The Chabert Formation : a newly defined stratigraphic unit of late early Aptian age in the souther Ardèche, SE France

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The Chabert Formation
a newly defined stratigraphic unit of late early Aptian age in the southern Ardèche, SE France

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Abstract

The subsiding Vocontian Basin in SE France was an important depocenter during the late Early Cretaceous. The rims of this basin were occupied by large carbonate photozoan platforms, locally known as "urgonian" platforms. During the late early Aptian, open marine heterozoan marls and carbonates accumulated on top of these former platforms, followed later by thick clayey sandy marls. In this succession, sediment accumulation was interrupted by several drowning phases which lead to hiatuses, encompassing up to several ammonite subzones. Such sedimentary successions are particularly well known in the Bas-Vivarais area of the Ardèche department (SE France). These sediments were mapped by the Bureau de Recherches Géologiques et Minières (BRGM) under various names whose definitions are imprecise and do not obey the rules of the stratigraphic nomenclature. Therefore, a compilation and revision of the available litho- and biostratigraphic data of the late early Aptian on the Languedoc platform is necessary to clarify the local stratigraphy. Here a new lithostratigraphic formation (the Chabert Formation) is proposed based both on lithological and sedimentologic criteria as well as ammonite biostratigraphy. In agreement with the nomenclature rules of lithostratigraphy, the type section and locality of the Chabert Formation are proposed for a section outcropping near the Chabert farm (SE Ardèche). This formation consists of heterozoan sediments (marls and crinoidal limestones) spanning the upper Deshayesites forbesi *to the upper* Dufrenoyia furcata *ammonite Zones. The Chabert Formation is subdivided into three members - the Violette, Rocherenard, and Picourel Members, respectively. Above the Chabert Formation, black marls of late Aptian age (uppermost* Dufrenoyia furcata *Zone and above) are present, which we propose to name as Frayol Formation.*

Keywords: *Ardèche-Gard region, Early Cretaceous, late early Aptian, lithostratigraphy, Chabert Formation, platform drowning, palaeoenvironmental change*

Résumé

La Formation de Chabert – une nouvelle unité lithostratigraphique d'âge Aptien inférieur élevé dans le sud de l'Ardèche, sud-est de la France.– *Situé dans le SE France, le bassin vocontien était une zone subsidente où se déposaient d'importants dépôts sédimentaires pendant la fin du Crétacé inférieur. Les bords de ce bassin étaient occupés par de grandes plates-formes carbonatées photozoaires. Au cours de la fin de l'Aptien inférieur, des marnes et des carbonates hétérozoaires de mer plus ouverte se sont accumulés sur ces anciennes plates-formes, suivis plus tard par d'épaisses marnes argilo-silteuses. Dans cette succession, l'accumulation de sédiments fut interrompue par plusieurs phases consécutives d'ennoiement qui conduisirent à des hiatus pouvant couvrir jusqu'à plusieurs sous-zones d'ammonites. Ces successions sédimentaires sont particulièrement bien connues dans le Bas-Vivarais (département de l'Ardèche, SE de la France). Ces sédiments furent cartographiés par le Bureau des Recherches Géologiques et Minières (BRGM) sous différents noms dont les définitions sont imprécises et n'obéissent pas aux règles de la nomenclature stratigraphique. Par conséquent, une compilation et une révision des données lithologiques et biostratigraphiques disponibles de l'Aptien inférieur de la plateforme du Languedoc est nécessaire pour clarifier la stratigraphie locale. Une nouvelle formation lithostratigraphique (la*

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Formation Chabert) est proposée dans le présent papier, basée à la fois sur des critères lithologiques et sédimentologiques, ainsi que sur la biostratigraphie par ammonites. En accord avec les règles de nomenclature lithostratigraphique, la section et la localité type de la Formation Chabert sont proposées pour un affleurement situé près de la ferme de Chabert (SE de l'Ardèche). Cette formation se compose de sédiments hétérozoaires (marnes et calcaires crinoïdaux) couvrant la partie supérieure de la Zone à Deshayesites forbesi *jusqu'à la fin de la Zone* Dufrenoyia furcata. *La Formation Chabert est subdivisée en trois membres - respectivement les membres de la Violette, de Rocherenard et de Picourel. Au-dessus de la Formation Chabert, des marnes noires (Formation Frayol) d'âge Aptien supérieur (extrême fin de la Zone à* Dufrenoyia furcata *et suivantes) sont présentes.*

Mots-clefs: *Ardèche-Gard, Crétacé inférieur, Aptian inférieur tardif, lithostratigraphie, Formation Chabert, ennoyement de plate-forme, changements paléoenvironmentaux*

1. Introduction

During the late Early Cretaceous, the Vocontian Basin was an important depocenter on the northwestern Tethyan margin. During the Barremian and earliest Aptian, large photozoan carbonate factories bordered the basin except for its eastern margin leading to the formation of the large, "Urgonian" carbonate platforms (Masse, 1976; Arnaud-Vanneau et al., 1979; Arnaud-Vanneau, 1980; Arnaud, 1981). Following the demise of the photozoan Urgonian platform during the early Aptian, the carbonate "factory" changed and open marine, heterozoan sediments dominated by marl and crinoidal limestone were deposited (Delamette, 1986; Föllmi, 1986; Linder et al., 2006; Pictet et al., 2015). In this time interval, sedimentation was interrupted by several emersion and consecutive drowning phases (Linder et al., 2006; Föllmi & Gainon, 2008; Masse & Fenerci-Masse, 2011; Pictet et al., 2015), which occurred: i) at the transition of the Urgonian platform carbonates to the overlying heterozoan sediments; ii) near the top of the heterozoan sediments; iii) and at the top of the heterozoan sediments below the upper Aptian marl and sandstone. These emersion surfaces are topped by phosphorites, which consist of decimetric condensed or reworked beds, encompassing up to several ammonite subzones or zones (Linder et al., 2006; Föllmi and Gainon, 2008; Pictet et al., 2015).

Historically, the upper part of the Urgonian Formation is called the upper Urgonian Member (see Arnaud and Arnaud-Vanneau (1990) for the definition of the Urgonian Formation and its members) and consists of photozoan carbonate of early Aptian age. The term "Aptian" was first introduced by d'Orbigny (1840) to describe the upper "Neocomian" ammonite fauna. D'Orbigny (1840) proposed to name the upper Neocomian layers "Aptian" in reference to the Apt valley in the Vaucluse Department. Later, Matheron (1842a, b) was the first to observe the sections at La Bédoule, stratotype of the unofficial "Bédoulian" Substage (Toucas, 1888; early Aptian; Bouches-du-Rhônes, SE France). He described two distinct units: i) a lower unit composed of 30 m of blue-grey limestone and marly limestone (*Calcaires marneux D et E*; Fig. 1); ii) an upper unit consisting of 30 m of blue-grey marl with abundant belemnites (*Marnes néocomiennes F*; Fig. 1). Hebert (1872) reproduced the observations of Reynès (1861) in the same area, but added the ammonite fauna (*Ammonites nisus*, *A. dufrenoyi* and *A. martini*) from the marl composing the upper unit.

Dumas (1876) reported two comparable and correlatable units in the Gard department (SE France) as part of the "*Argiles à Plicatules*", in reference to the "*Argiles à Plicatules*" of the Paris Basin (D'Orbigny, 1842; Fig. 1). Dumas (1876) described the lower unit as a 8 to 10 m succession of yellow marl and sandstone on top of the Urgonian limestone, which he called "*Sous-étage inférieur A*" (Fig. 1). The upper unit was described by Dumas (1876) as a 30 to 35 m series of blue marl containing pyritized ammonites (*A. nisus, A. martini,* and *A. dufrenoyi*) and named as "*Sous-étage supérieur B*" (Fig. 1)

In the Ardèche department (SE France; Fig. 2), Carez (1882) documented a succession comparable to the lower unit from La Bédoule and Gard under the name of "*Calcaires marneux à Ostrea aquila et céphalopodes*" (Fig. 1), which occurs equally on top of the Urgonian limestone. Later, Sornay (1962) described this formation more precisely in the vicinity of Saint-Montan, in the Ardèche department (Fig. 2). The interval of interest is 6 to 8 m thick and consists of sandy marly limestone, which becomes richer in carbonates towards the top. This unit overlies a sedimentary discontinuity, which marks the boundary with the Lafarge limestone (Kilian and Reboul, 1915, p. 8) corresponding to a lateral, hemipelagic equivalent of the Urgonian Formation. Kilian and Reboul, 1915 reported on the Ardèche side of the Rhone River a 100 m thick succession of nodular marly limestone above the Lafarge limestone, which they informally called "*Marno-calcaires de la Violette*" (Fig. 1).

Based on the observations in Ardèche and Gard, Carez (1882) defined the equivalent of the upper unit of La Bédoule and the Languedoc platform as

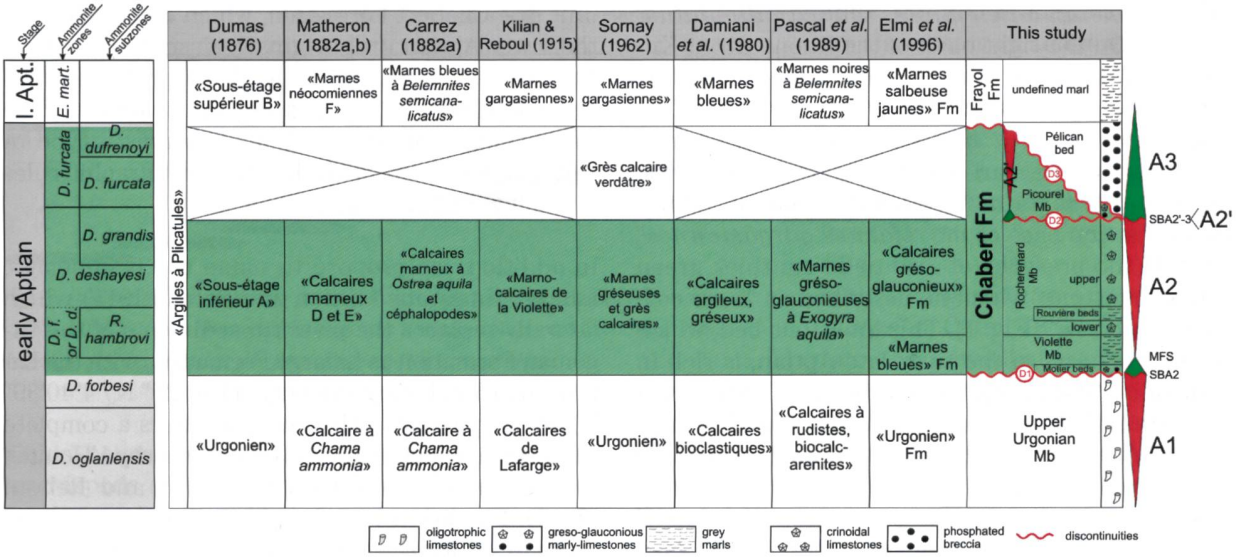


Fig. 1: Table of the various names given in the BRGM notices to the upper lower and lower upper Aptian sediments on the Languedoc platform (Pont-St.-Esprtit, Aubenas, and Bourg-St.-Andéol maps). On the left side the ammonite zones and subzones (following Ropolo et al., 2006, 2008b; Reboulet et al., 2011, 2014) are reported, and on the right side, the new terminology, the sediment types, and the sequential stratigraphic interpretation.

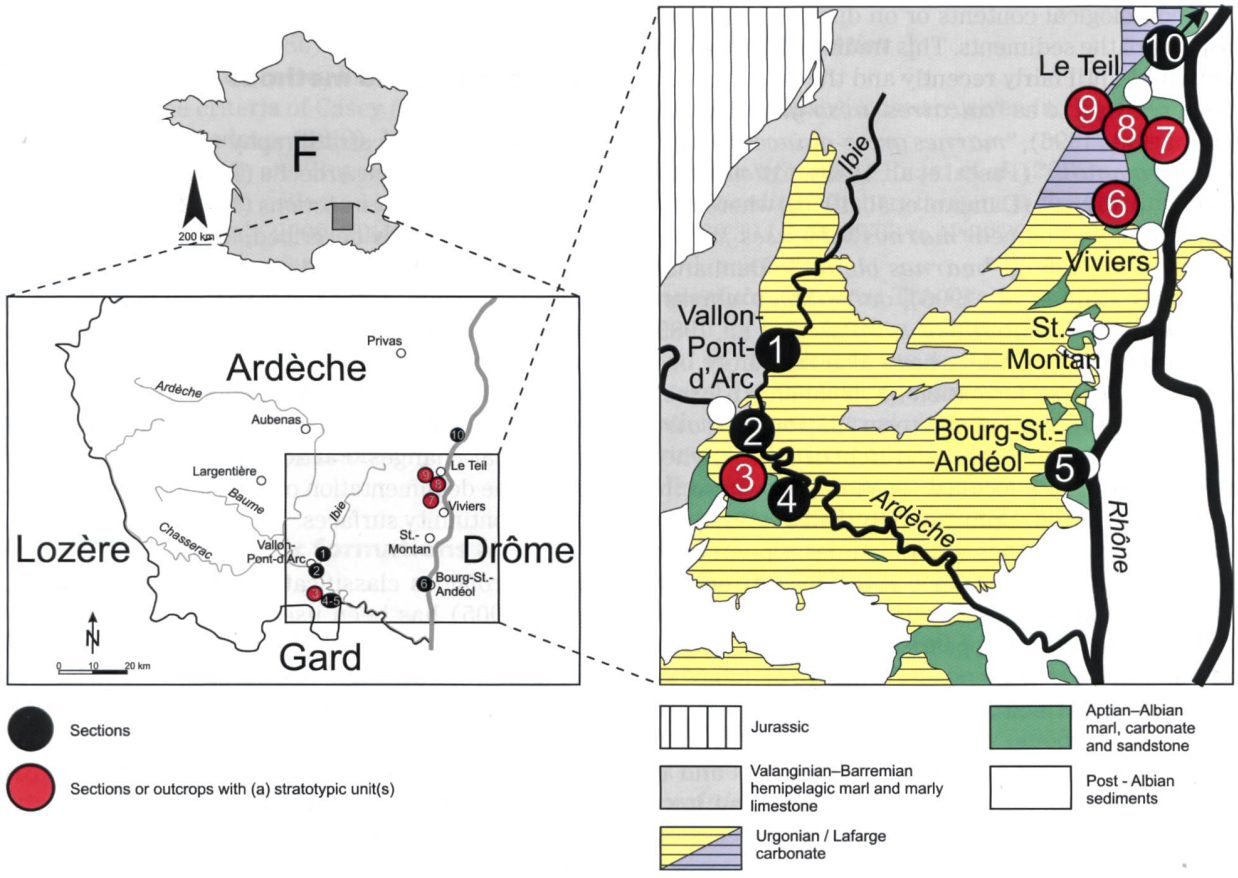


Fig. 2: Geographical map of the south Ardèche department (SE France) and the position of the sections: '1' Michelet (N 44°25'37" / E 04°25'50"); '2' Mezelet (N 44°23'33" / E 04°24'10"); '3' Picourel (N 44°21'26" / E 04°22'19"); '4' Labastide de Virac (N 44°21'18" / E 04°24'34"; '5' Bourg-St.-Andéol (see section description); '6' Chabert (N 44°30'39" / E 04°39'03" to N 44°30'54" / E 04°38'54"); '7' La Violette area (N 44°32'01.7" / E 04°40'59.1"); '8' La Rouvière area (N 44°32'13.9" / E 04°39'53" to N 44°32'12.6" / E 04°39'33.5"); '9' Pélican (N 44°32'14" / E 04°39'10" to N 44°32'27" / E 04°39'22"); '10' Les Ribes (N 44°37'07" / E 04°44'01" to N 44°37'14" / E 04°43'53"). The red points represent the stratotype sections.

"*Marnes bleues à Belemnites semicanaliculatus*" (Fig. 1). On the right bank of the Rhone River, Kilian and Reboul (1915) reported the presence of the "*Marnes gargasiennes*" (early late Aptian; Fig. 1) containing *Oppelia nisus* and *Neohibolites aptiensis* above the marl-limestone alternations of the "*Marno-calcaires de la Violette*". Sornay (1962) noticed at the base of the "*Marnes gargasiennes*" (Fig. 1) the presence of a 10 to 20 cm thick green sandy limestone, which he described as "*Grès calcaire verdâtre*" (Fig. 1). This limestone bed, which marks the onset of the early late Aptian, is rich in glauconite and phosphatized fossils (*Dufrenoyia* aff. *lurensis*, *D.* sp. ex gr. *lurensis*, *Epicheloniceras* cf. *martini*, *E. occidentalis*, *Nautilus* sp., *Duvalia grasiana*, *Neohibolites semicanaliculatus*, *N.* sp. ex gr. *aptiensis*, *Plicatula placunea*, *Ostrea* sp. *Rhynchonella* sp. ex gr. *multiformis*, *R. lata* var. *minor*, *Sellithyris* sp., debris of echinoids, gastropods and solitary corals).

The history of the lithostratigraphic nomenclature used for the two Aptian units in southeastern France demonstrates that it has been mainly based on the palaeontological contents or on distinct lithological aspects of the sediments. This tradition has been perpetuated until fairly recently and the lower unit has been referred to as "*calcaires gréso-glauconieux*" (Elmi et al., 1996), "*marnes gréso-glauconieuses à Exogyra aquila*" (Pascal et al., 1989), "*calcaires argileux, gréseux*" (Damiani et al., 1980), whereas the upper unit was named "*marnes sableuses jaunes*" (Elmi et al., 1996), "*marnes bleues*" (Damiani et al., 1980; Elmi et al., 1996), or "*marnes noires à Belemnites semicanalicatus*" (Pascal et al., 1989). Moreover, the two units have also randomly been defined either as formation or member. An exception is the proposal of the term "*Marno-calcaires de la Violette*" by Kilian and Reboul (1915), where they referred to a locality (la Violette), where this unit was exposed. Unfortunately, Kilian and Reboul (1915) did not provide a detailed description of the section at this locality. Since at this locality only the lowermost part of the unit studied here is preserved, the use of this name appears meaningful in the definition of the lower member ("Violette Member") of the newly described formation.

A compilation and a revision of the litho- and biostratigraphic data of the upper lower and lower upper Aptian sediments in the Ardèche is necessary to clarify the local stratigraphy, in accordance with the rules of the International Stratigraphic Commission (ISC) stating that each lithostratigraphic unit is a body of rock that should be defined by a geographic component, its lithologic properties and its stratigraphic relation (Hedberg, 1976). With this study, we suggest the definition of a new lithostratigraphic unit, the Chabert Formation, which corresponds to the lower Aptian unit originally described as "*Calcaires marneux à Ostrea aquila et céphalopodes*" by Carez (1882). The type section is located near the Chabert farm (SE Ardèche), which serves as type locality in agreement with the lithostratigraphic rules of the ICS.

In addition, we propose to name the hemipelagic Lafarge limestone (Kilian and Reboul,1915) which laterally replaces the platform sediments of the Urgonian Formation as Lafarge Formation, with the Lafarge quarry (Lafarge locality, 44°31'20" N / 4°40'39" E) as type locality. This outcrop offers a complete succession, which is not the case in nearby L'Homme d'Arme quarry described by Kilian and Reboul (1915). Furthermore, we suggest the name "Frayol Formation" for the "*Marnes bleues à Belemnites semicanaliculatus*" of Carez (1882), which crop out along the Frayol river, between Mélas (44°32'31" N / 4°40'38" E) and le Pont Neuf (44°33'11" N / 4°39'23" E) as type locality. These two formations and the sections at the type localities remain in need of a detailed definition and description.

2. Materials and methods

The revision of the stratigraphy of the upper lower Aptian interval in the Ardèche (Languedoc platform) has been based on ten sections (Fig. 2) which eight of them were carefully described, logged and sampled. Sequence stratigraphy, sedimentology, and ammonite biostratigraphy were applied to each section (Pictet et al., 2015), while microfacies analyses (thin sections) have been taken in key sections (Michele, Picourel, Bourg-St.-Andéol, and Chabert) at a variable sampling space (few centimetres to a metre) depending on the lithological changes. Particular attention has been paid to the documentation of depositional geometries and discontinuity surfaces.

The microfacies classification of Arnaud-Vanneau (1980, 2005) has been used to describe the environmental changes in order to infer the sea-level changes (Fig. 3). This classification comprises 11 types of microfacies ranging from F0 to F11, which documents environments along the platform transect going from the outer shelf to the beach. Microfacies types shallower than F5 are not present in the studied sections. An additional microfacies type - FT (transgressive facies) has been used to define the transgressive sediments capping the drowning surfaces according to Blanc-Alétru (1995).

Palaeoecological interpretations have been based on the microfacies and on the collected macrofauna, which is composed of cephalopods (ammonites, nau-

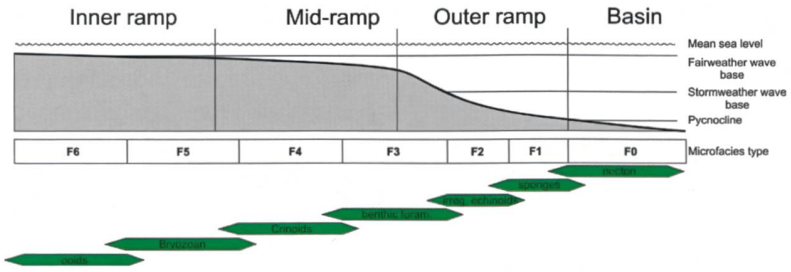


Fig. 3: Distribution of the first seven microfacies types of Arnaud-Vanneau (1980, 2005) in a schematic transect of a distally steepened carbonate ramp throught the Languedoc platform during the early Aptian.

tiloids, belemnites), gastropods, bivalves, serpulids, brachiopods, sponges, corals and fishes. These macrofossils have been used to infer environmental conditions, i.e. depth, temperature, luminosity, nutrients, and currents.

Ammonite stratigraphy has been based on the zonal scheme of the Tethyan region proposed by the IUGS Lower Cretaceous "Kilian Group" during the 4th and the 5th International Meeting (Reboulet et al., 2011, 2014), and also on the contributions by Ropolo et al. (2006, 2008b) on the stratotype from La Bédoule. The ammonites have been determined according to the criteria of Casey (1960-80), Dutour (2005), Moreno-Bedmar (2010), Moreno-Bedmar et al. (2009, 2010, 2012), and Ropolo et al. (2006, 2008 a-b). The bed-by-bed collected ammonites (partly figured in Pictet et al., 2009, 2015) are represented by a black ammonite symbol on the sections. In addition, fossils collected on the same sections for other studies (e.g. Sornay, 1958, 1962; Contensuzas, 1980; Elmi et al., 1996; Clavel et al., 2013) have also been considered. Ammonites supplementing our collections are represented by red (Clavel et al., 2013) and by green (Sornay, 1962) symbols.

3. Lithostratigraphic formations and sub-units

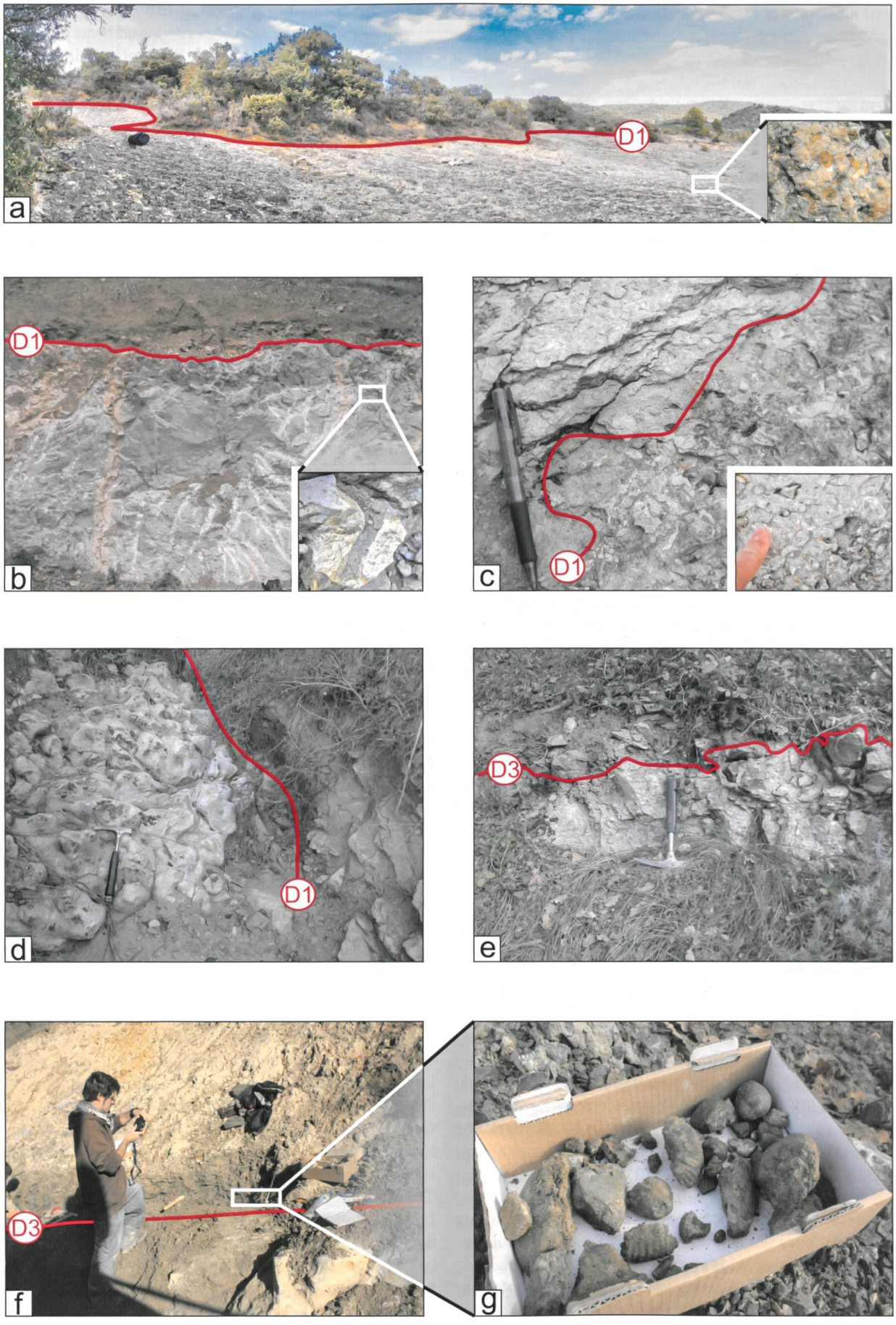
In the studied sections, the lithostratigraphic subdivisions reveal three main lithologies: i) photozoan limestone (rudist-coral-miliolid-dasycladacea assemblage); ii) heterozoan sediments (grey marl and crinoidal limestone with a sponge-crinoid-bryozoan-brachiopod assemblage); iii) grey to black marl. In the field, these lithologies show different ecological (e.g. oligotrophic to meso- and eutrophic) and lithological characteristics (e.g. carbonate to marl or sandstone). The most important lithological marker horizons between or within each type of lithology are formed by erosional surfaces, hardgrounds and firmgrounds. These particular lithological features are associated with significant hiatuses. Within these units, gradual lithological changes are also observed, and together with the distinct discontinuities, they allow to distinguish sub-units, members and beds.

The heterozoan sediments intercalated between the Urgonian limestone and the black marl ("*Marnes bleues à Belemnites semicanaliculatus*" of Carez, 1882) are grouped into the new Chabert Formation. This formation comprises three members, the Violette Member embodying the basal marly interval, the Rocherenard Member composed of crinoidal limestone, and the Picourel Member representing a glauconitic marly limestone interval forming the upper part of the Chabert Formation. The Violette Member comprises a basal sub-unit, the Motier Beds, which are enriched in carbonate relative to the remainder of the member. In the middle of the Rocherenard Member, a marly interval corresponds to the Rouvière Beds.

3.1. Chabert Formation

Names previously in use are given in Fig. 1.

Creation of name: Pictet et al. (2015)
Type locality: Chabert farm, near Viviers, Ardèche; N 44°30'39 / E 04°39'03 to N 44°30'54" / E 04°38'54"; Fig. 2, point 6.
Underlying strata: The Chabert Formation overlies, in its type locality, a discontinuity surface D1 (Fig. 4d) limiting to the top the Lafarge Formation (lateral, hemipelagic equivalent of the Urgonian Formation) of the external platform. Laterally, on the internal platform, the Chabert formation is downward delimited by the same discontinty D1 which terminates the photozoan rudist-coral-stromatoporoid-bearing limestone of the Urgonian Formation (Fig. 4a to c). The upper part of the Urgonian / Lafarge Formations corresponds to the *Deshayesites forbesi* Zone as suggested by the presence of the ammonites *Deshayesites weissi* and *Procheloniceras albrechtiaustriae* previously described by Kilian & Reboul (1915) and Sornay (1958) in the nearly l'Homme-d'Armes quarry (Drôme, SE France).
Overlying strata: The top of the Chabert Formation is separated from the overlying Frayol Formation by the discontinuity surface D3 (Fig. 4e and f). The D3 discontinuity is usually topped by a phosphatic conglomerate (the Pélican bed; Fig. 4g) of the uppermost *Dufrenoyia dufrenoyi* Subzone dated by the non-phosphatized index fossil (*D. dufrenoyi*) and primitive forms of *Epicheloniceras* (Pictet et al., 2015).


D1
a
D1
b
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c
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d
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e
D3
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g

Subdivision (from base to top): Violette Member, Rocherenard Member, Picourel Member.
Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).
Equivalent: La Bédoule marly-limestones (Ewald, 1850; Provençal platform), Upper Orbitolina Beds (Dauphiné platform; Burckhardt, 1896), Grünten Member (Helvetic platform; Linder et al., 2006; Föllmi and Gainon, 2008).
Thickness: 0 to 64 m from the internal to external parts of the platform.
Biostratigraphic age: Late early Aptian, upper *D. forbesi* Zone to uppermost *D. dufrenoyi* Subzone (Pictet et al., 2015).
Description: The Chabert Formation consists mostly of sandy marl and carbonate with a significant amount of detrital minerals (e.g. quartz), glauconite (crusts and grains), and phosphates (grains, clasts, and coated pebbles). More specifically, the Chabert Formation begins with the marl of the Violette Member, continues with the crinoidal limestone of the Rocherenard Member and ends with the glauconitic and partly phosphatic Picourel Member. A mesotrophic carbonate-producing community is preserved in these last two members and is composed of crinoids, bryozoans, endobiont bivalves, sea urchins, and ammonites. At the type locality near the Chabert farm, the sedimentary succession is well developed and includes the marly Violette Member and the crinoidal Rocherenard Member. The Picourel Member is absent in the Chabert section, but well documented in the Picourel section, the type locality of this member (Fig. 2, point 3). In more distal postion like the Ribes section (Fig. 5), distant of 15 km in direction of the northeast, the Chabert Formation is replaced by 5 metres of yellow marl rich in pyritic nodules and ammonites.

Fig. 4: ***a.*** *Discontinuity D1 separating the upper Urgonian Member from the Chabert Formation, in the Combe de Mars.* ***b.*** *Discontinuity D1 in the Mezelet section. The top of the Urgonian limestone is eroded, while the epikarstic pockets show three different generations of infills. The uppermost 3 m of the Urgonian limestone are bioturbated and the burrows (likely* Thalassinoides*) are infilled by glauconitic sand as shown in the boxes on the right side of the photo.* ***c.*** *Discontinuity D1 in the Michelet section showing the contact between the Urgonian Formation and the Motier Bed. This surface exhibits a karstic overprint and is covered with numerous burrows, bioperforations, and ferruginous and phosphatic crusts. Rudist shells in live position are completely dissolved and filled in by a reddish microbreccia, yellow micrite, and glauconitic sand* ***d.*** *Discontinuity D1 in the Chabert section, showing a densely bioturbated firmground at the top of the Lafarge Formation.* ***e.*** *Discontinuity D3 in the Michelet section, showing the erosion between the glauconitic limestone from the Picourel Member and the glauconitic sandy marl from the Frayol Formation.* ***f.*** *Discontinuity D3 in the Pélican section, constituting the boundary between the Chabert and Frayol Formations.* ***g.*** *Phosphatic fossils from the base of the Pélican Bed.*

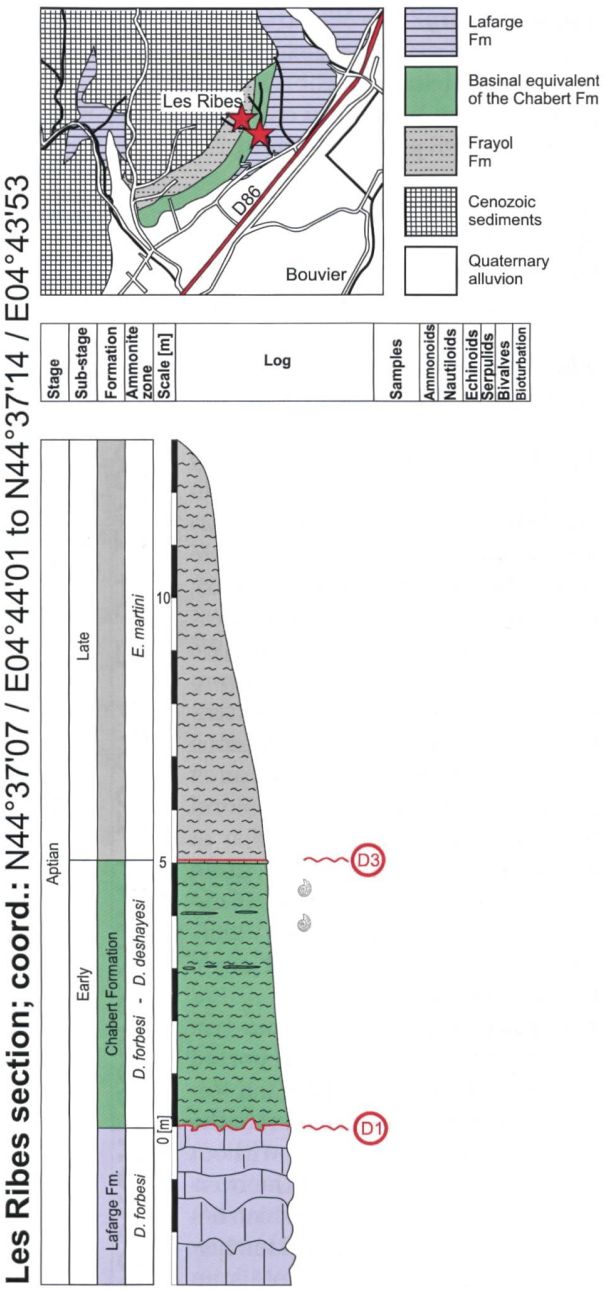

Fig. 5: Detailed section of Les Ribes outcrop, with the present fauna. The ammonites observed on this section are indeterminable pyritic forms.

3.1.1. Violette Member

Creation of name: Kilian & Reboul (1915).
Equivalent: Upper Errenaga Member (N. Spain; Millán et al., 2011).

Type locality: The Violette Member is named after the Violette hill, near Le Teil in Ardèche (Fig. 2, point 7), and outcrops well in the Viviers-Le Teil area; N 44°32'01.7" / E 04°40'59.1".

Subdivision: Motier Beds at the base of the member.

Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).

Thickness: 0.3 to 26 m from the internal to external parts of the former platform.

Biostratigraphic age: Late early Aptian, *D. forbesi* Zone *sensu* Moreno-Bedmar et al. (2009, 2010, 2012) and *Deshayesites deshayesi* Zone *sensu* Ropolo et al. (2000, 2006), and more precisely from the *Roloboceras hambrovi* Subzone. We prefer to not take position in the ongoing debate concerning the attribution of the *R. hambrovi* Subzone (Bersac and Bert, 2012; Skelton et al., 2013) to the *D. forbesi* (Moreno et al., 2007; García-Mondéjar et al., 2009; Moreno et al., 2009, 2010; Reboulet et al., 2011) or *D. deshayesi* Zone (Ropolo et al., 2000, 2006, 2008), since this is not the subject of the present contribution.

Previous studies: The marl of the Violette Member are reported for the first time by Kilian and Reboul (1915), who refer to marl in the southern part of the Teil without differentiating them from the overlying crinoidal limestone, which belongs to the Rocherenard Member. Sornay (1958) is the first to distinguish the ~30 m thick lower marly unit from the upper limestone unit to the northwest of Viviers. Pascal et al. (1989) observed a 40 m thick sedimentary succession overlying the Urgonian limestone near Bourg-St-Andéol, which is composed by a 15 m thick marly unit topped by 25 m of a yellow massive sandy limestone.

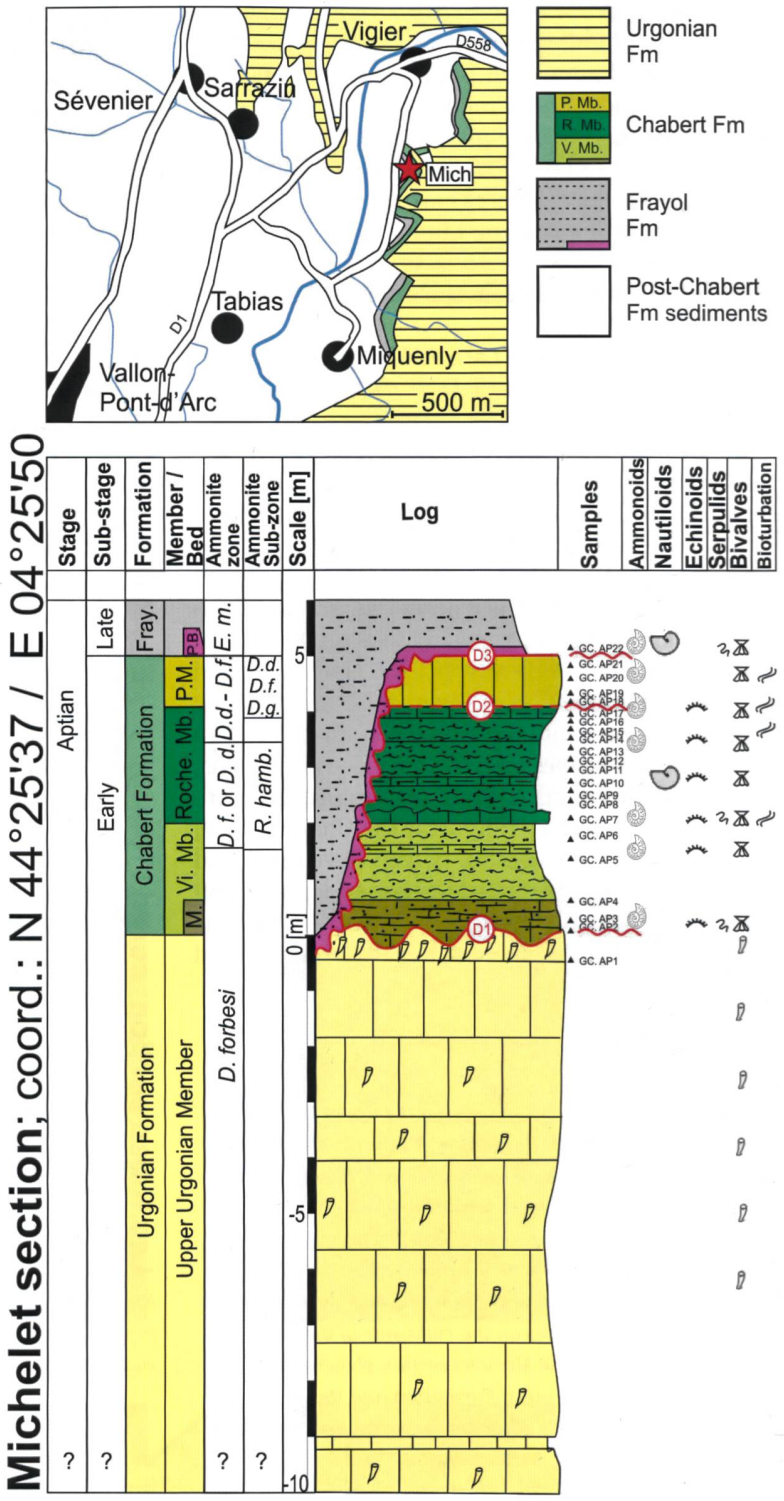

Fig. 6: Detailed section from Michelet outcrop (Mich.), with the reported sampled beds and the present fauna. Mb. = Motier Beds, Pico. F. = Picourel Fm, Fray. = Frayol Fm, Pél. = Pélican Bc, Desh. = D. deshayesi *Zone, Furc.* = D. furcata *Zone, Gran.* = D. grandis *Subzone, Dufr.* = D. dufrenoyi *Subzone.*

Description: The Violette Member, which may become yellowish with weathering, is either composed of blue-grey terrigenous mudstone or of sandy marl containing levels of carbonate nodules. The boundary with the underlying Urgonian Formation is defined by the discontinuity D1 (Pictet et al., 2015). On the former inner platform, a karstic surface covered with both numerous burrows and bioperforations, as well as ferruginous and phosphatic crusts, marks this discontinuity (Fig. 4c). Up to four suc-

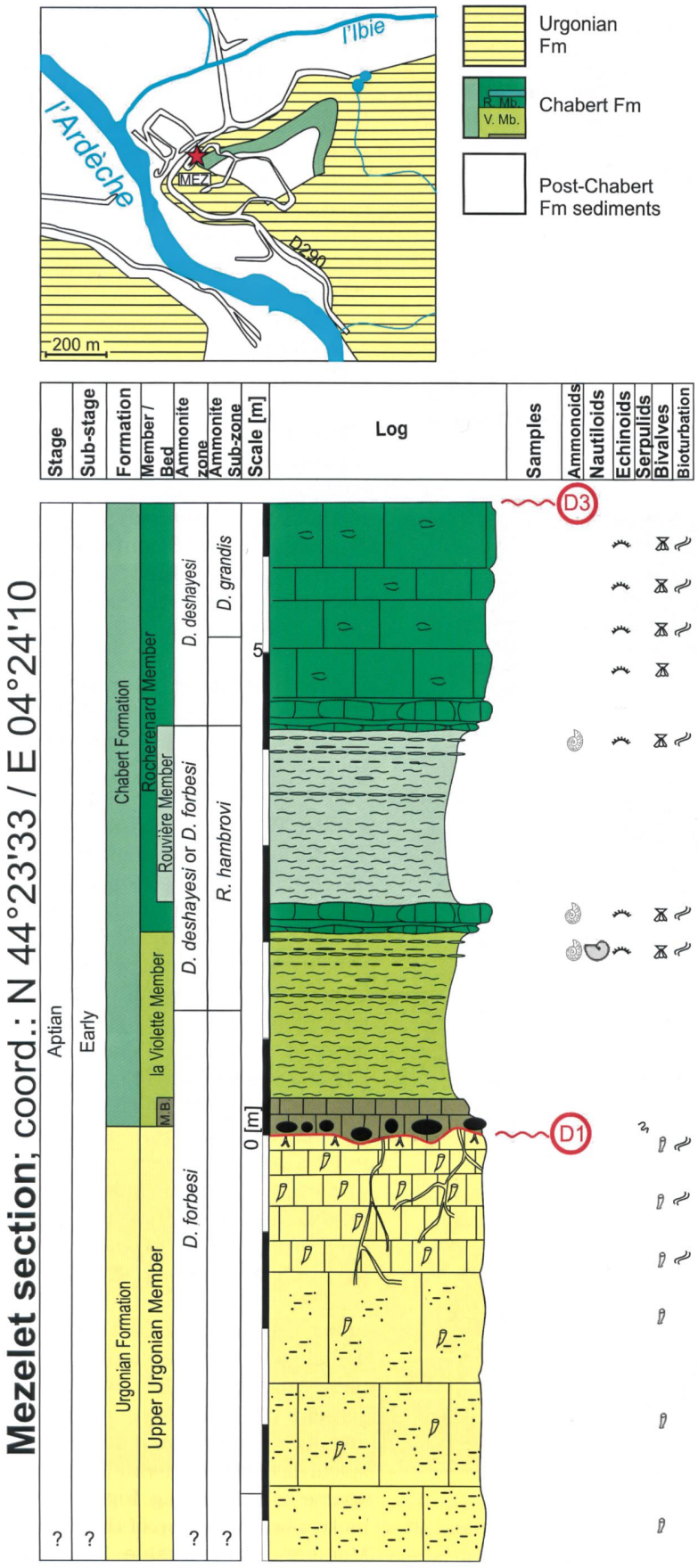

Fig. 7: Detailed section of the lower Aptian in the Mezelet outcrop (Mez.), with the present fauna. M.-M. = Motier Mb.

cessive phases of fillings consisting of terra rossa, lacustrine to palustrine, and marine sediments were observed in the epikarstic pockets (Pictet et al., 2015).

In this former platform area, the Violette Member starts above the discontinuity surface with the Motier Beds, which are topped by 0.3 to 2 m of grey marl (microfacies F3 to F0) rich in quartz, glauconite, and bioclasts (Michelet section, Fig. 6; Mezelet section, Fig. 7; and La Bastide-de-Virac section, Fig. 8; see chapter below; Fig. 9a). The macrofauna of the base of the Violette Member is composed of sponges, bivalves, oysters and ammonites (e.g. *Procheloniceras* and *Deshayesites* spp., Pictet et al., 2015), while the microfauna includes planktonic foraminifera. The grey marls become continuously more calcareous towards the top of the member and are sometimes replaced by a pseudo-nodular bioturbated marly-limestone. These last beds of this member contain ammonites (e.g. *Deshayesites* sp., *Cheloniceras cornuelianum*, Pictet et al., 2015), nautiloids (*Eucymatoceras requienianum*), bivalves (e.g. *Corbis corrugata*, *Pterotrigonia caudata*, *Plicatula placunea*, *Panopea*), and echinoids (e.g. *Toxaster collegnoi*). At La Bastide-de-Virac section, a massive occurrence of *Palorbitolina lenticularis* occurs within the Violette and Rocherenard Members, accompanied by an unusual neritic fauna of gastropods and echinoids (*Pyrina* n. sp.; Clavel personal communication).

At the boundary between the internal and the external former platform, the marly interval overlying the Motier Beds is thicker (up to 13 m; Bourg-St-Andéol section, Fig. 10; and Picourel section, Fig. 11). It mainly consists of blue-grey marl, which becomes yellow when oxidized during weathering (Fig. 9b and e). In terms of microfacies, the marl corresponds to a bioturbated spongolithic wackestone rich in quartz (microfacies F2 to F0;

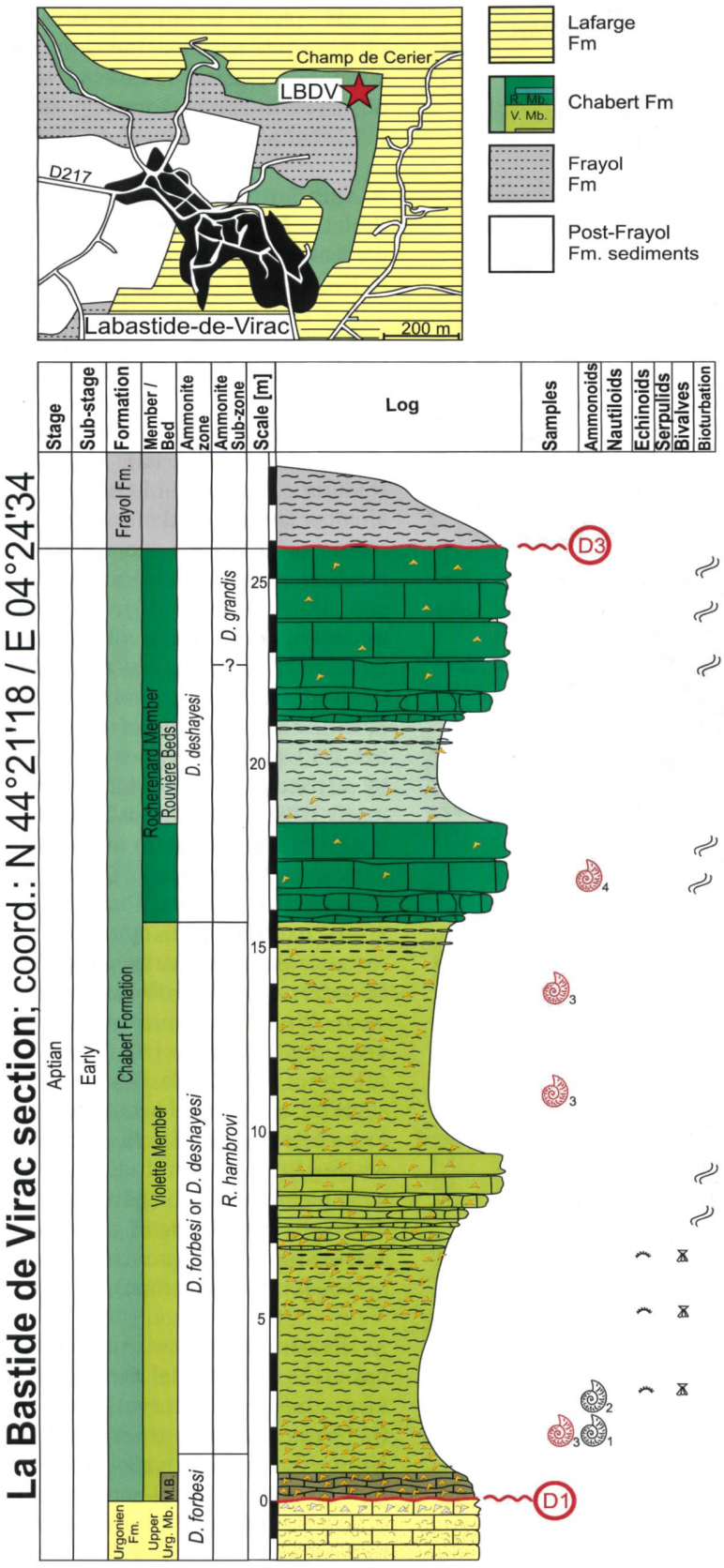

Fig. 8: Detailed section of the lower Aptian in the Labastide-de-Virac outcrop (LBDV), with the present fauna. M.-B. = Motier Beds. Ammonites: 1) Roloboceras hambrovi; *2)* Procheloniceras *sp. and* Cheloniceras *sp.; 3)* Deshayesites *sp. (Clavel et al., 2013); 4)* Cheloniceras chornuelianum *(Clavel et al., 2013).*

Fig. 9c). The microfauna includes sparse planktonic foraminifera (Fig. 9d), numerous benthonic biseriate foraminifera and glomospires. This marly interval gradually changes to alternating marl/sandy marl with nodular glauconitic calcareous sandstone/crinoidal limestone (microfacies F3 to F4). In the limestone beds glauconite shows an advanced stage of maturation. The limestone beds contain abundant large oysters (*Exogyra (Aetostreon) aquila*), other bivalves (*Corbis corrugata*), serpulids, brachiopods, sea urchins (*Toxaster collegnoi*, *Holaster prestensis*, *Pseudodiademma* sp.), nautiloids (*Eucymatoceras requienianum*), and sponges (Fig. 9b), especially in the Picourel section. A rich ammonite fauna was collected in this upper part (Pictet et al., 2009, 2015).

On the former external platform (Chabert section, Fig. 12; and Pélican section, Fig. 13), the karstic surface is replaced at the discontinuity D1 by a highly bioturbated surface (*Thalassinoides*; Fig. 4d). The surface does not show evidence of ferruginous crusts or epifaunal perforations. This bioturbated surface is overlain by the Motier Beds, which are surmounted by 20 to 30 m of grey marl belonging to the Violette Member (Fig. 9f). The microfacies of the Violette Member (F0 to F1) is a wackestone (Fig. 9g) with sparse ostracods and planktonic foraminifera (Fig. 9h). This marly interval becomes more calcareous upwards, where it includes nodular or discontinuous limestone beds (microfacies F0 to F3), and contains pyritized ammonites (*Deshayesites* sp., Pictet et al., 2015) (Fig. 9f). The upper 6 m of the Violette Member contain a few continuous calcareous beds (microfacies F3), which consist of a packstone with glauconite and quartz grains, abundant sponge spicules, benthonic foraminifera and sparse ostracods (e.g. Fig. 9c). Five metres below the top of the Violette Member, a remarkable 1 m thick grey bioturbated limestone bed contains large ammonites (*Pseudohap-*

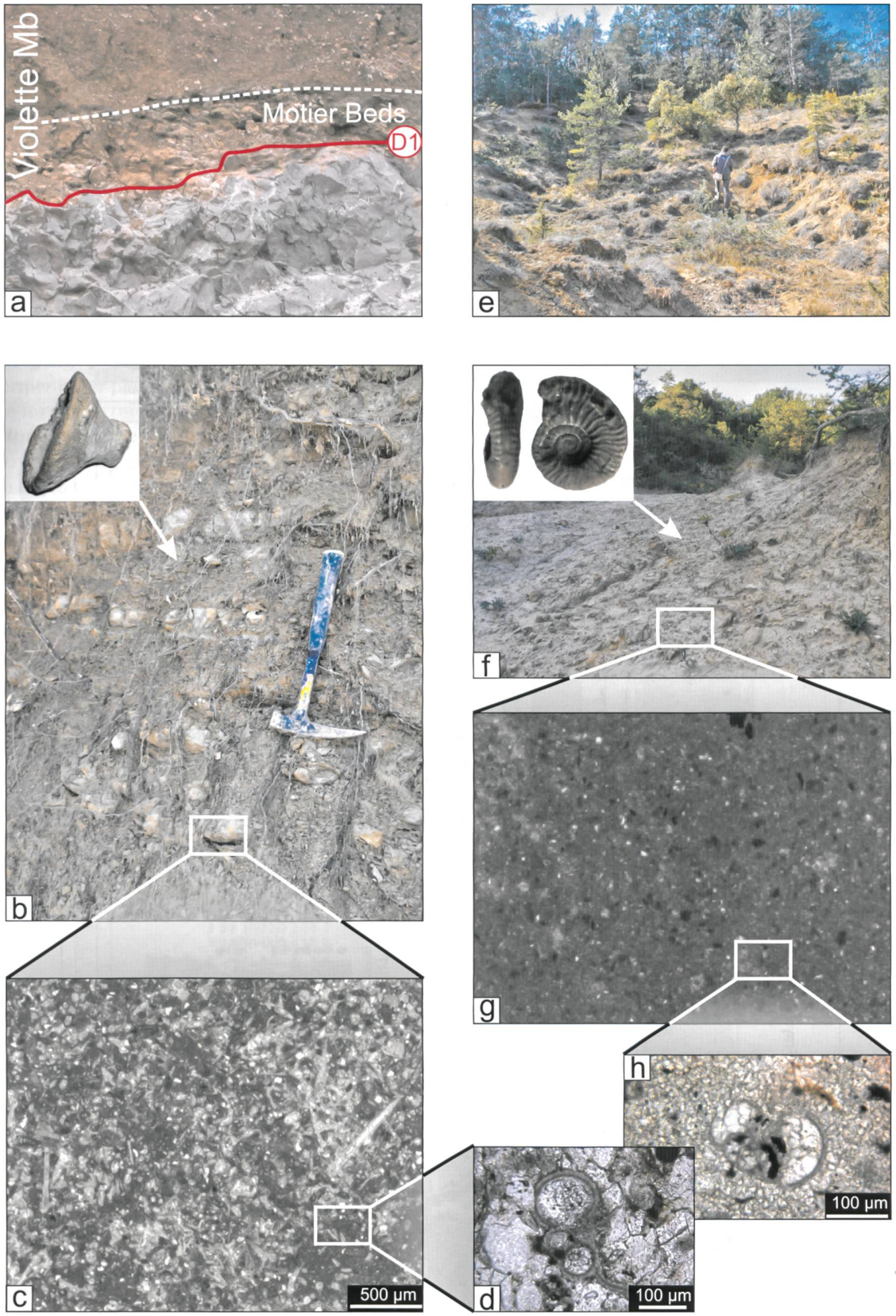

Fig. 9: Violette Member: ***a.*** *View of the Mezelet section, showing the Motier Beds at the base of the member.* ***b.*** *Yellow to grey marl-limestone alternation with sponges in the Picourel section.* ***c.*** *Focus on the spongolitic packstone (F1).* ***d.*** *Focus on a planktonic foraminifera from the Michelet section.* ***e.*** *General view of the yellow to grey marl on the Picourel hill.* ***f.*** *View of the clay with pyritic ammonites composing the outer platform deposits (Pélican section).* ***g.*** *Focus on the wackestone in the Pélican section.* ***h.*** *Focus on a planktonic foraminifera from the Chabert section.*

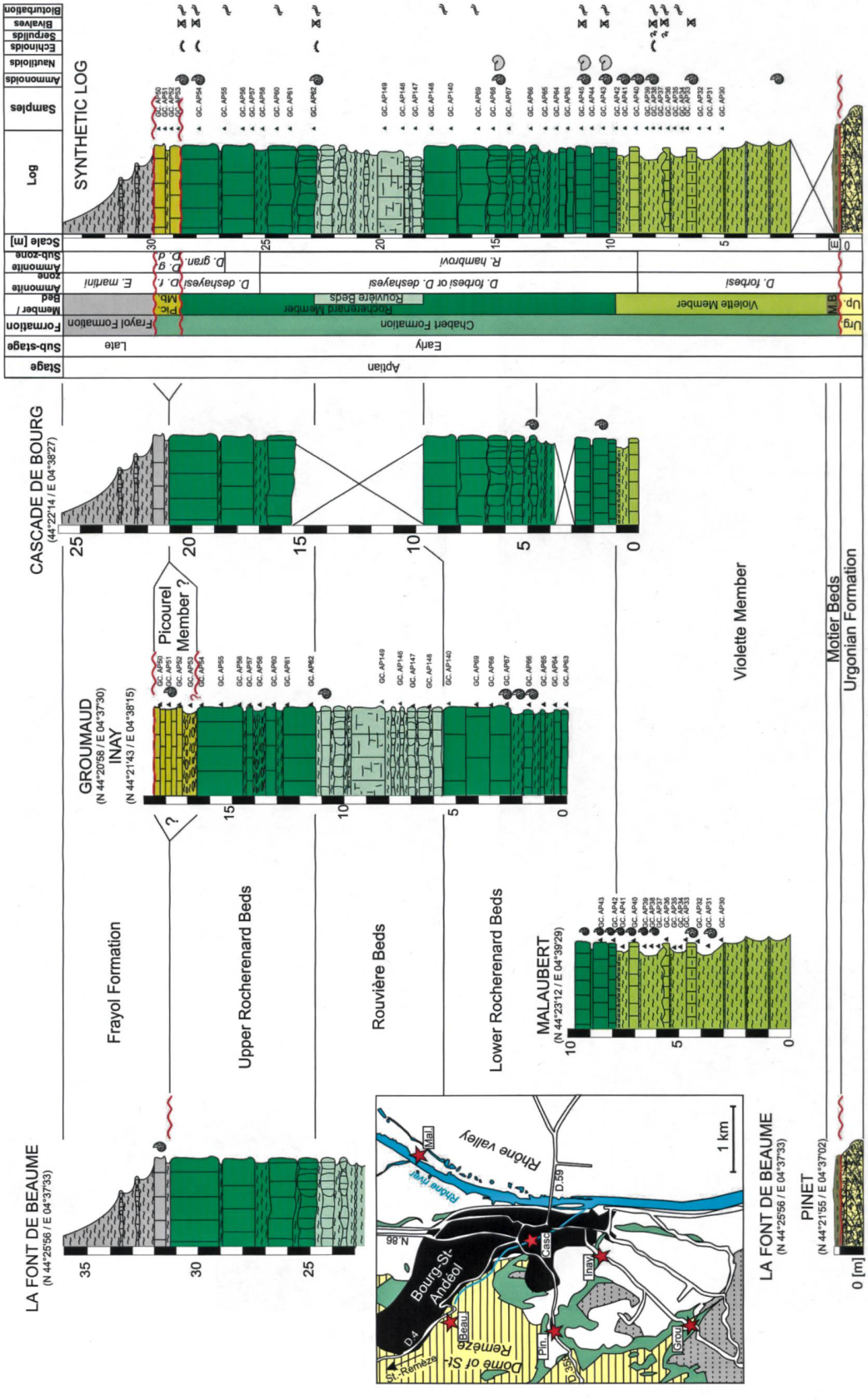

Fig. 10: Composite lower Aptian section from the Font de Beaume (Beau.), Pinet section (Pin.), Malaubert (Mal.), Inay, Groumaud (Grou.), and the cascade de Bourg (Casc.). Samples and ammonites are reported on left side of the synthetic log.

loceras sp., "*Tropaeum*" sp., Pascal et al., 1989; and *Ammonitoceras* sp., Pictet et al., 2015). The top of the member changes progressively into a crinoidal limestone belonging to the Rocherenard Member.

3.1.1.1. Motier Beds

Equivalent: Unknown.
Type locality: The name is derived from the Motier stream located next to the Chabert farm near Viviers; Fig. 2, point 6; Fig.12, point Rmo), where this unit outcrops well and shows its maximal thickness of about 2 m; N 44°30'39 / E04°39'03 to N 44°30'54 / E 04°38'54.
Underlying strata: Upper Urgonian Member on the former inner platform and the Lafarge Formation on the former external platform.
Overlying strata: The upper Violette Member.
Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).
Thickness: 0.5 to 2 m from internal to external parts of the former platform.
Biostratigraphic age: Late early Aptian, *D. forbesi* Zone (Pictet et al., 2015).
Previous studies:
The Motier Beds were first observed by Sornay (1958) near the Chabert farm to the north of Viviers in Ardèche (Fig. 2, point 6), where he described a 10 to 15 cm thick interval of glauconitic sandy limestone. In the fieldtrip guide of the French Group of the Cretaceous (Busnardo et al., 1977), a ~20 cm thick glauconitic sandy interval is mentioned in the outcrop of the Michelet farm in the Valley of the Ibie in Ardèche (Fig. 2, point 1).
Description: The Motier Beds are composed either of a sandy limestone bed or of marl-limestone alternations depending on their location on the former platform.

On the former inner platform, the Motier Beds consist of a single 0.1 to 1 m thick glauconitic sandy marly limestone bed (Fig. 14a and b), which locally contains large phosphatic pebbles. The corresponding microfacies (FT; transgressive facies according to Blanc-Alétru, 1995; Fig. 14c) is a packstone containing about 10% of small angular quartz grains, mature reworked glauconite, pyrite, lithoclasts, fragments of serpulids, bryozoans, echinoderms, small broken benthonic foraminifera and rare planktonic foraminifera. This bed also contains some ammonites (*Prochelonicera* sp., Pictet et al., 2015; *Pseudosaynella* cf. *bicurvata*, *Tropaeum* sp., and *Deshayesites* sp., Elmi et al., 1996), and sponges.

On the former external platform, the Motier Beds are composed of a 2 m thick, thinning-upward alternation of grey-beige marly limestone beds and grey marl (Fig. 14d and e). Its microfacies (F4 to

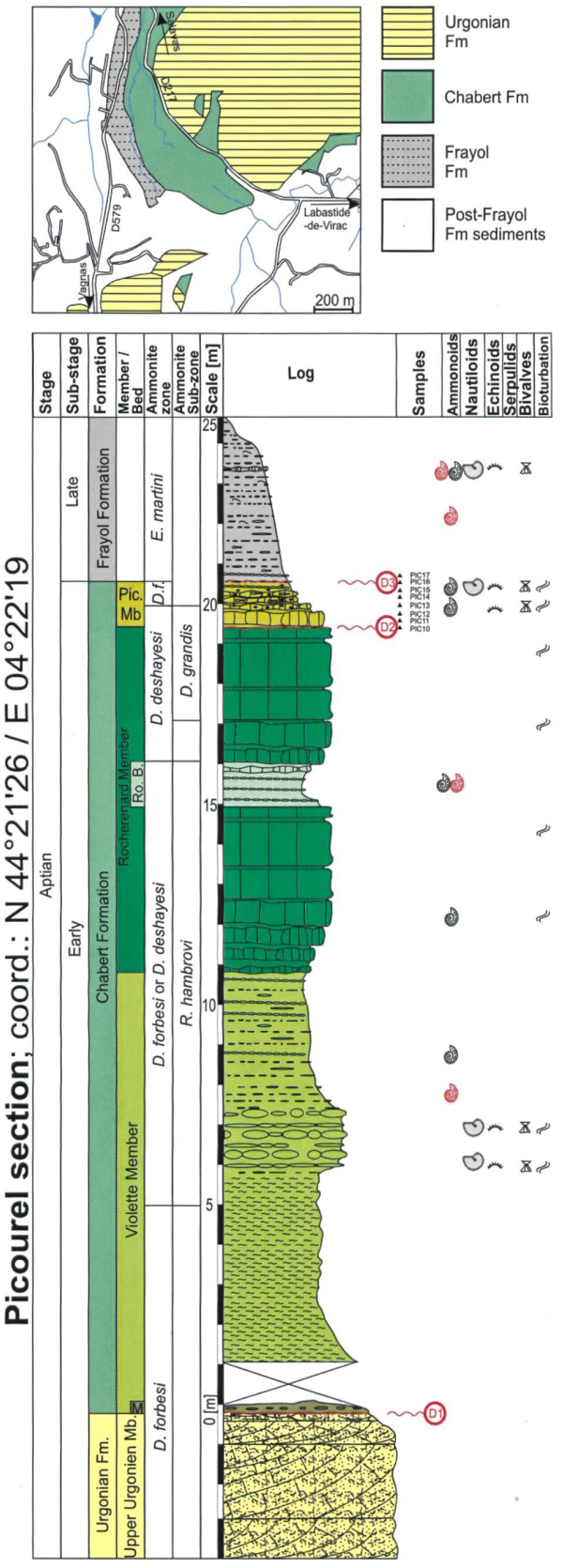

Fig. 11: Detailed section of the lower Aptian in the Picourel outcrop, with the present fauna. Urg. = Urgonian Formation, M. B. = Motier Beds, Pic. Mb. = Picourel Member, D. gran. *and* D. g. = D. grandis *Subzone,* D. f. = D. furcata *Zone,* D. d. = D. dufrenoyi *Subzone.*

F1; Fig. 14f) is a wackestone relatively similar to the microfacies of the Lafarge limestone (F1). The matrix is slightly phosphatised and contains organic matter and glauconite. The Motier Beds also contain abundant sponge spicules, few ostracods, and sparse small benthonic foraminifera. This unit also includes a few ammonites (ancyloceratidae, Pictet et al., 2015; *Procheloniceras* sp. and *Pseudohap-*

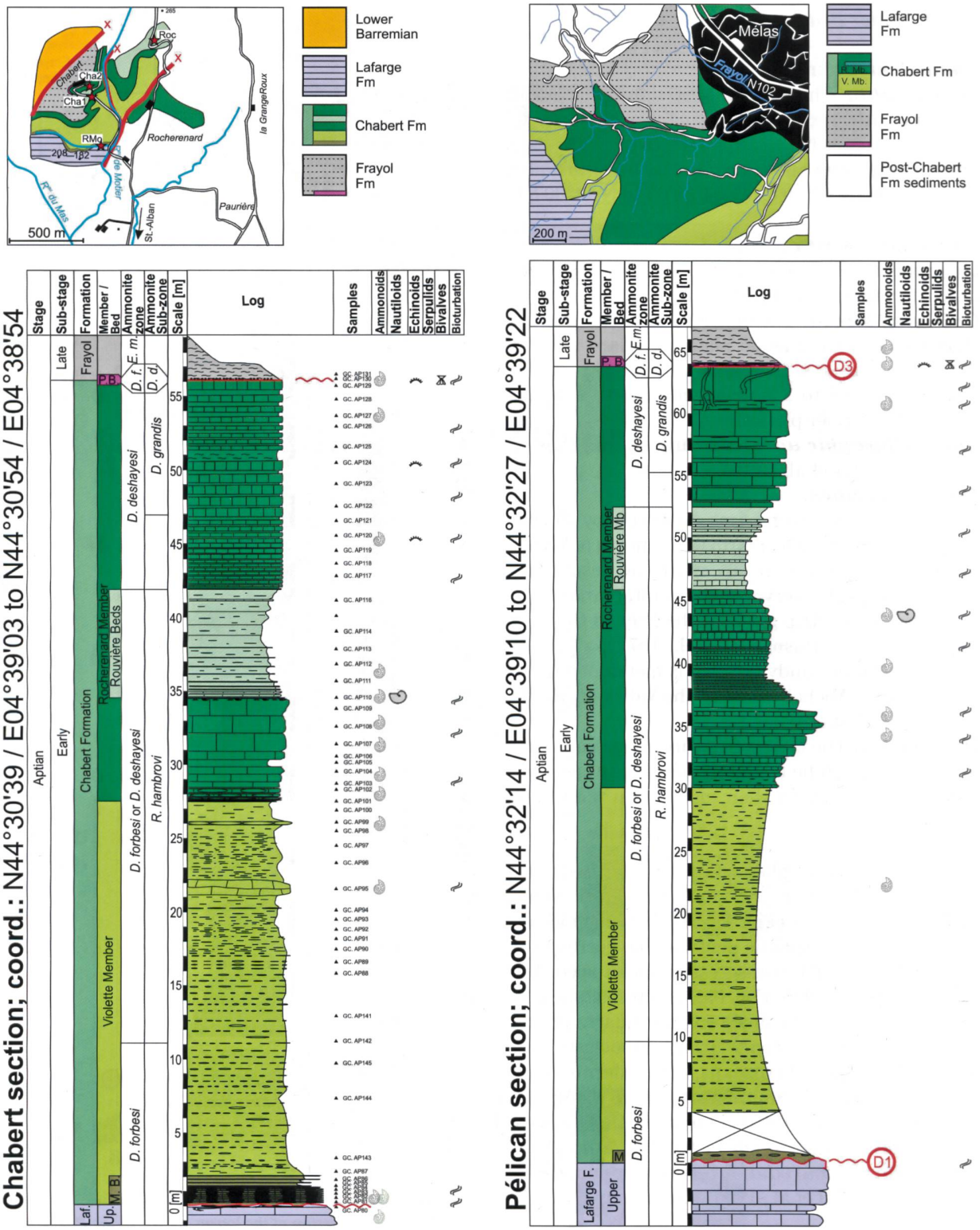

Fig. 12: Detailed section of the lower Aptian in the Chabert outcrop, with the sampled bed and present fauna. M.B. = Motier Beds, D. f. = D. furcata *Zone,* D. d. = D. dufrenoyi *Subzone.*

Fig. 13: Detailed section of the lower Aptian in the Pélican outcrop, with the present fauna. M. = Motier Beds, P.B.= Pélican Bed, D. f. = D. furcata *Zone,* D. d. = D. dufrenoyi *Subzone.*

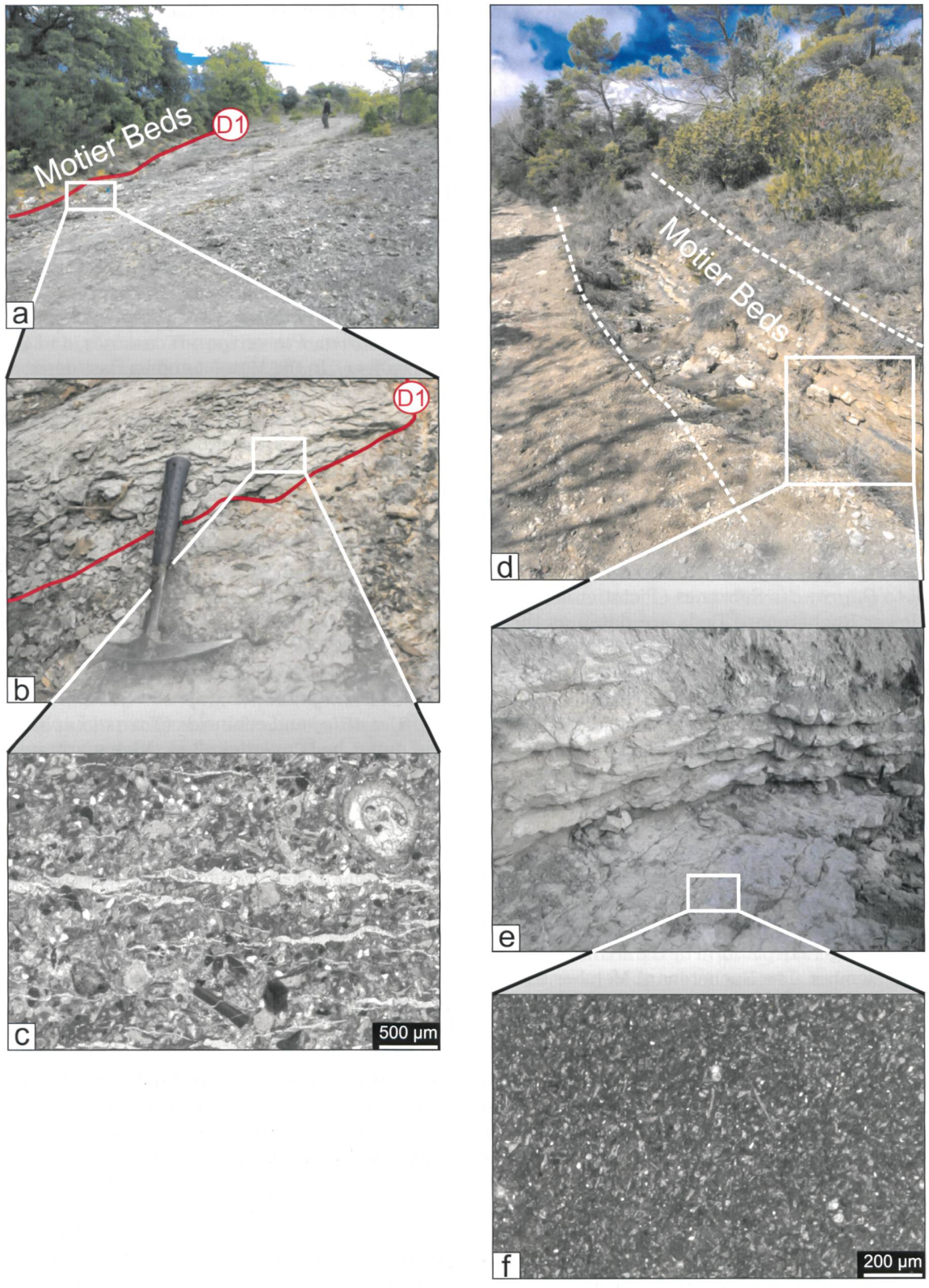

Fig. 14: Motier Beds: ***a.*** *View of the contact between the Urgonian Formation and the Motiers Beds (Violette Member) separated by the discontinuity D1 on the internal platform (Michelet section).* ***b.*** *Focus on the contact between the Urgonian Formation and the sandy carbonate of the Motier Bed, Michelet section.* ***c.*** *Focus on the microfacies FT composing the Motier Bed, which is a sandy glauconitic echinodermic packstone, Michelet section.* ***d.*** *General view of the marly-limestone alternation composing the Motier Beds on the distal platform (Chabert section).* ***e.*** *Focus on the 2 m thick thinning-upward marl-limestone alternation, which evolves upward from a crinoidal (F4) to a spongolithic wackestone (F1), Chabert section.* ***f.*** *Focus on the microfacies F1, composed by a spongolithic wackestone.*

loceras sp., Sornay, 1960; *Costidiscus* sp. and *Pseudohaploceras* sp., Pascal et al., 1989), and echinoids (*Toxaster collegnoi*).

3.1.2. Rocherenard Member

Creation of name: Pictet et al. (2015)
Equivalent: Sarastarri Formation (N. Spain, García-Mondéjar et al., 2009; Millán et al., 2011)
Type locality: Between the Rocherenard and Chabert farms, near Viviers, Ardèche; from N44°30'52.6" / E04°39'00" to N 44°30'53.8" / E 04°38'57.4"; Fig. 2, point 6.
Subdivision: Rouvière Beds in the middle of the Member.
Underlying strata: Violette Member.
Overlying strata: Picourel Member or Frayol Formation (Pélican Bed).
Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).
Thickness: 1 to 34 m from the inner to the outer ramp.
Biostratigraphic age: Late early Aptian, *R. hambrovi* to *D. grandis* Subzones (Pictet et al., 2015). The lower Rocherenard Beds are dated as the *R. hambrovi* Subzone, while the upper Rocherenard Beds are dated as the *D. deshayesi* Zone and the lower part of the *D. grandis* Subzone.
Previous studies: The Rocherenard Member is a limestone interval, which was first described by Sornay (1958) to the north of Viviers. Near Bourg-St-Andéol, Pascal et al. (1989) observed a massive yellow sandy limestone unit of about 8 m overlying a marly interval.
Description: The Rocherenard Member has been deposited on a morphology which is henceforth more similar to a ramp, due to the infilling of the talus of the former Urgonian platform by the sediments of the Violette Member. The Rocherenard Member usually consists of two main limestone bars or beds (lower and upper beds). Both bars consist of thickening-upward, yellow sandy crinoidal limestone beds, which are rich in echinodermal debris, sponge spicules and bryozoans (microfacies F1 to F4). The lower beds appear progressively on top of the Violette Member and are overlain by the Rouvières Beds. The upper beds occur progressively above the Rouvière Beds and are marked by an erosive discontinuity D2 at their top (Pictet et al., 2015).

On the inner part of the ramp (e.g., Michelet section), the Rocherenard Member consists of two beds (Fig. 15a). The first bed (lower beds) is a 0.15 m thick nodular and bioturbated limestone bed with abundant sand grains and crinoid fragments (microfacies F2 to F3; Fig. 15b). In this bed, sparse ammonites (*Cheloniceras cornuelianum*, Pictet et al., 2015), bivalves (e.g., *Corbis corrugata*, *Pterotrigonia caudata*, *Plicatula placunea, Panopea)*, and echinoderms (*Toxaster collegnoi*) are also observed. The second bed (upper beds) is a 1 m thick sandy marly limestone. Its microfacies (F2 to F3; Fig. 15b) corresponds to a ferruginous quartz-rich carbonate matrix containing phosphate and reworked glauconite grains. The bioclasts are fragmented and composed of sponge spicules, oyster shells, serpulids and small benthonic foraminifera. This bed contains some ammonites (*Deshayesites* sp. and *Cheloniceras disparile?*, Pictet et al., 2015) and a rich benthonic fauna with echinoids (*Toxaster collegnoi)*, gastropods and bivalves (*Corbis corrugata*, *Plicatula placunea*, *Pterotrigonia caudata*, and *Quadratrigonia)*. In the Mezelet and La Bastide-de-Virac sections, which are still part of the inner ramp, the first bed is replaced by marl-limestone alternations (~0.3 to 2.5 m thick; lower beds). The limestone beds are rich in crinoids and bioturbated. The microfacies (F3 to F4) corresponds to an crinoidal packstone with oyster shells, serpulid clasts, and benthonic foraminifera. The limestone beds contain 10 to 20% of quartz, angular phosphatic clasts, and mature glauconite grains. These beds include nautiloids (*Eucymatoceras requienianum)*, ammonites (*Deshayesites* sp. and *Cheloniceras* sp., Pictet et al., 2015), bivalves (*Corbis corrugata*, *Pterotrigonia* sp., *Plicatula placunea)*, oysters (*Exogyra (Aetosteron) aquila)* and echinoids (*Toxaster collegnoi)*. The upper beds overlie a 2 m thick marly interval of the Rouvière Beds (see 3.1.2.1) and is composed of a 2 to 5 m thick heterogeneous bioturbated rudstone with abundant large echinoderms and bryozoan fragments. The limestone also contains oysters, sponges and benthonic foraminifera. Its microfacies (F4 to F5) is a packstone with abundant large and well-rounded quartz grains (10 to 20%). Phosphatic and glauconitic grains are present and the latter is advanced in maturity. Silicification is also very extensive in the limestone. The Rocherenard Member ends with a poorly visible discontinuity (D2).

On the middle ramp (Picourel and Bourg-St.-Andéol sections), the lower beds consist of a 4 to 5 m thick yellow, bioturbated, nodular, thickening-upward, crinoidal limestone (microfacies F4; Fig. 15c). These lower beds contain ammonites (*Pseudohaploceras* sp., *Cheloniceras cornuelianum*, *Megatyloceras ricordeanum*, *Roloboceras hambrovi*, Pictet et al., 2015) and nautiloids (*Heminautilus lallierianus* and *Josanautilus lacerdae*; see Baudouin et al., 2016). The upper beds are 3.5 to 4 m thick and are composed of a yellow bioturbated thickening-upward crinoidal limestone (microfacies F4; Fig. 15d). Ammonites (*Cheloniceras cornuelianum*, *C. kiliani?*, *C.* sp., *Pseudohaploceras* sp., *Deshayesites* sp., Pictet et al., 2015), some echinoids (*Toxaster collegnoi)* and oysters (*Exogyra (A.) aquila)* are also

observed in this interval. In the Picourel section, the Rocherenard Member is topped by an irregular and bioturbated discontinuity surface (D2), which is covered by pebbles of the Rocherenard Member.

On the outer ramp, the lower beds are 7 to 16 m thick and consist of two limestone bars separated by a thin marly bed (Fig. 15e, small dotted lines). The first bar is 2.5 to 7 m thick and corresponds to a thickening-upward limestone with smaller beds ranging from 0.1 to 0.6 m thick. Its microfacies (F1 to F4; Fig. 15f) is a packstone with abundant sponge spicules, foraminifera (*Textularidae*), mollusc fragments, echinoids and bryozoans. The sediment matrix is slightly phosphatic and contains 10 to 20% of well-rounded quartz grains and rare glauconite grains. Some ammonites (*Pseudohaploceras* sp., *Roloboceras hambrovi, Megatyloceras ricordeanum*, Pictet et al., 2015; *Cheloniceras cornuelianum* and *Ancyloceras toucasi*, Clavel et al., 2013) and nautiloids (*Eucymatoceras requienianum*) were found inside this bar. Above, a 1 to 4.5 m thick interval of marl and marl-limestone alternations (wackestone; microfacies F1 to F3) contains abundant sponge spicules, numerous Textularidae and other small benthonic foraminifera, and less than 10% of small rounded quartz grains. In this interval, rare ammonites have been observed. A second thickening-upward bar (3.5 to 4.5 m thick; packstone; microfacies F1 to F4) is composed of smaller beds ranging from 1 to 1.5 m. The upper part of the bar contains large ammonites (*Pseudohaploceras* sp., Ancyloceratidae, *Roloboceras hambrovi*, Pictet et al., 2015) and nautiloids (*Eucymatoceras requienianum*). The top of the bar is quite bioturbated and richer in large ammonites. Above, the upper beds consist of 11.5 to 14 m of alternating blue limestone beds and marl (Fig. 15g). The limestone beds are slightly phosphatized (see the black arrow on Fig. 14h) and contain between 10 and 20% of large rounded quartz and glauconite grains. Its microfacies (F1 to F4; Fig. 15h) is a packstone with sponge spicules, abundant Textularidae, other small benthonic foraminifera and echinoderms. The macrofauna consists of sparse ammonites (*Pseudohaploceras* sp., *Pseudosaynella* cf. *bicurvata*, *Cheloniceras crassum*, *Deshayesites* gr. *grandis*, *Tropaeum*, and *Deshayesites* sp. trans. *Dufrenoyia*, Pascal et al., 1989; Clavel et al., 2013), and echinoids (*Toxaster collegnoi*). On the external ramp, the Rocherenard Member ends with a polyphased erosional surface (D2-3; Pictet et al., 2015).

3.1.2.1. The Rouvière Beds

Type locality: Between the Pélican section and the Violette hill near Le Teil (Ardèche); from N 44°32'13.9" / E 04°39'53" to N 44°32'12.6" / E 04°39'33.5"; Fig. 2, point 8.

Underlying strata: Lower Rocherenard Beds.
Overlying strata: Upper Rocherenard Beds.
Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).
Thickness: 0 to 7.5 m from the internal to the external part of the ramp.
Biostratigraphic age: Late early Aptian: *D. forbesi* Zone *sensu* Moreno-Bedmar et al. (2009, 2010, 2012) and Reboulet et al. (2011) and *D. deshayesi* Zone *sensu* Ropolo et al. (2000, 2006), and more precisely from the uppermost *R. hambrovi* Subzone (Pictet et al., 2015).
Description: The Rouvière Beds mainly consist of yellow marl with abundant sponge spicules. The marl gradually appears on top of the lower Rocherenard Beds (microfacies F3 to F1). Towards the top, the Rouvière Beds gradually change into thickening upward marl-limestone alternations.

On the internal ramp (Mezelet section), the Rouvière Beds appear in the middle of the Rocherenard Member with marl (wackestone/packstone; microfacies F2) enriched in bivalves (*Corbis corrugata*), brachiopods and sea urchins (*Toxaster collegnoi*).

On the middle ramp, the Rouvière Beds are barely observable (e.g., the Picourel section) except for a 1 m thick marly interval (microfacies F1 to F2), which is rich in calcareous nodules and contains few ammonites (*Cheloniceras cornuelianum*; *Deshayesites* sp. and *Roloboceras hambrovi*, Clavel et al., 2013).

On the outer ramp (Chabert and Pélican sections), as well as in the type locality (Fig. 2, point 7), the Rouvière Beds consist of 7 to 7.5 m of yellow marl, which are rich in sponge spicules. At the base of this interval, the transition is gradual between the lower Rocherenard Beds, which contains large ammonites (*Pseudohaploceras*) at its top (packstone; microfacies F4), and a 1 m thick marly interval (microfacies F0 to F1) interrupted by thin carbonate beds (microfacies F3 to F1). The Rouvière Beds continue with gradually thickening-upward marl-limestone alternations (microfacies F2 to F3). In the limestone beds, abundant ammonites (*Pseudohaploceras* sp., *Roloboceras hambrovi*, *Megatyloceras* cf. *ricordeanum*, *Deshayesites* aff. *consobrinus*, and *D. evolvens*) are observed.

3.1.3 The Picourel Member

Creation of name: Pictet et al. (2015)
Equivalent: Zamaia Formation (N. Spain, Fernández-Meniola et al., 2013), Lareo Formation (N. Spain, García-Mondéjar et al., 2009; Millán et al., 2011), Villarroya de los Pinares Formation (SE Spain, Peropa-

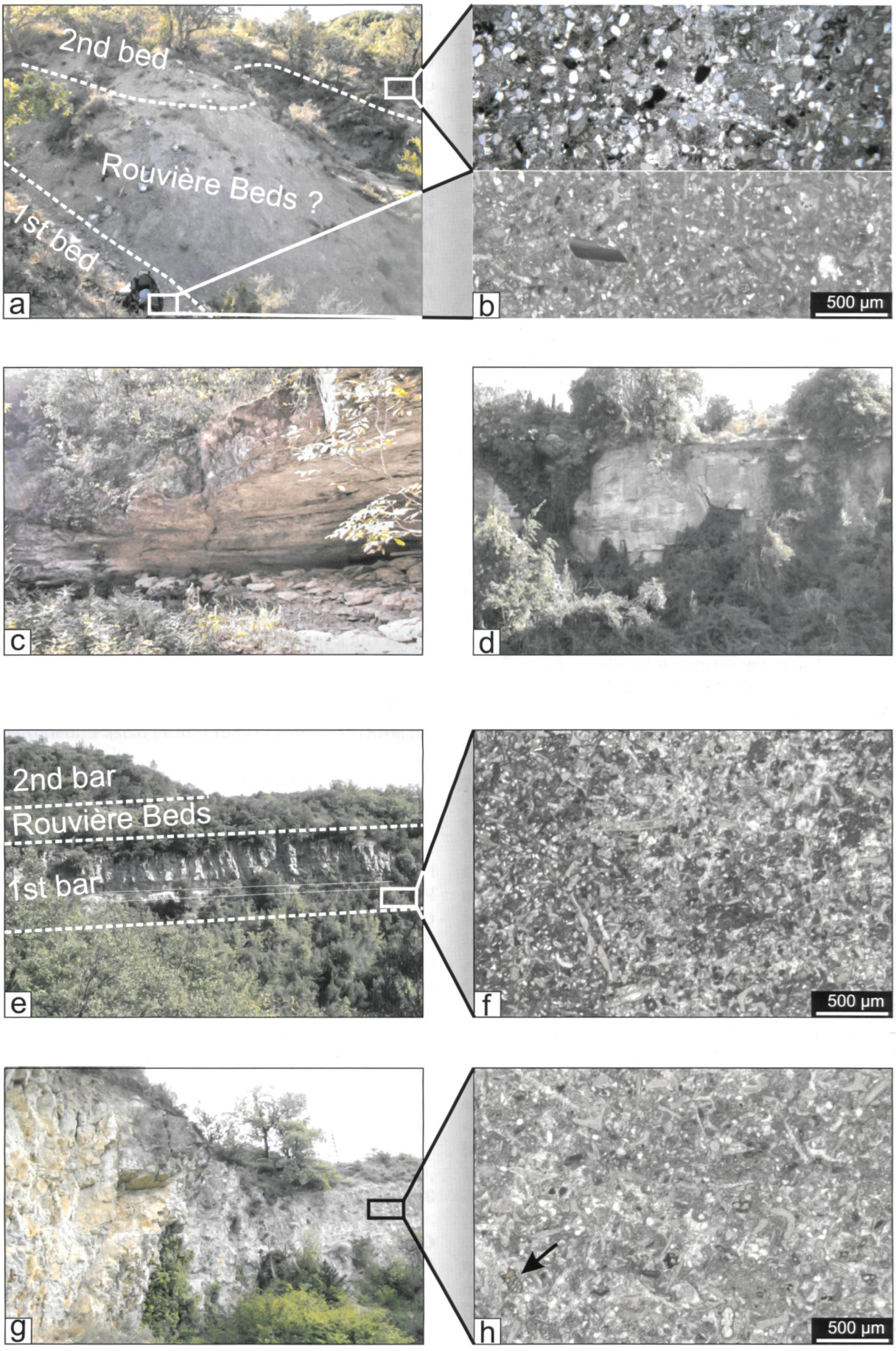
2nd bed
Rouvière Beds ?
1st bed
a
b
500 µm
c
d
2nd bar
Rouvière Beds
1st bar
e
f
500 µm
g
h
500 µm

Fig. 15: Rocherenard Member: ***a.*** *General view of the two beds (lower and upper Rocherenard Beds) and the Rouvière marls intercalated in between, which compose the Rocherenard Member on the internal ramp (Michelet section).* ***b.*** *To the bottom, focus on the microfacies from the lower Rocherenard Beds, which is composed by a sandy crinoidal packstone (microfacies F2 to F3; Michelet section). Top the top, focus on the microfacies from the upper Rocherenard Beds, which is composed of a coarse sandy crinoidal packstone (microfacies F2 to F3; Michelet section).* ***c.*** *General view of the Rouvière and upper Rocherenard Beds on the middle ramp (Bourg-St.-Andéol section, Groumaud outcrop).* ***d.*** *View of the Upper Rocherenard Beds along the road D4 from Bourg-St.-Andéol to St.-Remèze.* ***e.*** *General view of the Rocherenard Member on the distal ramp (Chabert section).* ***f.*** *Focus on microfacies F2 to F4, which is here a spongolithic packstone with some crinoidal fragments.*

dre et al., 2013), Upper Grünten Member (France, Switzerland, Austria, Germany; Linder et al., 2006; Föllmi and Gainon, 2008)

Type locality: Picourel hill, located between Salavas and Labastide-de-Virac (Ardèche); from N 44°21'26" / E 04°22'19"; Fig. 2, point 3).

Underlying strata: Rocherenard Member

Overlying strata: Frayol Formation (Pélican Bed)

Occurrence: Languedoc platform (Gard and Ardèche departments, SE France).

Thickness: 0.5 to 1.5 m independent of the position on the ramp.

Biostratigraphic age: Late early Aptian: *D. deshayesi* Zone, *D. grandis* Subzones to upper *Dufrenoyia furcata* Zone, upper *Dufrenoyia dufrenoyi* Subzone (Pictet et al., 2015).

Description: This new stratigraphic unit lies unconformably on top of the Rocherenard Member and is characterised either by a single limestone bed or by alternating marl and nodular limestone beds, which are rich in glauconitic and phosphatic grains.

On the inner ramp (Michelet section), the Picourel Member occurs as a single 0.5 m thick bioturbated glauconitic grey limestone bed (Fig. 16a). It contains abundant brachiopods, bivalves and ammonites (*Deshayesites* gr. *grandis, Cheloniceras crassum,* Pictet et al., 2015; and *Eotetragonites*?). Its microfacies (F4) is composed of a microsparitic packstone (Fig. 16b) with large rounded quartz grains, and mature rounded glauconitic and phosphatic grains. Most of the bioclasts, such as molluscs, echinoderms and benthonic foraminifera, are replaced either by sparite (Fig. 16b to d) or by silica. This bed is strongly eroded at its top (discontinuity D3).

On the middle ramp (Picourel section), the Picourel Member is defined by a 1.5 m thick interval of sandy grey marl alternating with nodular limestone beds (Fig. 16e). This unit contains abundant glauconite and phosphate. Its microfacies (FT) evolves upward from a packstone (Fig. 16h) to a wackestone, before returning to a packstone. Quartz grains are very abundant and angular, while glauconite grains are dark green, abundant, rounded and mature. Phosphate grains are always present in small quantity, except in the upper part of the member. The main bioclasts are echinoderms (crinoids and echinoids), oysters, brachiopods, benthonic foraminifera (e.g. biseriate, *Lenticulina* and glomospires), ostracodes, fish teeth and coprolites. Planktonic foraminifera are always present but more abundant in the upper part of the member. These sediments also contain a rich endobiontic fauna of bivalves (*Panopea plicata)* and echinoids (*Toxaster collegnoi)*, and nektonic fauna of ammonites (*Deshayesites grandis* (Fig. 16f), *Cheloniceras minimum*, *C.* sp., *Dufrenoyia furcata*, Pictet et al., 2015) and nautiloids (*Cymatoceras neckerianum)*. The Picourel Member is topped by the discontinuity D3.

On the outer ramp (Chabert and Pélican sections), the Picourel Member is completely absent, which is likely due to erosional processes linked to the discontinuity D3 (Pictet et al., 2015). These erosive processes resulted in the accumulation of a phosphatic conglomerate (lag deposit), which forms the Pélican Bed at the base of the Frayol Formation (Fig. 16g). This unit contains numerous decimetrical pebbles and abundant fossils. Ammonites (*Deshayesites deshayesi?*, *D.* gr. *grandis*, *Cheloniceras cornuelianum*, *C. crassum*, *Dufrenoyia furcata*, *D. praedufrenoyi*, *D. dufrenoyi*, *Toxoceratoïdes royerianum*, *Colombiceras crassicostatum*, *Macroscaphites striatisulcatus*, *Pseudohaploceras angladei*, *P. liptoviensis?*, divers ancyloceratidae, *Lithancylus*? sp., *Ammonitoceras* sp., *Cheloniceras minimus*, and *C. quadrarium*, Pictet et al., 2015), nautiloids *(Cymatoceras neckerianus)*, belemnites (*Neohibolites aptiensis*, *Duvalia grasiana*), bivalves (*Plicatula placunea*, *Ostrea* sp., *Lima parallela*, *Mytilus* sp., *Arca robinaldina*), gastropods (*Natica sueurii*, *N.* sp., *Pleurotomaria* sp., *Rostellaria rouxii*, *R.* sp.), brachiopods (*Rhynchonella* sp., *Sellithyris* sp.) and echinoids (*Hemidiadema* sp., *Toxaster collegnoi*) are notably observed.

4. Lateral variations and correlations

The study of the Chabert Formation provides inedit information on a depositional model of heterozoan sediments on a drowned platform. A 2D transect from the inner to the outer ramp allows the

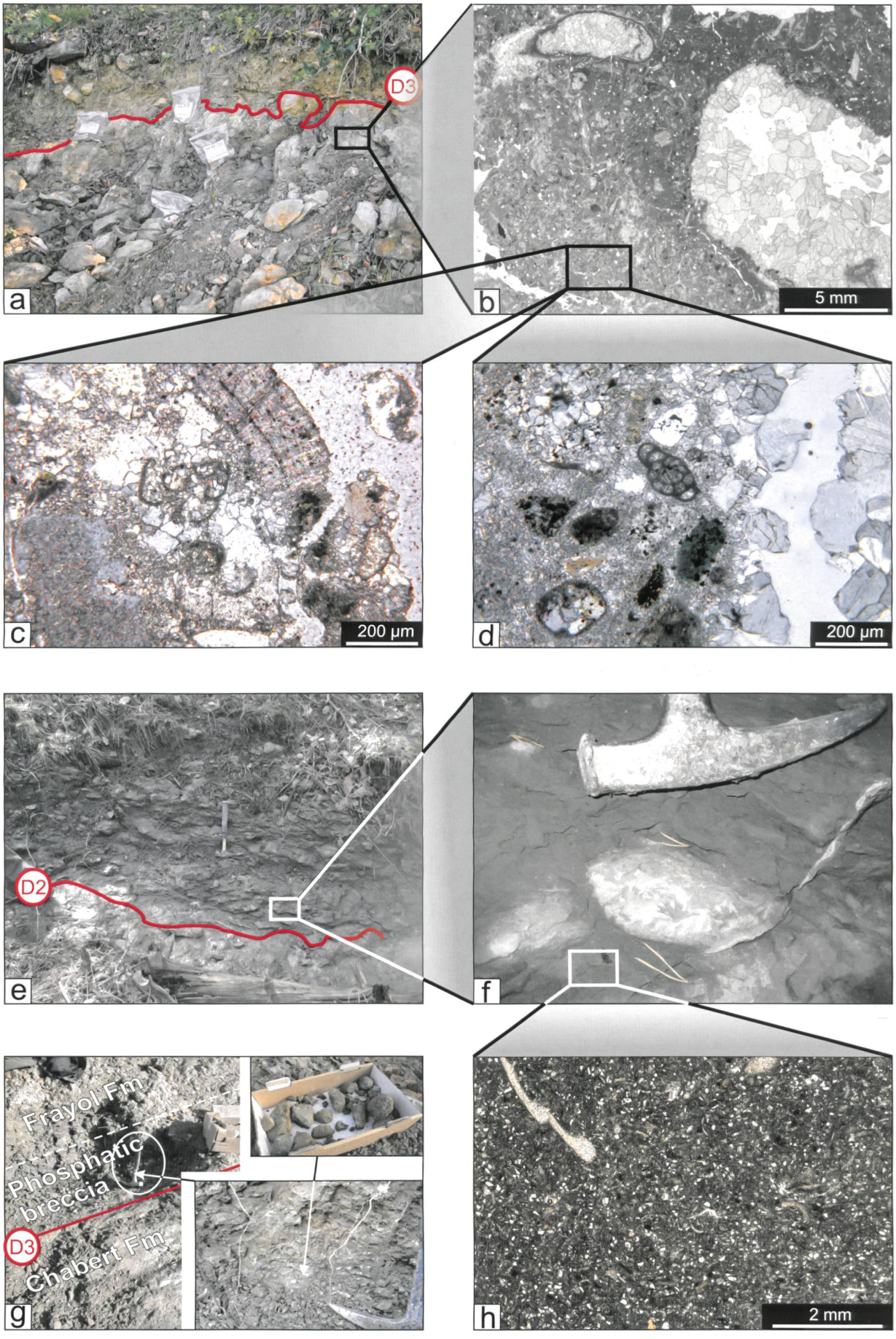
a
D3
b
5 mm
c
200 µm
d
200 µm
e
D2
f
g
Frayol Fm
Phosphatic breccia
D3
Chabert Fm
h
2 mm

Fig. 16: Picourel Member: ***a.*** *General view of the Picourel Member on the inner ramp (Michelet section), separated from the Frayol Formation by discontinuity D3.* ***b.*** *Focus on the microfacies F4 composing the Picourel Member, which is a glauconitic microsparitic packstone with numerous bioclasts.* ***c.*** *Focus on the microsparitisation of the matrix and the recrystallisation of the foraminifera.* ***d.*** *Focus on the mature glauconitic grains and phosphates.* ***e.*** *General view of the Picourel Member on the middle ramp (Picourel section), separated from the Rocherenard Member by the discontinuity D2.* ***f.*** *Focus on the marl-limestone alternation containing ammonites (e.g.* Deshayesites grandis*).* ***g.*** *General view of the boundary between the Rocherenard Member and the Frayol Formation on the distal ramp (Pélican section), separated by a polyphased discontinuity. This erosive surface is surmounted by a fossil-rich phosphatic conglomerate, the Pélican Bed* ***h.*** *Focus on the microfacies FT composed by a glauconitic wackestone to packstone.*

observation of important sedimentological changes that occur within short distances (few kilometres; Fig. 17).

The geometry of the Chabert Formation is controlled by the inherited morphology of the Urgonian platform. On top of this, the thickness of the mantling sediments irregularly increases toward the east and the northeast (Fig. 17). The lack of building organisms led to a sedimentation, which during a first phase, closely followed the morphology of the former Urgonian platform. Once the former urgonian topography was gradually filled and leveled, the sedimentation deposited on a morphology of distally steepened ramp, which prevailed during the rest of the Aptian. Thus, a maximum sedimentation rate can be assumed on the former platform talus. Onlap patterns occur within large Aptian lenses, especially in the most internal parts of the ramp, which are probably due to synsedimentary tectonical movements. Furthermore, the Picourel Member, which is usually absent due to erosion processes, is preserved in some places, probably because of possible structural depressions developed during the latest early Aptian, preserving a more complete stratigraphic record.

These sedimentary geometries implie important facies changes from the inner to the outer ramp (Fig. 17). The Violette Member shows a gradual change from an internal sedimentary setting dominated by quartz-rich incomings to an outer sedimentary setting mostly free of continental spreadings. At the same time, condensation processes are decreasing with a dilution of the glauconite and phosphate content from proximal to distal settings. Environmental modifications are also observable with a deepening of the microfacies inside a same unit like in the middle of the Violette Member in which microfacies evolve basinward from a bioclatic marl (microfacies F3 to F0; Michelet, Mezelet and La Bastide-de-Virac sections), to a spongolithic marl (microfacies F2 to F0; Bourg-St-Andéol and Picourel sections), and finally to a clay with pyritized fossils (microfacies F1 to F0, Chabert and Pélican sections, Fig. 17). Such evolution is also observed in the Rocherenard Member, which has been deposited on a morphology henceforth more similar to a ramp, due to the infilling of the talus of the former Urgonian platform by the sediments of the Violette Member. Microfacies indicate a progressive basinward deepening with a quartz-rich bryozoan-crinoidal limestone (microfacies F4-F5, e.g. Michelet and Mezelet sections), evolving to a purer encrinite (microfacies F4, Picourel and Bourg-St.-Andéol sections), and finally to a spongolithic to crinoidal limestone (microfacies F1 to F4, Fig. 17).

In the same way, the thickness of the formation strongly varies from the inner to the outer ramp (Fig. 17). Thus the observed thickness on the most internal part of the ramp varies between 0 and 26 metres, and rises up to a maximum of 64 m on the ramp prior to diminish again toward the basin. In outermost parts of the ramp, the thick succession of the Teil area is rapidly reduced to the northeast to only 5 metres of yellow marl rich in pyrite nodules and ammonites (Ribes section). This setting reminds the basinal Vocontian record, which lacks of limestone and sandstone intercalations. Thus, another paleogeographic belonging can be envisaged for the sediments cropping out on the Ribes section, as they should probably be part of a new formation grouping the Aptian and Albian marl from the Vocontian basin.

5. Conclusions

The present compilation and revision of the litho- and biostratigraphic data of the upper lower and lower upper Aptian sediments in the Ardèche allows to clarify the local stratigraphy in accordance with the rules of the International Stratigraphic Commission (ISC). With this study, we propose a new lithostratigraphic unit, the Chabert Formation, which gathers the lower Aptian heterozoan and terrigenous sediments originally described as "*Calcaires marneux à Ostrea aquila et céphalopodes*" by Carez (1882).

The Chabert Formation geographically extends on the Languedoc platform (Gard and Ardèche departments), between the Gard river to the south, Le Teil to the north, the Rhône River in the east, and the Alès – Largentière – Privas line to the west.

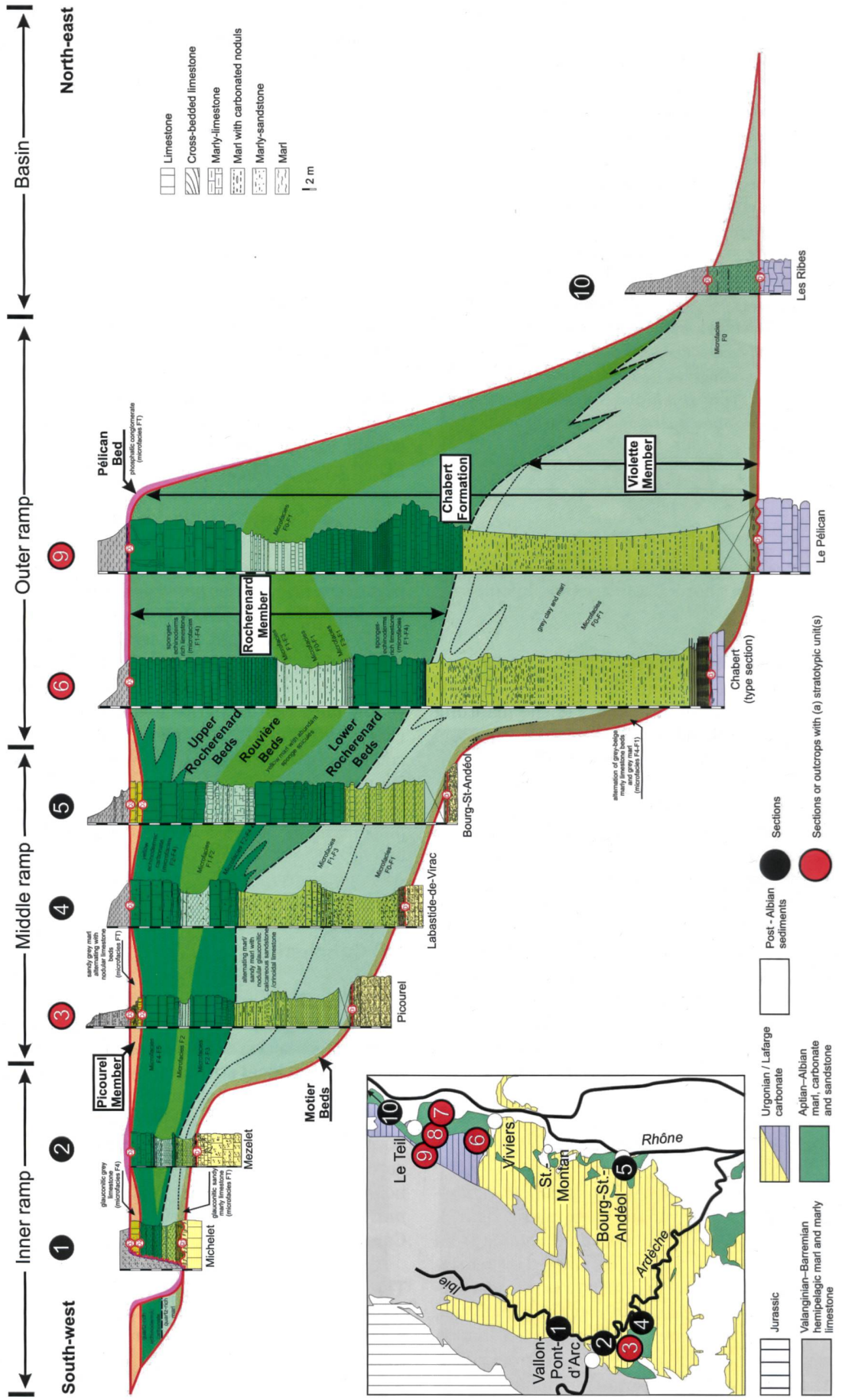
Inner ramp
Middle ramp
Outer ramp
Basin
South-west
North-east
Limestone
Cross-bedded limestone
Marly-limestone
Marl with carbonated nodules
Marly-sandstone
Marl
2 m
Pélican Bed
Chabert Formation
Violette Member
Rocherenard Member
Picourel Member
Motier Beds
Upper Rocherenard Beds
Rouvière Beds
Lower Rocherenard Beds
Mezelet
Michelet
Picourel
Labastide-de-Virac
Bourg-St-Andéol
Chabert (type section)
Le Pélican
Les Ribes
Le Teil
Viviers
St. Montan
Bourg-St. Andéol
Vallon-Pont-d'Arc
Rhône
Ardèche
Urgonian / Lafarge carbonate
Aptian–Albian marl, carbonate and sandstone
Jurassic
Valanginian–Barremian hemipelagic marl and marly limestone
Post - Albian sediments
Sections
Sections or outcrops with (a) stratotypic unit(s)

Fig. 17: Schematic transect of a distally steepened carbonate ramp throught the Languedoc platform during the early Aptian, highlighting the correlation of the main discontinuties and of the eight sections. Main facies (Members and Beds) and microfacies evolution are presented along this inner to outer ramp transect according to the classification of Arnaud-Vanneau (1980, 2005) and Blanc-Alétru (1995) (microfacies FT).

Stratigraphicaly, the formation occurs between the Urgonian Formation or its hemipelagic equivalent, the Lafarge Formation, and the late Aptian black marl of the Frayol Formation. The Chabert Formation comprises three members - the Violette Member composing the lowermost marly interval, the Rocherenard Member formed by crinoidal limestone, and the Picourel Member consisting of the uppermost marly glauconitic limestone. The Violette Member comprises a basal sub-unit, the Motier Beds, which are richer in carbonate. In the middle of the Rocherenard Member, a marly interval corresponds to the Rouvière Beds.

The Chabert Formation measures up to a maximum thickness of 64 m on the platform talus, thereby transforming the former platform into a ramp, which prevailed during the remainder of the Aptian. As a consequence, the thickness shows important variations from the inner to the outer ramp, which during a first phase closely followed the morphology of the former Urgonian platform before evolving to a distally steepened ramp. Important facies changes are observed between the inner and the outer ramp with, in the most proximal environments, sand-dominated sediments as well as by condensation, and on the outer platform purer marl and crinoidal limestone. The Picourel Member is a particular sedimentary unit, which consists of highly condensed sediments. Basinward, the Picourel Member is completely absent and replaced by a phosphatic conglomerate.

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