the calcareous nannoplankton, even though the determinations and biostratigraphic allocations put forward by Godet et al. (2011) have been formally challenged by Clavel et al. (2007) and Conrad et al. (2012). Details of the accepted stratigraphic ranges of some other fossil groups in comparison with interpretations of Godet et al. (2011) are shown in Fig. 2.

Although some fossil groups have a lesser resolution than the ammonites (Godet 2006, p. 65–75), we would argue that they deserve being taken into consideration. Even some long ranging taxa may prove to provide accurate information, depending on the context. For instance, when a calpionellid genus like *Tintinnopsella*, ranging from the Tithonian to the Hauterivian, is found above the MU, it dates the Late Hauterivian (Fig. 1), unless the specimen is reworked (which has yet to be demsonstrated).

Godet et al. (2011) report three dasycladalean algae in the UJ: two species appear and one ends in the Late Hauterivian (Jaffrezo 1975; Conrad and Masse in Remane et al. 1989; Masse 1976, 1993; Clavel et al. 2007, 2010) with an overlap corresponding to the Late Hauterivian. A fourth species, *Dissocladella hauteriviana*, was illustrated by Clavel et al. (2007, Plate 6, Fig. S): it was found in the lower part of the UB at Eclépens and determined by one of us (M.C.) for Blanc-Alétru (1995), a detail which is omitted in publications of Godet et al. (2010, 2011, 2012).

Godet et al. (2011) cite two rudists, *Agriopleura* sp., a genus that in the Northern Tethyan Domain ranges from the Late Hauterivian to the early Late Barremian and *Requienia renevieri* which is Late Hauterivian (Masse 1976, 1995, 2011 oral com; Masse et al. 1998). *Pachytraga tubiconcha*, which is lacking in their list, is included in our Fig. 2. A full chapter dedicated to the "limestone with *Pachytraga*" was issued by Masse et al. (in Remane et al. 1989), stressing its Hauterivian age, as later confirmed by Masse (1995) and (1998). Its presence was also reported by Blanc-Alétru (1995) at the base of the UB, but it is not mentioned in Godet et al. (2010, 2011, 2012). Elsewhere, the species is so far only known from the Hauterivian in Provence.

Last but not least, the levels sampled at Eclépens for calcareous nannofossils were also analysed by an independent expert for the dinocysts, resulting in both being dated from the Late Hauterivian, excluding the latest part of the stage (Clavel et al. 2007). Other samples containing dinocysts, taken from the same intervals, were analysed by two other experts (Godet 2006). One ascribed them a "latest Barremian–earliest Aptian" age, whereas the other obtained an Hauterivian age. Neither of these determinations are mentioned in Godet et al. (2011).

In conclusion, on the basis of our interpretation of the biostratigraphical data (Figs. 1, 2), the Urgonian in the western Swiss Jura is mainly Late Hauterivian in age, not Late Barremian as proposed by Godet et al. (2011). On the Early Cretaceous time scale of McArthur et al. (2007) this corresponds to a numerical age range of 132–130 Ma, as compared to the range of 130–125 Ma proposed by Godet et al. (2011). This brings us to a discussion of the methodology of the radiometric age dating reported in Godet et al. (2011) and their interpretation of the results.

3 Interpretation of $^{87}Sr/^{86}Sr$ measurements

Godet et al. (2011) sampled 19 rhynchonellid shells in six sections, sited in the cantons of Neuchâtel and Vaud in the western Swiss Jura. On these, they performed Sr-isotope analyses "in order to derive Sr model ages". Out of the original set of 19 samples, Godet et al. (2011) only retain fourteen measurements (op. cit. Table 1); five were discarded due to diagenetic alteration. Plotting the $^{87}Sr/^{86}Sr$ ratios, which are given to six digits of precision, against a stratigraphic column of the Early Cretaceous results in a bell-shaped curve (McArthur et al. 2001; McArthur and Howarth 2004). The ratios gradually increase over the Berriasian, Valanginian and Hauterivian times, they reach a plateau in the Early Barremian, and then decrease through the Late Barremian and Bedoulian ("Lower Aptian"). Keeping in mind the gross stratigraphic framework of the interval studied, an age range can then be estimated in terms of ammonite zones for each sample by "cross-plotting" its Sr-isotope ratio on the correlative portion of the curve. Rather than considering the LOWESS version 3 curve of McArthur et al. (2001), Godet et al. (2011) use their own curve, which is calibrated on ammonite biozones (op. cit. Fig. 6). The curve they use is mainly based on a combination of measurements obtained from belemnites collected in the Vocontian Trough by Schootbrugge (2001) for the Hauterivian and by Bodin et al. (2009) for the Barremian. Additional data to build the Hauterivian portion of this synthetic curve include mean values for the ammonite zones computed by McArthur et al. (2007). The data for the two parts of this calibration curve are shown in Fig. 3 (red dots from Schootbrugge 2001, black dots from Bodin et al. 2009, and red circles from McArthur et al. 2007). This forms the basis for the following discussion.

3.1 "Marnes bleues d'Hauterive" (MBH)

Rhynchonellid shells collected from this formation (lying below PJN, not shown on Fig. 1) provide six $^{87}Sr/^{86}Sr$ measurements, of which one was discarded (Godet et al. 2011, Table 3). The ratios are closely set, ranging between 0.707413 and 0.707434. The projections of these two extreme values onto the curve intercept it over an interval spanning the Radiatus, Loryi and Nodosoplicatum zones on the McArthur–Schootbrugge portion of the synthetic curve, i.e. the whole of the Early Hauterivian. The graphical correlation intercepts the curve again higher in the stratigraphic column, at the level of the Giraudi Zone (latest Barremian), which is obviously out of the time in focus and consequently was not taken into account. Guided by their own biostratigraphical constraints, Godet et al. (2011) retained only the upper part of the Radiatus Zone. In our opinion, this interval could have been extended into the lower part of the Loryi Zone on the basis of the ammonite record (Busnardo and Thieuloy in Remane et al. 1989), see Fig. 3.

Godet et al. (2011) also used these five consolidated values to calculate an "absolute" numerical age. They conclude that their mean "age value (132.29 Ma, Table 3) corresponds particularly well to the age range to be expected from the biostratigraphical indications calibrated against the most recent time table compiled by the International Commission on Stratigraphy". To us, however, this seems to be more the result of a circular calculation.

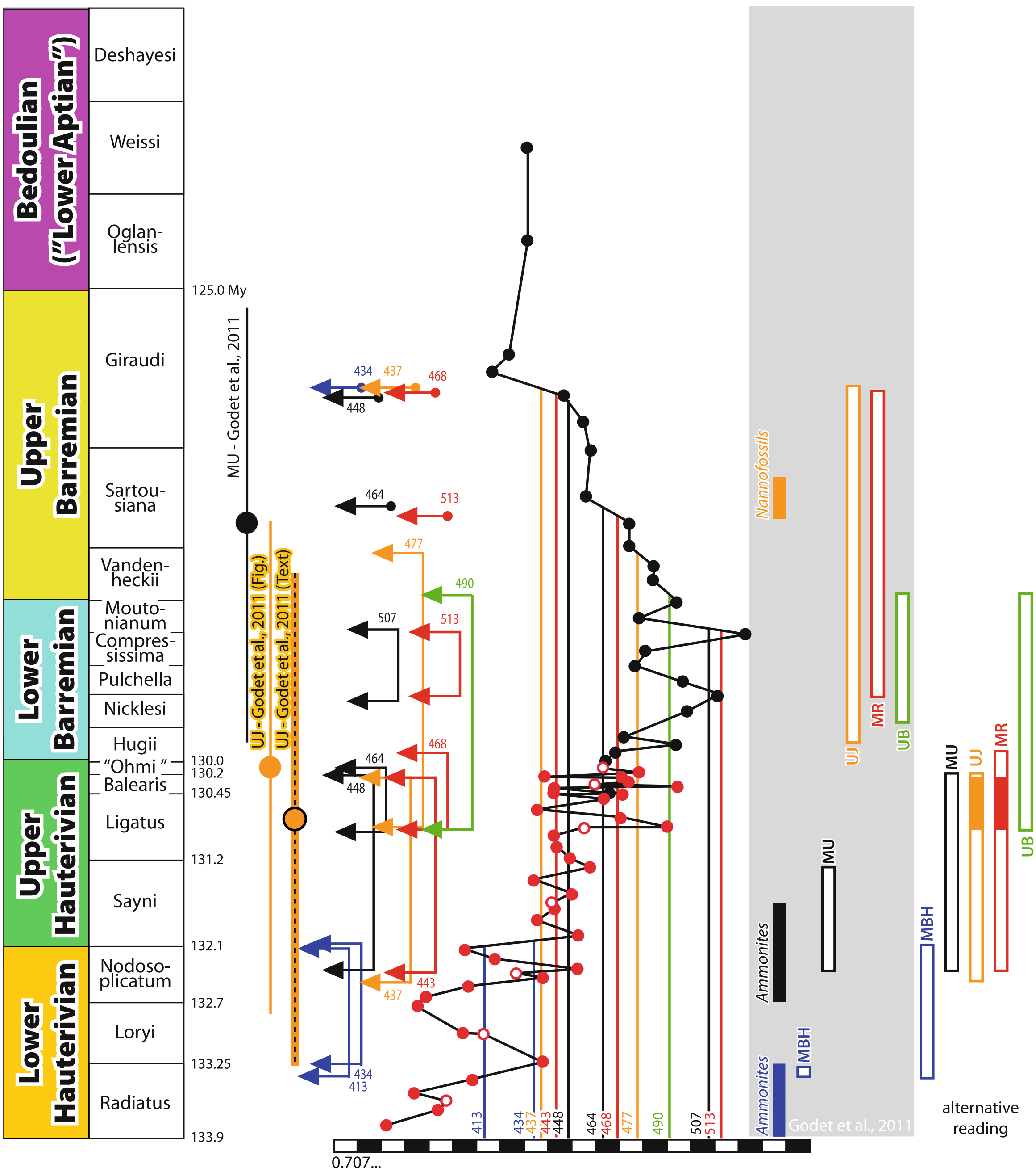

Fig. 3 Comparison of the Sr-isotope ratios measured on rhynchonellids from the western Swiss Jura with the ammonite-calibrated $^{87}Sr/^{86}Sr$ curve obtained from belemnites from the Vocontian Trough after Godet et al. (2011, Fig. 6, modified) *red dots* from Schootbrugge (2001), *black dots* from Bodin et al. (2009), *red circles* from McArthur et al. (2007). Absolute ages on the vertical axis (*Y*) are from McArthur et al. (2004, 2007). There are two numerical ages for the "Urgonien jaune" in Godet et al. (2011): redrawn after their figure and another one centered on the value given in their text. Regarding the Sr-isotope ratios, the first three digits after the decimal point are 707, the next three digits are displayed on the horizontal axis (*X*). The *discrete arrows* indicate when the curve is intercepted sporadically, the *joined arrows* indicate larger intervals of interception (spanning several ammonite zones). The last two columns present ranges identified by Godet et al. (2011) and an alternative reading derived from the same data set (this discussion). From *base* to *top MBH*, Marnes bleues de Hauterive (*blue*), *MU*, Marnes d'Uttins (*black*), *UG*, Urgonien Jaune (*orange*), *MR*, Marnes de la Russille (*red*), *UB*, Urgonien Blanc (*green*)

3.2 "Marnes d'Uttins" (MU) and "Pierre Jaune de Neuchâtel" (PJN)

Rhynchonellid shells collected in the MU type locality at Mont Chamblon, Yverdon (Vaud), provide four $^{87}Sr/^{86}Sr$ measurements of which three were accepted by Godet et al. (2011). The corresponding ammonite zones on the synthetic curve are (Fig. 3):

- 0.707448: either ranging from the Nodosoplicatum Zone up to the "Ohmi" Zone, i.e. late Early to latest

Hauterivian, on the McArthur–Schootbrugge portion of the plot, or crossing it in the Giraudi Zone on the Bodin portion, i.e. latest Barremian

- 0.707464: either spanning the Ligatus, Balearis and "Ohmi" zones on the McArthur–Schootbrugge portion of the curve, i.e. Late Hauterivian, or crossing it in the Sartousiana Zone on the Bodin portion, i.e. Late Barremian
- 0.707507: ranging from the Nicklesi Zone up to the Moutonianum Zone on the Bodin portion, i.e. Early Barremian

Their derived age interval spans both the Nodosoplicatum and Sayni zones (Godet et al. 2011, Fig. 6: column "$^{87}Sr/^{86}Sr$ derived ages"). This interval could have been shortened to the first zone only, because, as reported earlier herein, the genus *Lyticoceras*, some specimens of which were found in both the MU and the upper part of the "Pierre Jaune de Neuchâtel" (UPJN), is restricted to the Nodosoplicatum Zone (Thieuloy et al. 1983; Busnardo and Thieuloy in Remane et al. 1989; Bulot 1995), i.e. the late Early Hauterivian. In the end, guided by biostratigraphical constraints, Godet et al. (2011) retained only the lowest (0.707448) of the three values as valid; we come to the same conclusion (Fig. 3). However, they (Godet et al. 2011, Table 3) used the remaining two values, although they were not consolidated, to calculate a numerical "average $^{87}Sr/^{86}Sr$-derived age".

3.3 The "Urgonien Jaune" (UJ)

Rhynchonellid shells collected in the middle part of the UJ at the Pourtalès Hospital (Neuchâtel) provided two measurements (Godet et al. 2011):

- 0.707437: either ranging from the Nodosoplicatum (or possibly from Radiatus) Zone up to the "Ohmi" Zone, i.e. late Early to Late Hauterivian on the McArthur–Schootbrugge portion of the plot, or crossing it in the Giraudi Zone on the Bodin portion, i.e. latest Barremian
- 0.707477: ranging from the Ligatus Zone on the McArthur–Schootbrugge portion of the curve up to the Vandenheckii Zone on the Bodin portion, i.e. Late Hauterivian to early Late Barremian

Godet et al. (2011) retained these two values to calculate an "average $^{87}Sr/^{86}Sr$-derived age" for the middle part of the formation.

The age range given by Godet et al. (2011, Fig. 6: column "$^{87}Sr/^{86}Sr$ derived ages") covers an interval from the Hugii Zone up to the Giraudi Zone, i.e. the whole of the Barremian. Actually, an Early Barremian age is consistent with one value only; a Late Barremian match is only possible, or we have to assume the measured $^{87}Sr/^{86}Sr$ ratio is lower than it should be. Finally, a possible Late Hauterivian age for the base of the interval on the reference curve is not taken into consideration, even though values displayed for the Ligatus and Balearis zones are compatible with both available measurements provided (because there is a graphical overlap).

In order to support their interpretation, Godet et al. (2011) use a nannofossil assemblage found in the lower part of the UJ at Eclépens, which should be "indicative of an early Late Barremian age (late *G. sartousiana* to early *H. feraudianus* zone)", i.e. part of the Sartousiana Zone auct. However, the same set of samples was analysed by three different investigators under the aegis of A. Strasser, University of Fribourg, Switzerland (cf. Godet 2006, p. 373–386) and gave different results, depending on the preservation of the specimens. One expert came up with Valanginian to Barremian ages for the large range and an Hauterivian age for the narrow range, whereas a second expert reported Early Cretaceous for the larger range and Late Hauterivian for the narrower range, both of them providing quite consistent results. In contrast, a third expert obtained quite different results, assigning six out of the eight samples to the Late Barremian and two even to the Late Albian. Godet et al. (2011), however, give full credit to the Late Barremian dating of the third expert, ignoring the (Late) Hauterivian datings of the other two, and rejecting information issuing from other fossil groups (see discussion above, Sect. 2.2).

3.4 The "Marnes de la Russille" (MR)

Three rhynchonellids sampled from the MR were taken at la Russille (Canton Vaud). The corresponding ammonite zones in the synthetic curve are as follows (Fig. 3):

- 0.707443: either ranging from the Nodosoplicatum Zone up to the "Ohmi" Zone, i.e. late Early to latest Hauterivian on the McArthur–Schootbrugge portion of the plot, or crossing it in the Giraudi Zone on the Bodin portion, i.e. latest Barremian
- 0.707468: either spanning the Ligatus, Balearis, "Ohmi" and Hugii zones on the McArthur–Schootbrugge portion of the curve, i.e. Late Hauterivian, or crossing it in the Sartousiana Zone on the Bodin portion, i.e. Late Barremian
- 0.707513: ranging from the Nicklesi Zone up to the Moutonianum Zone on the Bodin portion, i.e. Early Barremian

The age range given by Godet et al. 2011, Fig. 6: column "$^{87}Sr/^{86}Sr$ derived ages") covers an interval from the Nicklesi Zone up to the Giraudi Zone, i.e. most of the Barremian. The highest value, 0.707513, is indicative of an

Early Barremian age. However, because the underlying formation (UJ) was already ascribed a Late Barremian age, this value should not have been given any credence. Notwithstanding this fact, Godet et al. (2011) combined it with the other two values to calculate an "average $^{87}Sr/^{86}Sr$-derived age".

3.5 The case of the "Urgonien Blanc" (UB)

A single rhynchonellid specimen, sampled near the base of the UB at Eclépens, is considered of acceptable quality 0.707490. The correlative interval ranges from the Ligatus Zone on the McArthur–Schootbrugge portion of the curve up to the Vandenheckii Zone on the Bodin portion, i.e. Late Hauterivian to early Late Barremian.

The age range given by Godet et al. (2011, Fig. 6: column "$^{87}Sr/^{86}Sr$ derived ages") is narrowed to the Nicklesi–Vandenheckii interval, i.e. Early Barremian to early Late Barremian. However, because the underlying formations (UJ and MR) were already ascribed a Late Barremian age, this value should not have been considered as valid, a point not considered by Godet et al. (2011) who still used it to calculate a "$^{87}Sr/^{86}Sr$-derived age".

To summarize, if we exclude the measurements for the "Marnes bleues d'Hauterive" (they represent one-third of the valid values), out of the nine remaining valid values to deal with four stratigraphic units, only three can be consolidated when using Godet et al.'s constraints (that is one-third of their results, whereas the two-thirds remaining should have been rejected). On the contrary, if one strictly applies their technique, the correlative portions of the curve differ (Fig. 3) and one can consolidate up to six measurements out of nine. However, we are sceptical that their combination of three consolidated values together with six unconsolidated values (Godet et al. 2011, Table 3) helps in computing reliable numerical ages. In addition, Fig. 3 shows that their option, i.e. use the ascending part (McArthur–Schootbrugge portion) of the curve for MBH and MU and the descending part of the curve (Bodin portion) for UJ, MR and UB, is rather arbitrary. We believe that our option, i.e. to use only the ascending part of the curve, is more realistic, and implies an Hauterivian age for the series under investigation.

4 Interpretation of glauconite ages

Originally, K/Ar measurements on glauconite were used as a chronometer to build the geologic time scale. It was a one-way process, giving a minimum age with respect to the true age of a well-established biohorizon. Godet et al. (2011, and in Adatte et al. 2005) and Godet (2006) implemented the return process, a technique which can be called "reverse geochronology", i.e. identifying biozones corresponding to the glauconite ages. They sampled glauconite intervals of the Eclépens Quarry (Vaud) in both the MU and the UJ and had them analysed at three different laboratories. Subsequently, Godet et al. (in Adatte et al. 2005) and Godet (2006) successively displayed three sets of analyses, whereas Godet et al. (2011) retain only the last of these. The dates obtained were as follows:

1. Analysed at the Geological Institute of the University of Neuchâtel and the "Centre de Géochimie de la Surface" of the University of Strasbourg: UJ 123.3 ± 2.4 Ma, MU 126.2 ± 2.5 Ma
2. Analysed in the laboratory of the group "Interactions et dynamiques des environnements de surface" at the University of Paris Sud-Orsay: UJ 107.9 ± 1.5 Ma, MU 105.8 ± 1.5 Ma
3. Analysed in the laboratory of the "Centre de Géochimie de la Surface" of the University of Strasbourg: UJ 130.7 ± 2.6 Ma, MU 127.5 ± 2.3 Ma

The results are scattered. Measurements made in 2006 (the second and the third sets) differ by more than 20 Ma. Considering that the term "glauconite" covers a variety of authigenic clay minerals and that weathering may alter the composition of the iron potassium phyllosilicates, glauconite-derived ages are commonly younger than the true age. Here, however, the second set should be discarded, because the ages are far too young, although both sets of analyses are consistent in that the oldest ages were obtained on the (biostratigraphically) youngest samples. We are left with two sets, the first (in Adatte et al. 2005) and the third (in Godet 2006), and four measurements. Regarding the third set, we agree with Godet et al. (2011) that "the glauconite age of the MU appears too young relative to its ammonite age", even when considering the interval for analytical errors. These marls are dated by ammonites of the Nodosoplicatum Zone of the Early Hauterivian, whereas the oldest age limit (127.5 + 2.3 = 129.8 Ma) matches the Hugii Zone of the Early Barremian (Fig. 3). They probably applied the same rule to discard the first set of data, although this is not specifically stated. In conclusion, only one measurement remains, analysis (3) of the UJ with a range of 133.3–128.1 Ma and a mean value of 130.7 Ma. The range covers most of the Hauterivian and part of the Early Barremian, and is centred on the Ligatus Zone of the Late Hauterivian (Fig. 3). It should be noted that we detected an "artefact" in the graphical representation of the age uncertainties provided by Godet et al. (2011), as explained in the caption to Fig. 3.

5 Conclusions

To summarize, no contradiction exists between the conclusions drawn from our palaeontological data on one side and the few consolidated data derived from chemostratigraphy or geochronometry on the other side. Both chemostratigraphy and "reverse geochronology" require consolidation of their measurements, i.e. to decide whether they should be accepted or rejected by another independent unbiased tool, while biostratigraphy is a "self-supportive" discipline (see more examples in Conrad et al. 2012 or Granier and Busnardo 2012).

As a result of our detailed study of the paper by Godet et al. (2011), together with the results of our own research, we reach the following conclusions:

- Our interpretation of the biostratigraphical data remains as previously (e.g. Clavel et al. 2007, 2012), that the Urgonian in the western Swiss Jura is Late Hauterivian in age, not Late Barremian as proposed by Godet et al. (2011). On the Early Cretaceous time scale of McArthur et al. (2007) this corresponds to a numerical age range of 132–130 Ma, as compared to the range of 130–125 Ma proposed by Godet et al. (2011).
- Graphical correlations of measured $^{87}Sr/^{86}Sr$ ratios (plotted on the X axis) on the ammonite-calibrated synthetic curve for the Early Cretaceous times lead to identify not a single corresponding value, but best-fitting time intervals along the stratigraphic column (plotted on the Y axis). Applying the technique and the constraints used by Godet et al. (2011), we found that out of the nine valid values for the interval PJN–UJ, only three could be consolidated. In contrast, if one strictly applies their technique and ignores the disputable nannofossil datings, the correlative portions of the curve differ and one can then consolidate up to six measurements out of nine. Our Fig. 3 (derived from their Fig. 6) suggests that their option is rather arbitrary and that our option, implying an Hauterivian age for the series under investigation, is at least as viable.
- Only one of the six glauconite K/Ar radiometric ages reported by Godet et al. (2011) is reliable. This is the dating of the UJ, with a range of 133.3–128.1 Ma and a mean value of 130.7 Ma. The range covers most of the Hauterivian and part of the Early Barremian, and is centred on the Ligatus Zone of the Late Hauterivian. Although the resolution of this dating is low, it fits better with a Late Hauterivian than a Late Barremian age for the UJ, as the palaeontological data indicates.

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