

The stratigraphy of the Middle Jurassic

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Paleontological division of the Middle Jurassic

Since the end of the Toarcian period, the Poitou threshold and its Parisian and Aquitaine slopes have corresponded to a carbonate platform that persisted throughout the Middle Jurassic (Aalenian, Bajocian, and Bathonian). At that time, Poitou was located at the edge of the Tethys, a vast ocean between Gondwana and Laurasia (Fig. 1).

The first sediments deposited on this platform date back to the Aalenian (174 Ma± in ICS, 2024). Two ammonite lineages are commonly used to date the sediments of this stage: *Leioceratinae* and *Graphoceratinae*. The Toarcian-Aalenian boundary is difficult to define paleontologically because the last *Pleydellia* have affinities with the first *Leioceras* (Cariou and Hantzpergue, 1997). In platform regions such as Poitou, the Toarcian-Aalenian boundary is linked to an ecological change with a drop in sea level. The first ammonite zone corresponds to the appearance of *L. opalinum*. This is followed by two species of ammonites that are widespread in Western Europe: *Ludwigia murchisonae* and *Brasilia bradfordensis*, whose horizons determine the Middle Aalenian and are separated by a discontinuity. In Poitou, the Middle Aalenian ends with the *Brasilia gigantea* horizon. The Upper Aalenian corresponds to the appearance of *Graphoceras concavum*.



Figure 1 175 My paleogeographic map of the western Tethys with the Poitou area (GPLates 2.5).

A major renewal of marine fauna marks the first Bajocian transgression at the boundary between the *Concavum* and *Discites* zones. The carbonate platform is well dated by the Tethyan ammonite fauna in Western Europe, as the boreal fauna did not penetrate the epicontinental seas of the western Tethys. The ammonite zones of the Lower Bajocian are defined by *Hyperlioceras discites*, *Witchellia laeviuscula*, *Sonninia propinquans*, and *Stephanoceras humphresianum*.

The Upper Bajocian transgression lies between the *Humphresianum* zone and the *Niortense* zone. The epicontinental seas underwent a reactivation of the basement faults and an oolitic barrier extending along the Massif Central to the Pyrenees, marking the sedimentation in the Aquitaine Basin (Cariou and Hantzpergue, 1997). The zonation of the Upper Bajocian is based on the ammonites *Strenoceras niortense*, *Garantiana garantiana*, and *Parkinsonia parkinsoni*.

The appearance of *Zigzagoceras zigzag* marks the base of the Bathonian stage. In Poitou, boreal ammonites (*Gonolkites convergens*) coexist with Mediterranean ammonites (*Morphoceras parvum*). This mixture of fauna is a distinctive feature of this stage. The Lower Bathonian ends with the *Procerites aurigerus* zone. The Middle Bathonian includes the *Procerites progracilis*, *Tulites subcontractus*, *Morrisiceras morrisi*, and *Cadomites bremeri* zones. The Upper Bathonian includes the *Prohcticoceras retrocostatum* zone and the *Clydoniceras discus* zone.

Deposit sequences

The dating of carbonate deposits using ammonite fauna has enabled a detailed reconstruction of the sequence of deposits in the Paris Basin (Rioult et al., 1991). On the Poitou threshold, dating using ammonites is hampered by the rarity of pelagic fauna. Furthermore, the study of Middle Jurassic terrains on the edge of the

Massif Central, particularly in Haut-Poitou, is difficult due to lateral variations in facies (Glangeaud, 1895). Under the impetus of Professor Gabilly, the stratigraphy of the Poitou threshold was revised in the 1970s with the definition of 107 ammonite biozones from the Sinemurian to the Oxfordian (Gabilly and Rioult, 1971; Gabilly and Cariou, 1974). This zoning was clarified using a lithological and sedimentological approach. Even before the advent of sequential stratigraphy, Gabilly understood the importance of taking into account major sedimentary discontinuities and deposit facies (Gabilly, 1962), which were often ignored by earlier authors (Welsch, 1895). The Poitou threshold series was thus revised and divided into 13 sequences separated by discontinuities and presented in 1974 during the excursion organized by Gabilly and Cariou on the Poitou threshold. The comparison of pelagic ammonite zones (Deux-Sèvres and Charente) with the discontinuities separating each sequence made it possible to define a sequential stratigraphy of the Jurassic platform on the threshold where ammonites are rare or even absent in the outcrops studied (Gonnin et al., 1993; Branger and Gonnin, 1994).

Table 1 shows the initial stratigraphic division by Gabilly and Cariou (1974), which was subsequently used in the work of the Faculty of Geology at Poitiers and in the notes on the 1:50,000 geological maps. The numbers of the discontinuities (D6 to D11) are borrowed from the scale used in the work of the University of Poitiers (Mourier, 1983; Gabilly et al., 1985) and follow the logic of the 1974 sequences.

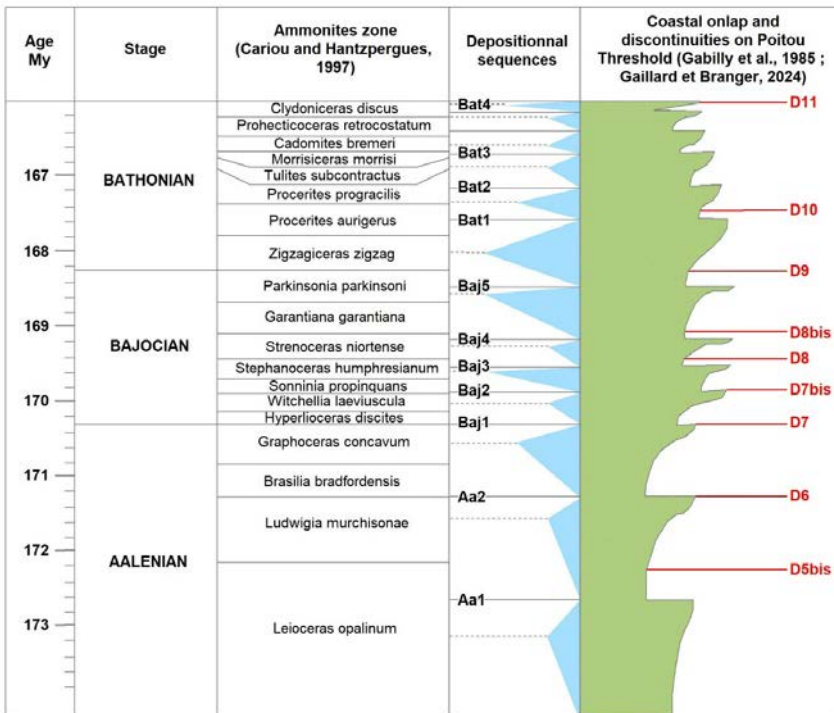


Table 1 Sequence stratigraphy of the Poitou Threshold.

With this sequential approach, the deposit sequences of the Poitou threshold can be precisely defined (Table 1). Discontinuities are associated with low sea levels on the eustatic curve. The sedimentary bodies correlate well with the discontinuities for the Aalenian and Bajocian. In the Bathonian, the deposit sequences follow a regressive trend. On the Poitou threshold, the determination of sequences with discontinuities is less precise.

Stratigraphy of the Middle Jurassic on the Poitou Threshold

Starting in the Early Jurassic period, the Poitou Threshold and its surroundings were gradually invaded by an epicontinental sea connected to the western Tethys Sea to the southeast. Throughout the Middle Jurassic, the region was a depositional area whose general physiography, inherited from the Permian-Triassic differential erosion of its Hercynian basement, allows several distinct areas to be identified. In simplified terms, an axis running from Pouzauges to Oradour-sur-Glane (Gabilly et al., 1978) separates, to the northeast, a shallow domain with abundant carbonate sedimentation and benthic fauna from a deeper domain to the southwest, where sedimentation was less abundant but often accompanied by a rich pelagic fauna of ammonites. This Pouzauges-Oradour-sur-Glane axis corresponds fairly closely to the Vasles fault line, which runs along the Nantes-Parthenay granite axis towards the Champagné Saint-Hilaire horst and the Availles-Limouzine fault (see southern limit in Gaillard and Branger, 2026). In detail, the shallowest deposits were formed on the northwestern edge of the Massif Central, which at that time formed a carbonate aureole bordering the central platform. The eastern edge of the Vendée Massif, also shallow, appears as a shoal backing onto the Armorican Landmass. These two areas are connected by the Pictavian domain. To the south of the paleogeographic axis lies the Melusine trough (see Gaillard and Branger, 2026), a depressed area linking the northern edge of the Aquitaine Basin, which can be traced as far as the Vendée coastline. The remarkable permanence of these sedimentary domains can be explained by low accumulation of deposits and the stability of the geological bedrock. Indeed, during this interval, the remobilization of the main Hercynian tectonic axes according to a tilted block model, which was paleogeographically decisive during the Callovian and Upper Jurassic periods, appears to have been very limited.

The deposit sequences are labeled D in reference to the discontinuities described by Gabilly et al. (1985).

Aalenian

Throughout the region, the sedimentary evolution that began in the Upper Toarcian with a reduction in clay inputs continued during the Aalenian (bodies labeled 1 and 2 in Fig. 2). The Lower Aalenian (*Opalinum* zone), which is very thin (2 to 3 m),

shows stratigraphic growth of fine clayey limestone beds. This is where the *Gryphaea beaumonti* lumachels are found, which constitute a regional stratigraphic marker.

D6

From the Middle Aalenian onwards (units 3-4-5-6), the paleogeography changes and two areas can be distinguished:

- a distal platform domain extending along the northern Aquitaine margin, characterized by highly condensed and lacunar sedimentation of calcareous biomicrites with ferruginous oolites, where nektonic fauna (ammonites, belemnites) and benthic fauna (mollusks) are equally abundant;
- a proximal carbonate platform edge domain, with much thicker sedimentation, consisting of fine dolomitic limestones with flints and predominantly benthic fauna, from a shallower environment with moderate energy.

In the basin area, from Niort to Saint-Maixent, the Middle Aalenian (*Murchisonae* zone) consists of thin marl beds and a more massive bank of clayey limestone. Above a marked discontinuity (D5bis?) is a level of reddish clayey limestone with ferruginous oolites and numerous fossils, gastropods, bivalves, belemnites, and ammonites characterizing the upper part of the zone. The whole is less than 1 m thick.

The Upper Aalenian, *Concavum* zone, is only represented from the Saint-Maixent graben and also at Vitré, north of Celles-sur-Belle, in the form of reddish, sometimes purplish, highly fossiliferous clayey limestones with ferruginous oolites and not exceeding 10 cm in thickness (unit 7).

In the Couhé-Vérac-Lusignan region, the Middle Aalenian thickens considerably (approximately 20 m) and occurs as dolomitic limestones with flints attributed to the *Murchisonae* subzone. The next 6 meters, *Bradfordensis* subzone, consist of often dolomitic limestones with flints alignments. The Upper Aalenian and the extreme base of the Bajocian (*Concavum* and *Discites* zones), nearly 5 m thick, correspond to pseudo-oncoïdes limestones. From Poitiers to Chauvigny, the Aalenian has the same facies with even greater thicknesses, from 19 to 27 m, for the whole. Islands dotted the platform with mangrove flora, giving rise to polyp limestones and driftwood. Continuing eastward into the Gartempe Valley, the Aalenian thins again as it approaches the northern edge of Limousin, with the return of ferruginous oolites in the *Bradfordensis* subzone and abundant pelagic fauna.

D7 – Lower Bajocian

Everywhere, the base of the Lower Bajocian is indicated by levels rich in ammonites, numerous Sonniniidae, and evidence of a major transgressive event (units 8 and 9). Along the entire northern Aquitaine border, there is a layer of gray limestone with ferruginous oolites, generally about 20 centimeters thick, rich in fossils, including

numerous benthic forms, bivalves, and gastropods, as well as cephalopods, ammonites, and belemnites. Above this, are thicker banks of very hard micritic limestone (paved limestone from the Niort region) dating from the *Laeviuscula* and *Propinquans* zones (units 10-11-12-13). In the Mellois region, these levels are very poorly developed and may still contain ferruginous oolites and phosphate nodules. The base of the *Humphriesianum* zone remains very fossiliferous (unit 14), particularly the *Umbilicum* horizon (*Humphriesianum* subzone). The rock contains large quantities of glauconite. Throughout the area, spongy bioherms developed during the *Subblagdeni* subzone. The top of the *Humphriesianum* zone is truncated by a major discontinuity, D8, as described by Gabilly et al. (1985).

In the Melusine gully and the Poitiers region, the Lower Bajocian reaches a thickness of around 20 meters, consisting of limestone with numerous pseudo-oncoides with nubeculars and flints levels. An oolitic bed marks the top of the zone at *Laeviuscula*, topped by calcarenites with crinoids containing very rare ammonites from the *Propinquans* and *Humphriesianum* zones (*Teloceras* cf. *subblagdeni* in the Vonne valley, Branger 1989). In the Boivre valley, polyp levels crown this series and probably constitute the lateral equivalent of the spongy bioherms developed in the distal domain. Towards the eastern part of the threshold, in the Gartempe valley, the Lower Bajocian ends with a flint-rich bank (silexite of Mourier, 1980, p. 35).

Further east, in the Civaux-Chauvigny region, it consists of granular limestone with tube worms, approximately 16 m thick, containing numerous flints and frequent dolomitic passages.

D8 – Upper Bajocian

A new transgressive episode marks the base of the Upper Bajocian (units 19-20-21). In Niort and Vendée, the *Niortense* and *Garantiana* zones, as well as the extreme base of the *Parkinsoni* zone, are recognized by a decimeter-thick layer of phosphate stromatolite nodules with reworked fossils (Branger, 1989). This bed becomes significantly more carbonated in the Mellois with multi-decimetric limestone banks rich in fossils. Moving towards the proximal platform, the transition from the Lower Bajocian to the Upper Bajocian is less distinct, but the fossiliferous beds of the *Garantiana* zone and the *Acris* subzone persist. Above, and throughout the sector, there are about ten meters more of massive beds of gravelly limestone, with abundant sponges and tuberoids (ferruginized intraclasts). These are the spotted limestones of the Saint-Maixent area (Cariou et al. 2006). Flints beds appear from the Saint-Maixent graben onwards.

On the Poitou platform, ammonites have also been collected at the base of the sub-stage. This is highlighted in the Poitiers cliffs by one or two burrow beds (units 20-21). Above, over about 20 meters, there are flint-dotted limestones (units 22 to 27). In the Vienne and Gartempe valleys, the facies indicate shallower environments. At a height of 25 to 40 meters, there are granular packstone limestones with isolated colonies of polyps (*Lochmaeosmilia*) interspersed with crinoid

grainstones (Lussac-les-Châteaux and Le Vigean sectors, Mourier and Gabilly, 1985). Exceptionally, in the terminal part of the stage, green clay lenses with ostracods can be observed (La Tour-au-Cognum).

D9 – Lower Bathonian

In northern Aquitaine, the base of the Bathonian stage corresponds to what former quarry workers called the “rotten bank.” This is characterized by one or two multi-decimeter limestone banks framed by greenish marl joints. In natural gamma-ray logs, this layer produces a marked peak that is easy to spot. It contains phosphate nodules and numerous fossils: bivalves, gastropods, sponges, and cephalopods typical of the *Zigzag* zone (units 28-29-30). As it approaches the Saint-Maixent graben, this level becomes much more carbonated but retains its paleontological characteristics (units 31 to 33). Above this, spotted limestones reappear over a thickness of about ten meters. Compared to those of the Upper Bajocian, there is an increase in the frequency of flints.

In Poitiers, at a height of about 3 meters, gravelly limestones with numerous *Ctenostreon* and, more rarely, a few ammonites from the *Zigzag* zone can be observed. Above this are thick beds of gravelly limestone with isolated flints (4 m). Moving eastward, this succession varies little, except for the upper part, which then consists of a marker level of oolitic limestone.

D10 – Middle and upper Bathonian

At the base of the Middle Bathonian, in the basin area, ammonites become frequent again (unit 36). The limestone facies with tuberoids and sponges remains predominant (approximately 3 meters), generally without flint, with a few greenish clay interbeds. Higher up, and only from la Crèche sector onwards, flints return temporarily. Sponges remain abundant and can locally form bioherm-type accumulations. At the top of the stage, much finer limestones (4 meters) are deposited, again rich in ammonites from the *Retrocostatum* zone. The virtual absence of *Clydoniceras* and the problems of correlation between the Tethyan and Boreal domains make it impossible to assess the extent of the gap in the late Bathonian. On the other hand, the erosion surface (D11) that truncates these beds and precedes the first Callovian deposits is well marked and, in most cases, easily identifiable thanks to the presence of glauconitic coatings.

As a result of their erosion, the Middle and Upper Bathonian deposits do not exist directly below the threshold. In Poitiers, this level consists of 5.50 m of gravelly and suboolithic limestone containing 4 to 5 continuous bars of flints, 0.15 to 0.30 meters thick. There are quite a few bivalves, polyyps, and rare ammonites (*Cadomites orbigny*). The stage ends with 7 m of gravelly to suboolithic limestone containing scattered flints. The whole is truncated by a weathering surface.

In the Chauvigny area, at a height of 21 meters, the Middle Bathonian consists of finely grained limestone with thin oolitic and oncolitic intercalations and a few beds rich in *Entolium* towards the top. Clayey intercalations of brackish origin persist at this level in the Creuse valley. The Upper Bathonian (25 to 30 meters) corresponds to the Chauvigny oolite. The lower part (10 to 12 meters) is formed of coarse limestone with colonies of polyps (*Lochmaeosmilina*), topped by fine oolite in massive banks. Here again, we find discontinuity D11 in the form of a flattened and threaded surface.

The various deposit sequences (systems tracts) are shown in Figure 2. Carbonate deposits are significantly thicker (gravelly and oolitic facies) on the threshold than on the Aquitaine slope (bioclastic facies). The discontinuities separating the deposit sequences extend from the basin to the platform. Correlations between the basin and the Poitevin platform with sedimentary discontinuities make it possible to define the geometry of the sedimentary bodies. An overall diagram of these deposit sequences is shown in Figure 2.

The ammonites indicating the biozones are shown in Plate 1.

Stratigraphy of the Bajocian south of Poitiers: the cliffs of Passelourdin

In Saint-Benoît, south of Poitiers, the Passelourdin cliffs in the Clain Valley provide an opportunity to observe the stratigraphy of the Lower and Upper Bajocian. The area has been briefly described by various authors (Gabilly, 1978; Benvel, 1978; Mourier et al., 1986). The cliff provides a detailed description of the Bajocian deposit sequences, thus providing a precise stratigraphic framework for this stage for the study of the results obtained at the Hydrogeological Experimental Site (HES) of the University of Poitiers.

The structural context is linked to the Ligugé horst (Fig. 3). The site is in fact at the center of a horst bounded to the south by the Mauroc fault and to the north by the Saint Benoît fault (Benvel, 1978). The Mauroc fault is parallel to the Ligugé horst faults and has a southward offset of approximately 10 to 12 m. It is not sufficient to bring the Bajocian and Pliensbachian into contact, as the Toarcian marls are approximately 22 m thick (see section of borehole 05894X0053/1030 on the horst). Together with the Saint Benoît fault, it thus delimits a small horst within which the equivalent of the Bajocian III of Benvel, 1978, in Figure 3 (Gaillard and Branger, 2024) outcrops.

A new survey was conducted in February 2025 with the help of a rope access technician. Due to very dense vegetation, the description is based on a synthetic survey of the entire height of the cliff (“survey with climbing”), illustrated by photographs (Plate 2).

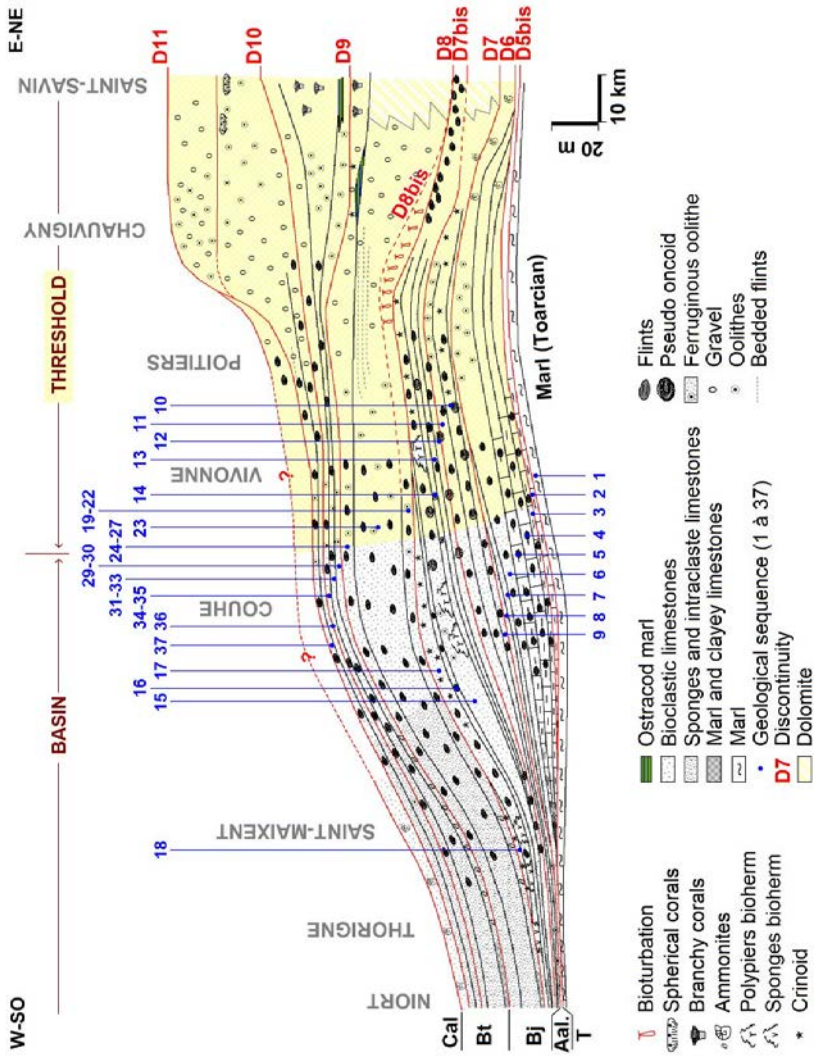


Figure 2 Geometry of strata of the Middle Jurassic on the Poitou threshold.

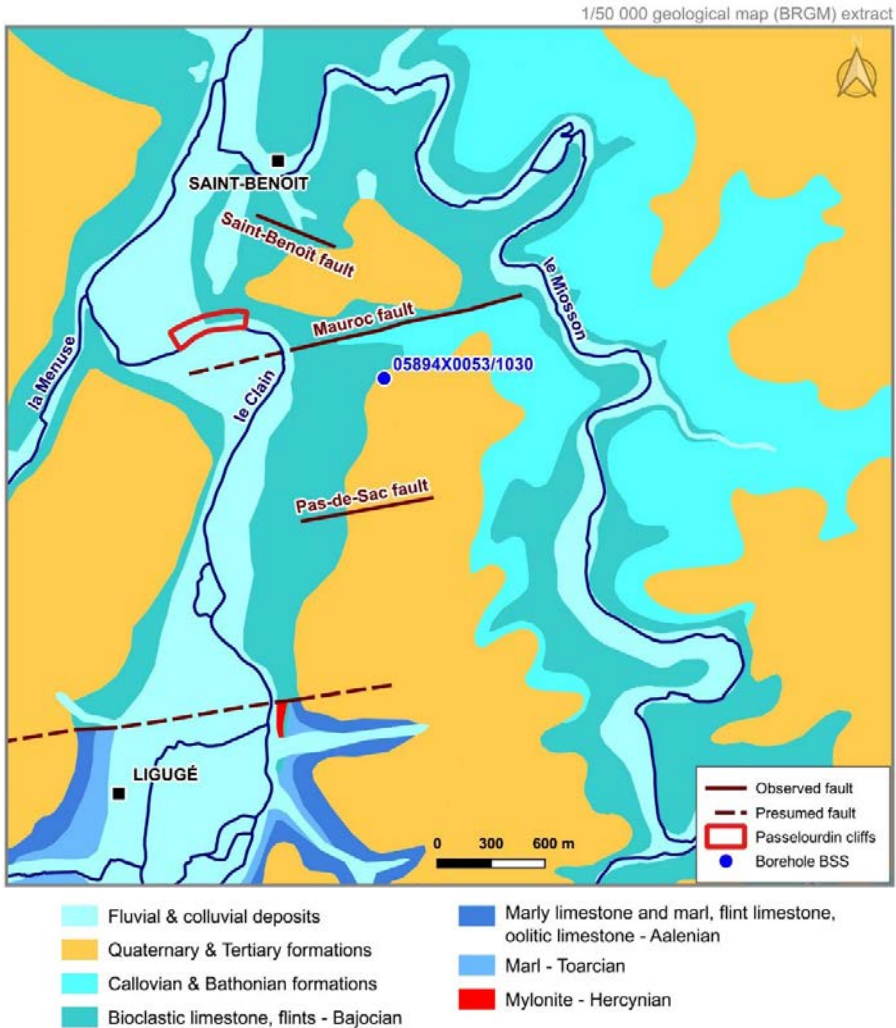


Figure 3 Geological map of the site (after Mourier et al., 1986).

Figure 4 shows the location of the different sections of cliff observed.

The oldest formations are observed at points known as “Yews n° 1 and n° 2.” At point n° 1, the presence of *Graphoceras concavum* identifies the Upper Aalenian. This ammonite is located immediately below a bank of white oolites, which is itself topped by banks of bivalves (Fig. 5). These two banks are thought to represent the *Laeviuscula* zone (not observed), with the D7 discontinuity (leveled at an altitude of approximately 78 m) as a marker for the base of the Lower Bajocian. The “Yews n° 3” site is located at a higher altitude (the zone between “Yews 1 and 2” and “Yews 3” is not observable) and allows the identification of the white oolitic

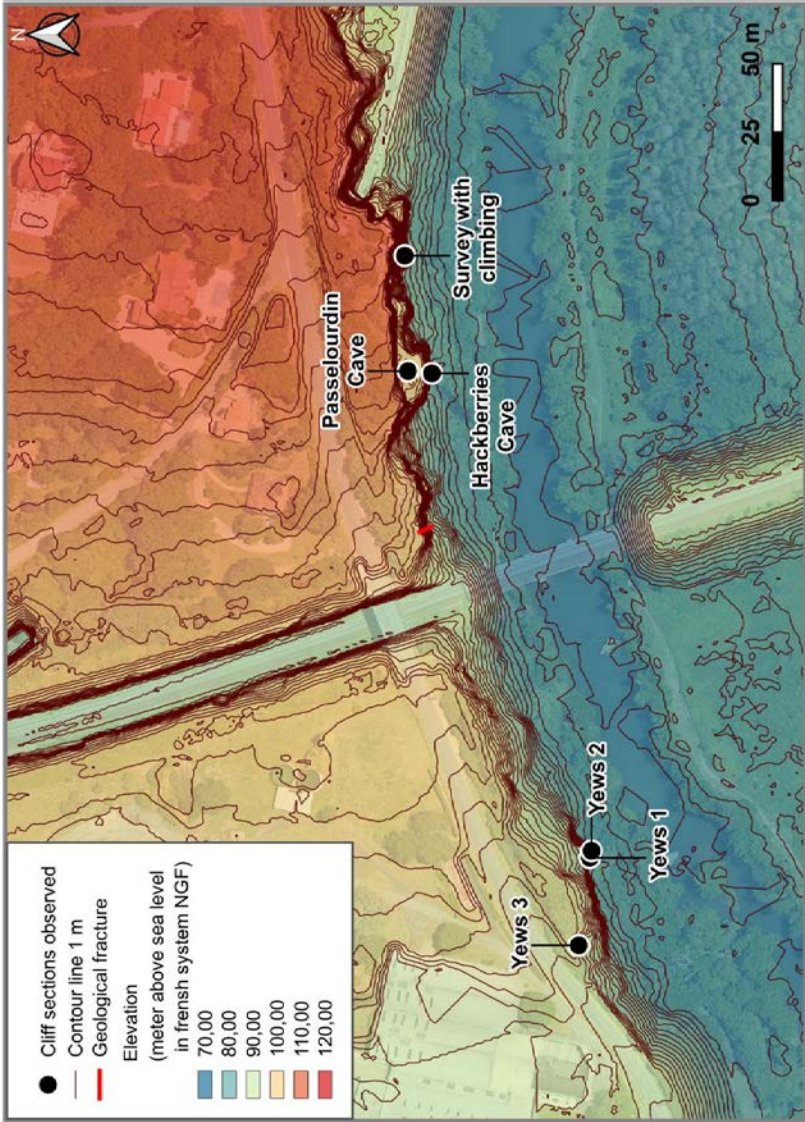


Figure 4 Status of geological surveys in Passelourdin.

limestone marking the end of the *Laeviuscula* zone, D7bis, located at an altitude of approximately 91.0 m. The thickness of the *Laeviuscula* and *Propinquans* formations is estimated to be at least 13 m.

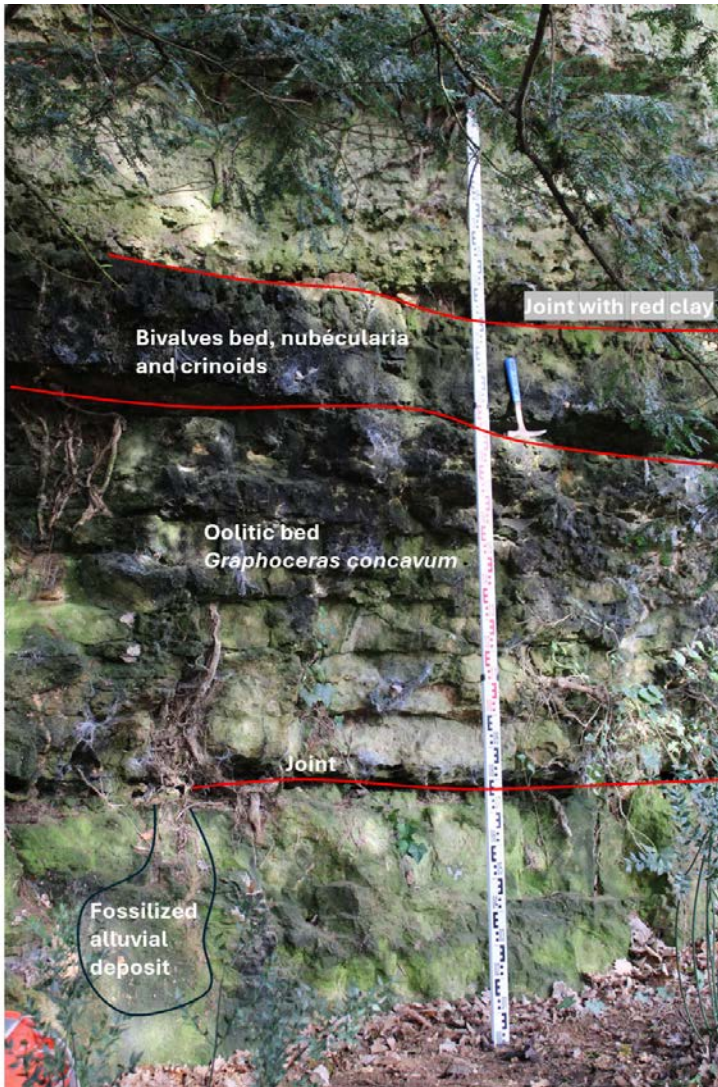


Figure 5 *Aalenian/Bajocian transition.*

In the east, the “survey with climbing” allows the entire height of the cliff to be recognized from the Lower Bajocian, with the continuity of a joint in the “ash cave,” where dolomitized limestones with *Trichites* are observed in metric benches ending in a level of small decimeter-sized vacuoles.

The cavernous dolomite is topped by an oolite bed identified as the last term of the *Laeviuscula* zone, placing the D7 bis discontinuity at an altitude of 90.6 m at this point (Fig. 6).



Figure 6 Oolitic facies from top of *Laeviuscula* biozone.

The upper parts could not be observed directly by a geologist (and cannot be sampled). They are illustrated by plate n° 2. Above the D7bis, the *Humphresianum* zone has a lower vacuolar level. The upper vacuolar level is illustrated by photograph 5. Above a ledge, decimetric and ovoid cavernous forms have developed (photograph 4, plate 2).

Discontinuity D8 is observed at an elevation of approximately 101 m, in the form of a karst joint (photograph 3) located above a nodular bench approximately 0.55 m thick that continues into the cliff. At the same place, at the “Passelourdin cave,” the cave floor rests on the pebble bench attributed by the authors to the reference level at the base of the *Niortense* zone, placing D8 at an altitude of approximately 99 m.

Above the D8, the burrowed zone (Gabilly, 1978) is illustrated by photographs 1 and 2. This formation corresponds to limestone with tubular structures several meters thick on the “survey with climbing” and at the “Passelourdin cave.” This formation corresponds to the beginning of the Upper Bajocian and ends with the D8bis discontinuity, which marks the upper limit of the *Garantiana* zone. These vertical burrow banks are overlain by hard limestone belonging to the *Parkinsoni* zone above the D8bis discontinuity.

Figure 7 shows the correlations between the cliffs observed, the discontinuities and the location of the photographs (plate 2).

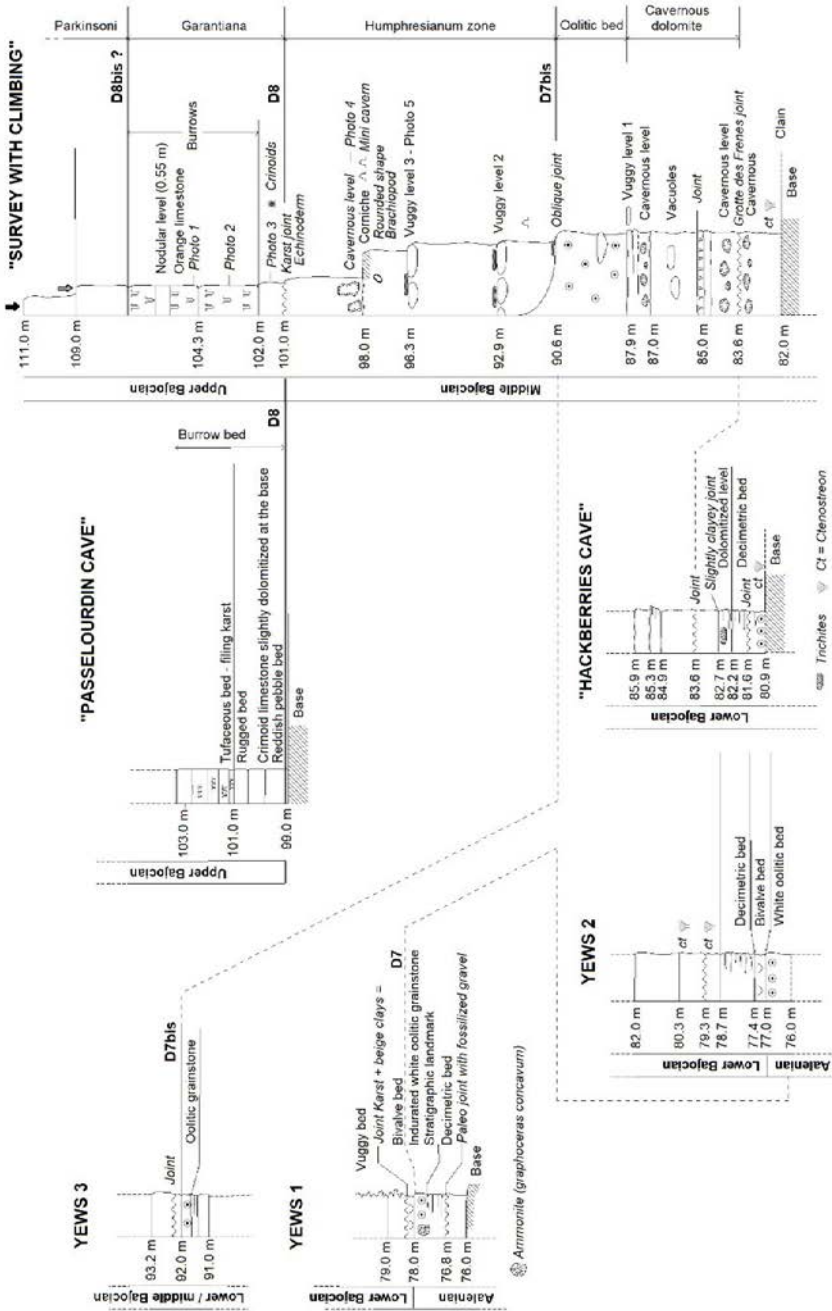


Figure 7 Logs from survey with climbing at Passelourdin cliff.

By comparing the different observation points on the Passelourdin cliffs, it is possible to see the very clear discontinuities along which the cavities are aligned. The dolomitized benches and vacuole zones are contained between the discontinuities previously identified by the authors:

- the Lower Bajocian (*Laeviuscula* zone) forms a locally dolomitized sequence constituting the karst at the base of the Bajocian, located between elevation 78 m (D7, top of the Aalenian) and below elevation 91 m (D7bis);
- above the *Laeviuscula* zone and D7bis, hollowed-out conduits line this surface, while overhanging benches feature aligned subhorizontal voids (vacuolar levels, Fig. 5). This complex ends with the pebble surface of the 'Passelourdin cave' (D8). This karst is therefore located between 91 and 99 to 101 m;
- above D8 and an altitude of 101 m, karst is initiated within the tubular limestones (burrowed zone). This so-called 'upper' karst has deepened to the pebble bench (D8), where the harground has limited its development.

Conclusion

The depositional sequences of the Poitou threshold end with discontinuities that appear to have planned the lower strata. These discontinuities allow correlations between, on the one hand, the distal facies in the Aquitaine basin and, on the other hand, the proximal facies in the center of the threshold defined by tectonics (Gaillard and Branger, 2026).

This precise stratigraphic framework allows to characterize the cliffs around Poitiers and highlight karst levels consisting either of cavernous levels in the *Laeviuscula* and *Humphriesianum* horizons or along discontinuities. These levels are developed and may have been filled with sediments (red clay or alluvial facies).

With this stratigraphic diagram, the position of the karstified levels can be more easily understood. The levels are not arranged randomly but are located at the edge of deposits or are concentrated within certain biozones in the form of vuggy levels.

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Plate 1 : Ammonites

Unless otherwise indicated, all ammonites come from the southern Deux-Sèvres region. Collection and photos P. Branger.



1 - *Leioceras opalinum* 28 cm
(block length)



2 - *Ludwigia murchisonae* (Ø 20 cm)



3 - *Brasilgia gigantea* (Ø 14.5 cm)



4 - *Graphoceras concavum* (Ø 13 cm)



5 - *Hyperlioceras discites* (Ø 12.5 cm)
(Charente)



6 - *Sonninia adicra* (Ø 14 cm)

2. The stratigraphy of the Middle Jurassic



7 - *Witchellia romanoides* (Ø 10 cm)



8 - *Sonninia propinquans* (Ø 14 cm)



9 - *Stephanoceras scalare* (Ø 16.5 cm)



10 - *Strenoceras niortense* (Ø 5.3 cm)



11 - *Garantiana garantiana* (Ø 6 cm)



12 - *Parkinsonia parkinsoni* (Ø 19 cm)



13 - *Zigzagiceras zigzag* (Ø 5.5 cm)



14 - *Procerites progradilis* (Ø 12 cm)



15 - *Morrisiceras morrissi* (Ø 11 cm)



16 - *Cadomites bremeri* (Ø 7.6 cm)



17 - *Prohecticoceras retrocostatum*
(Ø 5 cm) (Sud Deux-Sèvres)



18 - *Clydoniceras discus* (Ø 9 cm)
(Sud Deux-Sèvres)

Plate 2 : Passelourdin

Photographs M. Chollet.



Photo 1



Photo 2



Photo 3



Photo 5



Photo 4