

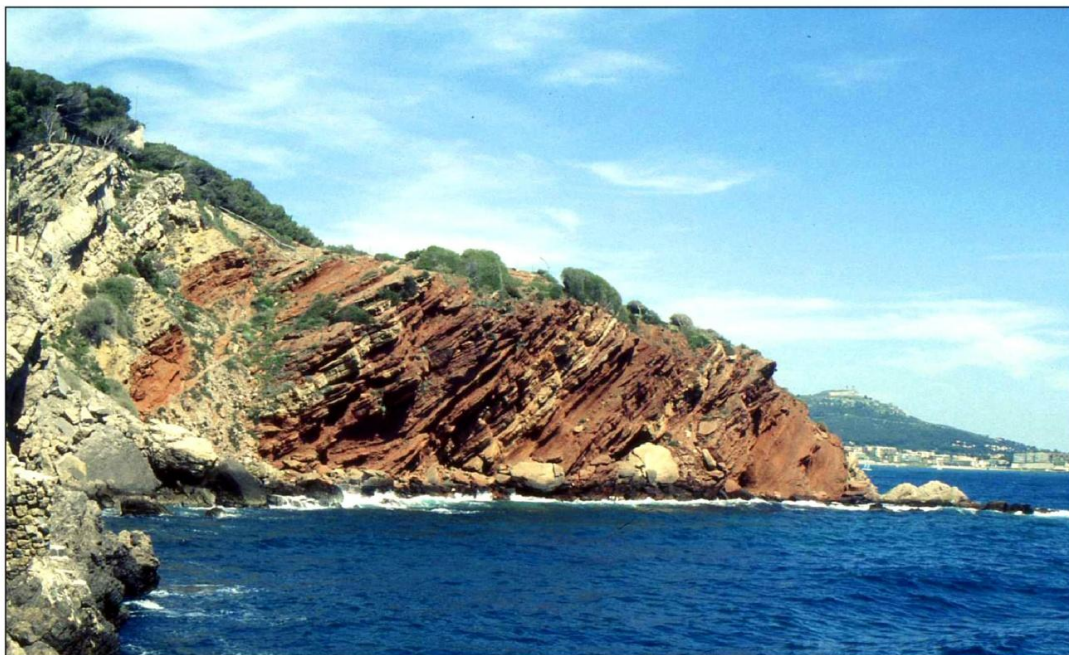


## **Pan-European Correlation of the Triassic**

### **8th International Field Workshop**

# **TRIASSIC OF SOUTHEAST FRANCE**

**(Provence : Var & Alpes-Maritimes)**



Marc DURAND, Jean-Paul CARON & Hans HAGDORN  
with contribution of José B. DIEZ-FERRER

**September 4-8, 2011**

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- a) 47 rue de Lavaux, F-54520, [mada.durand@orange.fr](mailto:mada.durand@orange.fr)
- b) 14-16 avenue de Fuveau, Allée Val brise 2, F-13013, [jph.caron@orange.fr](mailto:jph.caron@orange.fr)
- c) Muschelkalk Museum, D-74653 Ingelfingen, [encrinus@hagdorn-ingelfingen.de](mailto:encrinus@hagdorn-ingelfingen.de)
- d) Universidade de Vigo, SP-36200 Vigo, [jbdiez@uvigo.es](mailto:jbdiez@uvigo.es)

The printed preliminary version was sponsored by the AGPT (Association des Géologues du Permien et du Trias)

## General outlines of the French South-East Basin

Marc DURAND

The South-East Basin (Fig. 1) is one of the three great Mesozoic basins of France. It is limited to the west, along the Variscan Massif Central by a major fracture swarm (Cévennes Fault) trending SW-NE, going on, by the southern edge of the Jura Basin, up to the Swiss Alps. To the east and south-east, its infill was intensely affected by the Alpine and Pyrenean deformations respectively, so that the passage of this palaeogeographic domain to the Alpine area of sedimentation, with which it communicated, is difficult to specify. Most representations show a high zone towards the south, between the Maures and the Pyrenees, giving to the basin a roughly triangular shape (e.g. BAUDRIMONT & DUBOIS 1977). This morphology, which really prevailed during a part of the Jurassic, did not exist yet in the Triassic. As the palaeocurrents of the Buntsandstein and the biofacies of Muschelkalk show, the basin was open to the SW (Catalonia); moreover it is clear that the region of Toulon was then very close to the Nurra in NE Sardinia (RONCHI & DURAND 2002, CASSINIS et al. 2003).

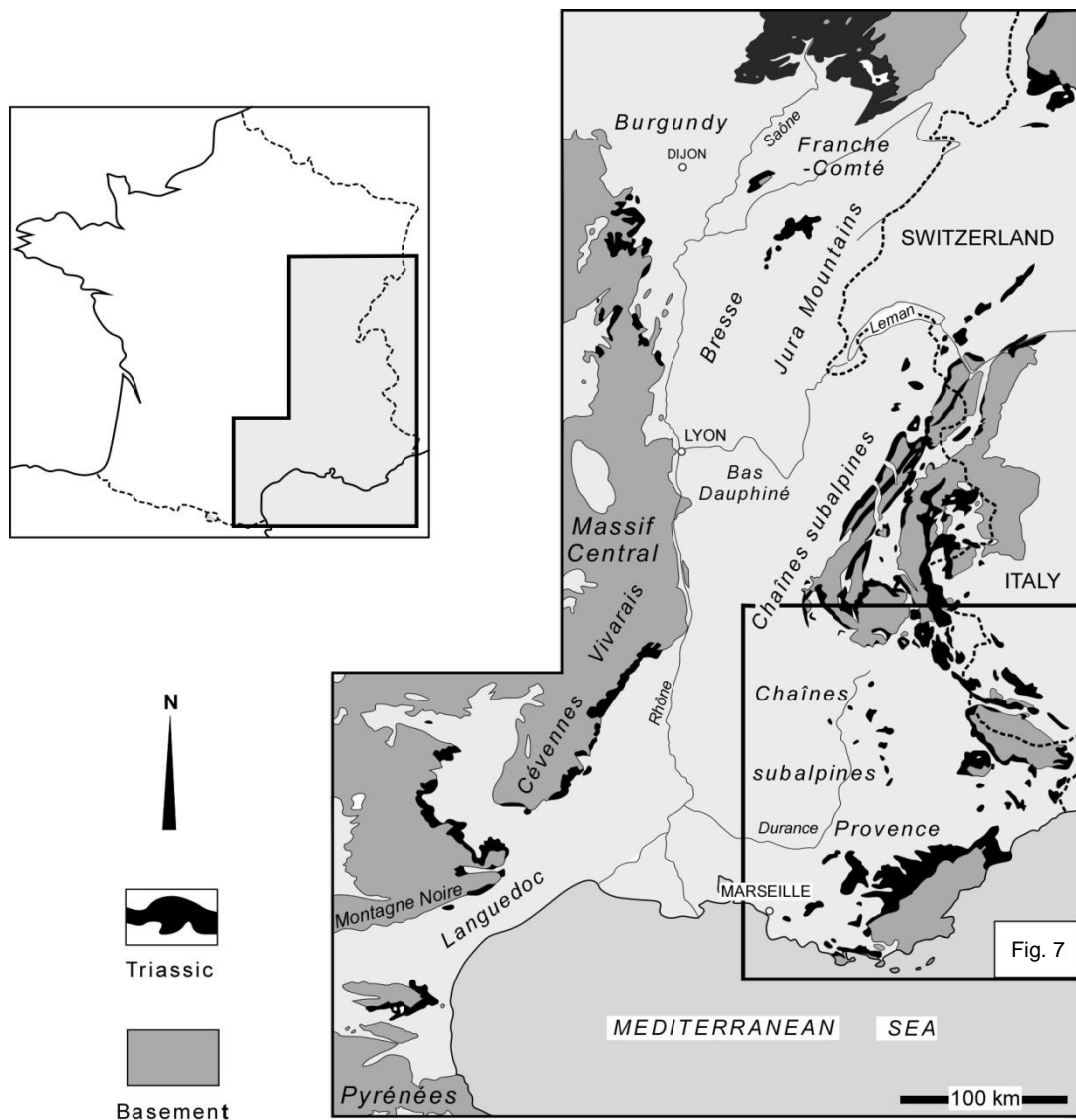
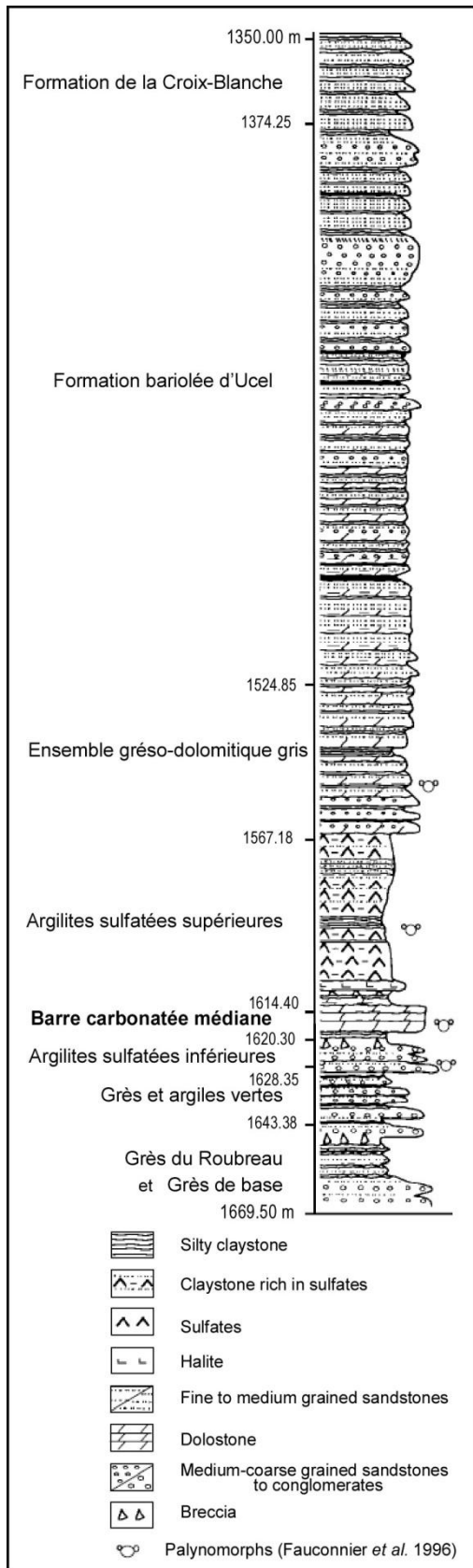


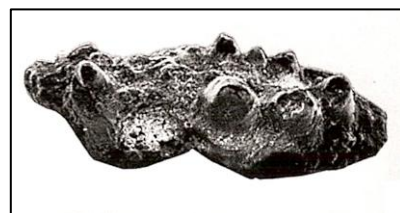
Fig. 1 – Zones of outcrop of the Triassic series within the South-Est Basin.



**Fig. 2** – Reference section of the Balazuc well (Deep Geology of France program) for the Vivarais Edge (Ardèche) of the Massif Central. After COUREL *et al.* (1998) and COUREL & DEMATHIEU (2000).

On the western side of the basin, Triassic strata crop out mainly at the south-eastern edge of the Massif Central (crystalline basement) along the Vivarais (Ardèche) and Cévennes mountains. Pinching out to the west, on a rather short distance, they thicken to the east: from about 50 m above the outcropping basement, to 320 m in Balazuc well (AQUILINA *et al.* 1996) about 20 km eastwards, and 430 m in Valvignères well again 20 km further. Until now no borehole still reached the basement in the central part, where evaporites are particularly developed.

Along the Ardèche margin the Triassic sedimentation began only during the Anisian. A reference section can be chosen in the Balazuc borehole (Fig. 2). The first marine deposits are sand prone : 'Grès du Roubreau' Formation. Associated dolostones yielded bivalve fragments and Ladinian foraminifera. Mudrocks layers, more or less cemented by dolomite, yielded Chondrichthyan scales and conodonts. It is particularly noteworthy that the sole illustrated specimen of conodont from the whole western part of the basin (Fig. 3), ascribed to the Ladinian *Pseudofurnishius huddlei* (HIRSCH in COUREL *et al.* 1998), is a Tethyan taxon indicative of the Sephardic province (HIRSCH 1972) also known as 'Westmediterranean-Arabische Faunen-provinz' (KOZUR 1980). Nevertheless, another marine formation, representing the most continuous lithostratigraphic marker : 'Barre carbonatée médiane', 9 m thick on average, is located higher. Palynological results of the Balazuc borehole corroborated the previous stratigraphic data (palynology, micropaleontology, tetrapod palaeoichnology), confirming an Anisian-Ladinian age for the 'Grès du Roubreau', and dating the base of the 'Barre carbonatée médiane' at the Ladinian-Carnian boundary (FAUCCONNIER *et al.* 1996).



**Fig. 3** – Conodont from the Barre carbonatée médiane. From FINELLE (1981 : pl.4-14).



It should be noticed that, in two wells on the Ardèche margin, remains of dasycladacean algae were revealed, by cathodoluminescence, in the 'Argiles sulfatées supérieures' of Carnian age (CROS & ARBEY 1999).

On the eastern side of the basin, the Triassic crops out, more widely, around the Maures-Estérel-Tanneron massif and the Mercantour-Argentera massif with its annex : the Dôme de Barrot. It is in this eastern region, where marine facies are best developed, that we shall limit the present field-trip (see figures 1, 4 and 7).

### Palaeogeographic relationships

It was often appealed to a hypothetical 'Burgundian Gate' to explain faunal immigrations from the Tethys towards the Germanic basin (e.g.: WAGNER 1956, BOIGK & SCHÖNEICH 1974, URLICHS & MUNDLOS 1985, HAGDORN et al. 1998, URLICHS 1999, POSENATO 2002a, KLUG et al. 2005, GÖTZ & LENHARDT 2011). Nevertheless, if some recent papers does not call any more upon it (e.g. MÁRQUEZ-ALIAGA et al. 2000, REIN 2008), it is partly because work completed within the framework of the *Synthèse géologique du Sud-Est de la France* (COUREL et al. 1984, LIENHARDT et al. 1984) had already shown, on the one hand, the unlikelihood of a fully marine communication with the Tethys by Burgundy during Anisian and Ladinian, and on the other hand, the need for a connexion via Switzerland as soon as the Anisian.

The first assertion rests on the existence of two ecological barrier. One found expression in the lagoonal 'Trigonodus Dolomite' facies (of the 'Rottweil-Formation'), at the top of the Upper Muschelkalk, stretching from southwestern Germany to the south-west of Vosges above the 'Eperon bourguignon' (COUREL et al. 1973), and the other is represented by the 'Eperon lyonnais' (COUREL et al. 1984), more in the south. The second assertion seems allowed, since another migration way was proposed in northern Switzerland, near the Alpenrhein depression (SZULC 2000), and named "Alemannic Gate" (KOZUR & BACHMANN 2010). Recent work specified its localization and showed its opening as soon as the earliest Anisian (GISLER et al. 2007).

It is thus improbable that the Germanic Basin, limited by thresholds, and the basin of the South-East of France, more open on Tethys, underwent a same succession of environmental fluctuations. This is why stratigraphical correlations seem a priori easier with Mediterranean regions.

During the Triassic, the currently emerged region nearest to Provence was that of Nurra (NW-Sardinia, Italy). In this relatively small area, above a 'Buntsandstein' very comparable with that of Toulon (see Stop 4 of Monday 5<sup>th</sup>), crops out – parsimoniously and in complex tectonic structures – a calcareous 'Muschelkalk' divided into two main parts by a dolomitic-marl interval (POSENATO 2002a). At Monte Santa Giusta, it is estimated about 190 m thick by BARTUSCH (1985) versus about 60 m by CARILLAT et al. (1999). Biostratigraphy, based on palynomorphs and Tethyan conodonts (of which *Carinella truempyi* defined in Provence: see Stop 5 of Monday 5<sup>th</sup>) allows to assume a Lower Ladinian to Lower Carnian age for that formation (CARILLAT et al. 1999). The classical Punta del Lavatoio section (Alghero), which was recently recognized as overturned (POSENATO et al. 2002), exposes only a rather short segment, rich in macrofossils (POSENATO 2002b), corresponding more or less to the Provençal 'Formation II' (Caron 1967a,b; see figure 8). At this place the coexistence of the ammonoids *Ceratites* (*Austroceratites*) *toulonensis* and *Gevanites cornutus* was noted by URLICHS and POSENATO (2002).

## General outlines of the Buntsandstein in Provence and Alpes-Maritimes

Marc DURAND

On the regional scale there is no difficulty distinguishing the Buntsandstein Group which constitutes the base of the Mesozoic sedimentary pile in Provence. Although reduced in thickness (maximum 80 m) it crops out along a narrow, practically continuous belt from Sanary (SW) to Cannes (NE) (Fig. 4). It reflects a clear change from local drainage systems in several distinct basins – a characteristic of the Permian palaeogeography – to a single widespread system that is typical of the Triassic, and thus constitutes the major criterion used to define the 'Buntsandstein' in France. It is noteworthy that, in Provence, the main Triassic palaeocurrents flowed to the SW, along the Maures Massif, that is – at least for the Toulon-Cuers area – in a direction opposite to the Permian palaeoflow (DURAND et al. 1989b, DURAND 1993).

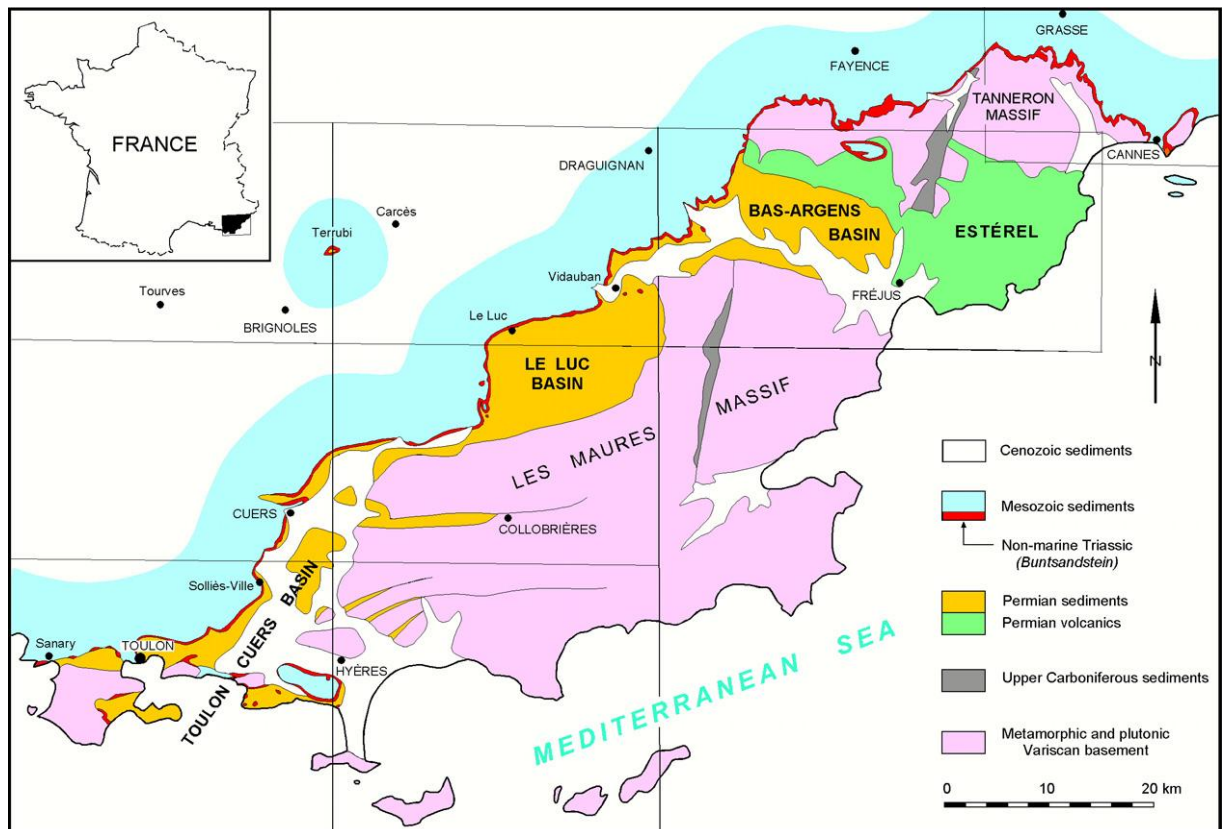
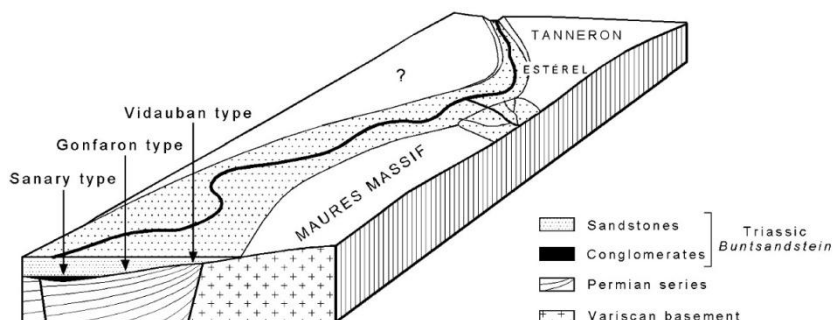


Fig. 4 – Overall sketch of the Buntsandstein (non marine basal Triassic) and Permian exposures in Provence.

### The Permian-Triassic Boundary

The boundary between the Permian and Triassic Systems can be observed in the field in many places in Provence and Alpes-Maritimes, with aspects changing over a short distance. Three different main types of contact can be distinguished in Provence (DURAND 2006 ; Fig. 5).



**Fig. 5** – Schematic diagram showing the locations, within a Lower Triassic palaeogeographical context, of the three forms presented by the Permian-Triassic boundary in Provence. Not to scale. From DURAND (2006).

In the 'Sanary type', most common, the very even infra-Triassic surface is disconformably blanketed with a 'basal' oligomictic orthoconglomerate composed of exclusively siliceous pebbles. The thickness of this 'Poudingue de Port-Issol' (GLINZBOECKEL & DURAND 1984) is commonly about 1 m and reaches a maximum of 8 m at the type section. The systematic occurrence of ventifacts in it, joined to the lack of transverse supply (as shown by a decrease of pebble size towards the borders) testify that the depositional area underwent clearly arid conditions. Another very important distinctive feature of this formation is its sharp upper boundary, marking an abrupt change in depositional style. The appearance of many indices of biotic activity (especially caliche nodules) conveys a climatic evolution into less extreme conditions, of semi-arid type. The apparently rapid character of the recorded climate change is probably due to only a more or less significant depositional hiatus. It should be noted moreover, that several sections in the neighbourhood of Toulon (Fabregas, Solliès-Ville) show the development of a palaeosol at the expense of the uppermost conglomerate layers; in another place (La Garonne beach) the Buntsandstein begins directly with a discontinuous dolocrete, and the Port-Issol Fm. does not exist.

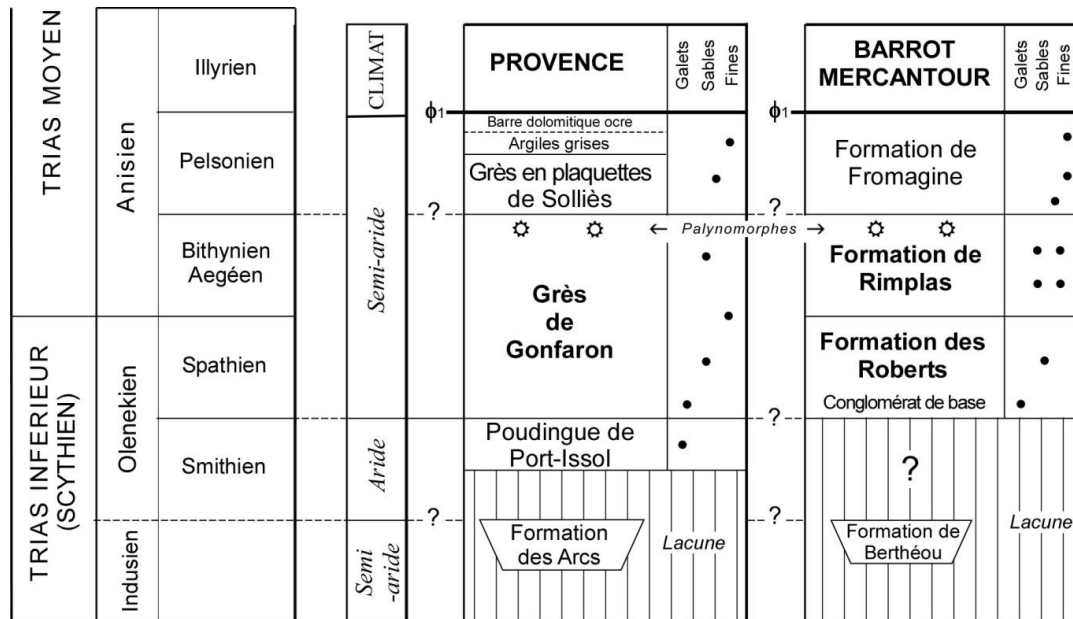
The 'Gonfaron type', less frequent than the former, corresponds to an apparent transition from Permian to Triassic deposits because of a lack of any conglomerate (see Stop 2 of Tuesday 6<sup>th</sup>). The 'Vidauban type', the least frequent, is that of a clearly angular unconformity (see Stop 3 of Tuesday 6<sup>th</sup>).

Figure 5 shows that the three types of contact between the Permian and Triassic series noticed in Provence depend on their location being more and more distant from the axis of the Triassic depositional basin. Attention must be drawn to the fact that the apparent transition does not correspond to the shorter basal gap.

### Dating elements

The Buntsandstein of the south-eastern part of the 'Bassin du Sud-Est' encompasses only a limited number of stratigraphic formations (Fig 6), which will be described at the occasion of the visit on their outcrops.

The main part, beginning in many places above pebble beds (with ventifacts) totally devoid of clues about biotic activity, is everywhere barren of fossils, with sometimes the exception of invertebrate traces (*Scoyenia*, *Beaconites*, *Phycodes*, *Arenicoloides*, etc.) deserving further study but without biochronological significance.



**Fig. 6** – Stratigraphy of the basal detrital series of the eastern part of the South-East Basin. From DURAND & GAND (2007).

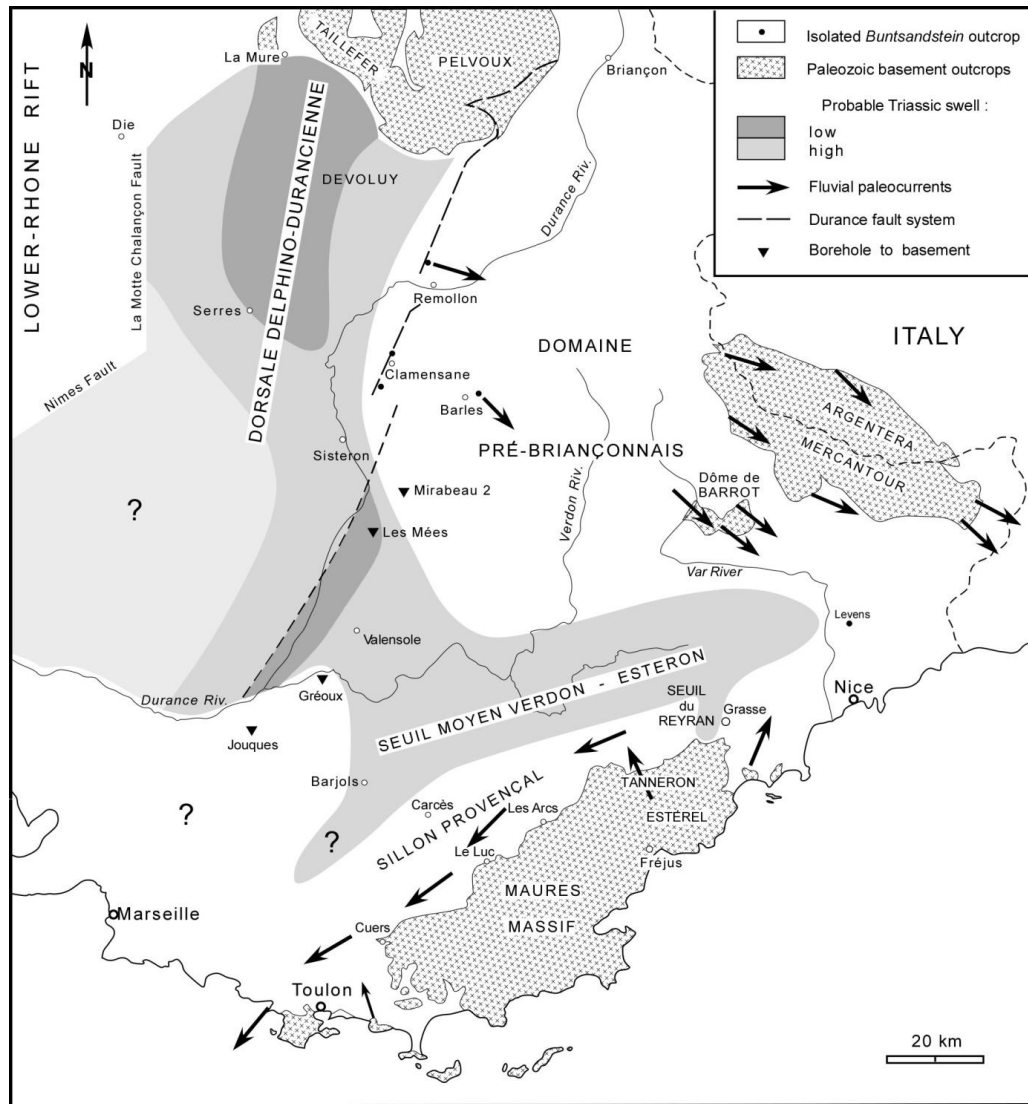
The only palaeontological elements that enable dating of that unit are palynomorphs from the uppermost part, in the Toulon area (Sollès-Ville), near Cannes-Grasse (Pégomas), as well on the Dôme de Barrot, where the Triassic sandstones were classically reputed “Werféniens”. Their assemblages, in the course of revision (J.B. DIEZ), seems everywhere of early Anisian age (ADLOFF in DURAND et al. 1989b). Very comparable associations also represent the oldest Triassic palynofloras in the upper Buntsandstein of the NE Iberian Peninsula and the Balearic Islands (DIEZ et al. 2010).

Moreover occasional occurrences of tetrapod footprints were also noted, although in general rather badly preserved with compared with the Permian ones ; they are mostly chirotheroid traces (*Chirotherium*, *Brachychirotherium*) with some *Rhynchosauroides* and *Capitosauroides*. They are much less discriminating than palynomorphs, but their stratigraphical ranges also encompass the early Anisian (DEMATHIEU & DURAND 1991).

Since the Port-Issol Conglomerate corresponds to the uppermost part of a cycle deposited under very arid conditions, of Smithian age (DURAND 2006 ; BOURQUIN et al. 2007, 2011), one can point out that neither the presence of the Upper Permian (i.e. Lopingian) nor of the lowermost Triassic (i.e. Induan) are proven in Provence up to now (DURAND 2006). Thus the sub-Triassic unconformity represents there probably a hiatus estimated at 10 - 15 Ma.

### Palaeogeography

The sedimentological study of Buntsandstein of the Dôme de Barrot (palaeocurrents, nature and size of the phenoclasts) and of neighbouring sectors led to the definition of a particular paleogeographic entity: the ‘Domaine prébriançonnais’ (DURAND et al. 1988), definitely distinct from the ‘Bas-Rhône rift’ on the one hand and from the ‘Sillon Provençal’ on the other hand (Fig. 7), all three constituting an integral part to the future large South-East Mesozoic Basin.



**Fig. 7** – Tentative palaeogeographic reconstitution, starting from the study of the Buntsandstein facies, of the oriental part of the South-East Mesozoic Basin at the beginning of the Middle Triassic (according to DURAND et al 1988, supplemented).

The paleogeography considered herein can be integrated neither in the Permian tectono-sedimentary context, dominated by a distension N-S, nor within the framework of the Mesozoic opening of Ligurian Tethys. Indeed, the Tethysian rifting, initiated well east of the Mercantour, is characterized by a purely distensif mode, since the affected domain remained primarily marine; in the South-East of France, it resulted in the appearance, during the Lias, of narrow tilted blocks restricting the lateral extension of detrital spreadings. On the other hand, the widespread 'Prébriançonnais' Triassic fans imply the formation of an epeirogenic doming located more to the west, and stopped by the collapse of the Bas-Rhône basin, which would correspond thus with the model of rift generated by a mantellic plume.

Although the Triassic crustal movements are often regarded as the discrete precursors of the Tethysian rifting they seem rather to correspond to a distinct event, as testify the various "abortive rifts" known not only on the opposite margin of the Tethys but also apart from the fields of Jurassic oceanic opening.



## General outlines of the Muschelkalk and Keuper of Provence

Jean-Paul CARON

Among all the sedimentary series of Provence, Triassic deposits was those which were studied the least as regards stratigraphy, although the “*Conchylien*” was reported since 1829 by A. BRONGNIART « *près Toulon, le cap de Seine et le pied du Mont Faron* ».

Middle Triassic limestones crop out near the city of Toulon, the harbour and the military fortifications; they were exploited in quarries since the 17<sup>th</sup> century to provide construction materials (hardcores), while the Urgonian limestones were used for dimension stones. Most quarries were open in fossiliferous limestones of the Muschelkalk, in which are intercalated marly layers, having yielded a plenty of fossils.

The Triassic succession, suggested by HAUG (1925) on the sheet ‘Toulon’ of the geological map at the 1/50,000 scale was used as reference up to the second edition (CARON in GOUVERNET 1969). The detailed survey undertaken for this second edition showed the diversity of the Triassic formations and their complex structure related to their implication in the Pyrenean - Provençal tectonics (mainly Paleocene - Eocene). The reconstituted, and simplified, stratigraphic scale presented herein (Fig. 8), in the course of establishment for the third edition, highlights the main features of the middle and upper Triassic.

### Lower Muschelkalk

There is no continuous outcrop showing the passage from the ‘Grès en plaquette de Solliès’ to the overlying beds (**t 3a**) of the Lower Muschelkalk. They are marls, clays and gypsum, which can be observed only on occasions thanks to work of civil engineering, excavation, drilling, etc...(CARON & DUROZOY 1966).

These rocks, ductile and tectonically incompetent, made it possible the Mesozoic sedimentary cover to get loose from the thick detrital formations (Permian and Buntsandstein), transgressive on the Variscan basement of the Maures Massif, which constitute the tectonic tegument. The displacement of the cover caused planing, with ablation of these rocks in certain sectors and their accumulation into others; it is particularly the case of gypsum which one finds in lenses under the Lower Muschelkalk limestones. It is thus not possible to give the initial stratigraphic thickness of these deposits, of which the present structural thickness varies from few meters with more than 30 m, and which are affected by disharmonic folds. This **t 3a** unit constitutes the decollement zone **Ø 1**, whose extension is quasi-general in Provence.

The following unit (**t 3b**) represents the first calcareous formation of the Triassic, which was never identified nor differentiated from the fossiliferous limestones in the Toulon area before the sixties (CARON 1968, 1969), but is present in the whole Provence, including the eastern and northern parts. It was mapped by the author on the sheets at 1/50,000 ‘Toulon’ (GOUVERNET 1969), ‘Cuers’ (BLANC et al. 1974) and ‘Brignoles’ (MENESSIER et al. 1979), including sectors having not been the subject of recent revisions. Its main features will be evoked on Stop 3a of Monday 5<sup>th</sup>.

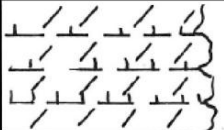
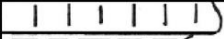


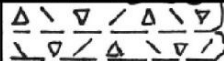
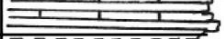
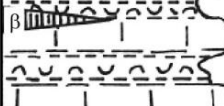










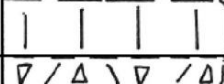
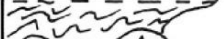

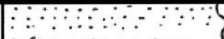
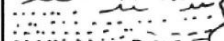



HETTANG.	> 50 m		I 1-2	Cellular dolostone ~ green marl
RHETIAN	5-10 m		t7b	Beige fine-grained limestone
	45-50 m		t7 t7a	Green marl and yellow-ocher limestone interlayering Fossiliferous layers  Fossil bearing microconglomerate: <i>Rhaetavicula contorta</i>
KEUPER	a few to >30 m		t5-6	Red clays with bipyramidal quartz Gypsum = Decollement zone Ø <sup>3</sup> Marls with boxwork structure, whitish clays
MUSCHELKALK	15-20 m		t4	IV Rauhwacke, cherts Dolostone, dolomitic limestone
	5-18 m		t3d	III Two-tone limestones: <i>Costatoria goldfussi</i> , <i>Dentalium</i>
	22-25 m		t3d	II Marly limestone: <i>C. vulgaris</i> , <i>Ceratites toulonensis</i> , <i>Encrinurus</i> ... Limestone with Dasycladaceae. Basalt (Rougiers, Blanque) Marly limestone: <i>C. vulgaris</i> , <i>Encrinurus</i> ... Limestone with Solenopores, <i>Tolypammina</i> , burrows.
	7-18 m		t3d	I Dolostone, dolomitic limestone, rauhwacke
	0-30 m		t3c	Basalt intercalation (Rampale, Méounes, Tourves)
	10 m		t3c	Marly limestone, white marl
	0-10 m		t3c	Gypsum accumulation = Decollement zone Ø <sup>2</sup>
	10 m		t3c	Dark limestone ~ light-grey dolomitic limestone
	10 m		t3c	Marls with lignite intercalations (?)
	0-25 m		t3c	Marls and clays, gypsum heaps
Lower	3-5 m		t3c	Decollement zone Ø <sup>2</sup>
			t3c	Argillaceous limestone ~ marly limestones, finely laminated
	5-10 m		t3b	Dolostone, dolomitic limestone, rauhwacke
	50 m		t3b	Massive dark limestones with platy intercalations
	5-10 m		t3b	Dolostone, dolomitic limestone, rauhwacke
BUNTSANDSTEIN	0-30 m		t3a	Marls and clays Gypsum in irregular accumulations
	5 m		t3a	Decollement zone Ø <sup>1</sup>
			t3a	Platy halite-pseudomorph bearing silty sandstone
	60 to 80 m		t2	Dolomitic sandstones, with ripple-marks, alternating with micaceous flagstones, and cross-bedded argillaceous sandstones  Sandstones (coarse ~ silty-micaceous) with nodules and cross-bedding
	5-10 m		t1	Basal conglomerate, sandstone
	> 1 km		r	PERMIAN: generally red mudrocks J.-P. CARON - 2011

Fig. 8 – Reconstituted synthetic section of the Triassic series of Provence

### Middle Muschelkalk

The lithology of this series **t 3c** is comparable with that of the basal part (**t 3a**) of the Lower Muschelkalk. Owing to their plasticity, its components are tectonically incompetent, and, being affected by disharmonic folding, enabled the compact Lower Muschelkalk limestones to form folds and/or slices, structurally independent from the Upper Muschelkalk, and whose geometry can be specified. Like for the **t 3a** Lower Muschelkalk, it is not possible to give the initial stratigraphic thickness of these deposits, of which the present one varies from a few meters up to more than 30 m, because gypsum can accumulate in thick lenses or can be totally laminated. Thus, the Middle Muschelkalk constitutes the second decollement zone **Ø 2**, whose extension is quasi-general in Provence.

Recent geological survey highlighted, within this formation, a calcareo-dolomitic unit, the thickness and facies of which make possible to refer it neither to the calcareous Lower Muschelkalk **t3b** nor to the fossiliferous Upper Muschelkalk **t 3d - t 4**. This unit is isolated within the plastic and incompetent rocks, folded dysharmonically, by two decollement surfaces for which we retain the notation **Ø 2** when it is not possible to differentiate them. In the vicinity of Saint-Cyr-sur-Mer (Rampale), volcanoclastics were reported (CARON in BLANC et al. 1977). They remind of those described by CARON (1970) and mapped on the sheets 'Cuers' (BLANC et al. 1974) and 'Brignoles' (MENESSIER et al. 1979). Finally, a marl bed with lignite intercalations, whose stratigraphic attribution is dubious, was recently discovered.

### Upper Muschelkalk

It is the calcareous and calcareo-dolomitic formation classically known for its fossiliferous layers. For this reason, it drew very early the attention of geologists and paleontologists, and the first comparisons with the 'Germanic' Triassic were carried out. But later it is especially its tectonic behaviour which was being investigated, leading to the understanding of its role in the separation of the Mesozoic cover from the Variscan basement and its tegument of Buntsandstein, with its consequences in the uplift of the main mountain ranges of Provence

Studies undertaken in the field from 1960, in order to revise and/or to establish the maps of Provence at 1/50,000, made it possible to draw up precise profiles of all the important quarry walls and outcrops. Many located samples were taken, studied on polished surfaces and thin sections, and were the subject of petrographic and sedimentological descriptions. A standard succession was established for the Upper Muschelkalk, highlighting the main following facts. There is a remarkable horizontal continuity of the principal beds, without notable variation of facies, and with relatively moderate variations in thickness. Some layers are characterized by special microfauna and microflora, and thus constitute key beds of very constant extension. The comparison between various profiles and their structural analysis made it possible to highlight the complex tectonics affecting the calcareo-dolomitic Upper Muschelkalk, and in particular to define its normal stratigraphic succession. The study of sedimentary structures and up-down criteria shows that certain structural units were completely overturned, others more or less verticals, and finally, some were in normal position (CARON 1965a). Four lithological units of regional extension were defined there (CARON 1967a,b ; CARON & GAUTHIER 1968).

### Formation I

Often with brecciated aspect, they are dolomitic limestones and dolostones, light gray to clear yellow, jointed and carginized in contact with the decollement zone **Ø 2** of the Middle Muschelkalk. So the stratigraphic thickness (19 m minimum at L' Escaillon) never could be measured entirely.

## Formation II

It is characterized by an alternation of marls (or clays) and fossiliferous limestones, compact or nodulous, and its thickness ranges from 22 to 25 m. The lower limit corresponds to the top of the last dolomitic limestone bed of Formation I. The upwards succession of the main lithofacies is the following:

- Encrinitic limestone
- Limestone with *Tolypammina* [ formerly described as '*Nubéculaires*' (CARON 1965b) ]
- Oolitic and pisolitic limestone
- Lower marly limestone, sometimes fossiliferous
- Lower shelly complex showing an intercalation of several facies: limestone with *Coenothyris*, little or not reworked, grainstone to wackestone calcirudites and calcarenites, and encrinitic calcirudite
- Limestone with Dasycladaceae, compact and dark, sometimes vermiculated
- Encrinitic limestone, present in all the area.
- Upper marly limestone, with a layer of ochre sandy limestone
- Upper shelly complex
- Limestone with Solenoporaceae.
- Encrinitic limestone. The passage to Formation III, is more progressive than its lower limit.

## Formation III

Its thickness varies from 5.30 m (Bandol) up to 17.80 m (Hyères). It is a rhythmic alternation of dark and light gray limestones (or limonitized biosparites in the lower part), separated by corrugated joints. These repeated rhythms, 3 to 8 cm in thickness, give a typical two-tone aspect. Large intraclasts (10-15 cm) of dark limestone, intraformational microconglomerates, and small channels 15-20 cm deep are frequent. Dark limestones with vermiculations are well represented, and look like those of the Lower Muschelkalk. Only some yellow marly limestone beds show a certain lateral continuity.

## Formation IV

Its lithofacies show great similarities with those of Formation I: dolomitic limestones and clear yellow to light gray dolomites, of which they are difficult to differentiate in spite of a better marked stratification. The thickness ranges between 15 m minimum near Toulon (Faron) and 6 m near Cuers; these variations can be explained by a development of dolomitization of the Formation IV, which invaded Formation III. At the top of the formation, siliceous and/or anhydritic concretions, in layers or lenses, of a few centimetres thick, constitute frequently a good key-bed near the Keuper boundary.

## Keuper

The sedimentary succession that is usually referred to the Keuper is composed of clays and marls containing locally bipyramidal quartz, mostly gypsum in lenses (not appearing on the surface), and locally lignites, thin and discontinuous, which were in the past mined in an artisanal way; dolostones were reported locally (CARON & GOUVERNET 1961). That Keuper, ductile and incompetent, is affected by disharmonic folds, as the Lower Muschelkalk t3a and the Middle Muschelkalk t3c. No continuous stratigraphic profile can be established. It can miss completely - the lower Rhetian resting then on the last Upper Muschelkalk beds - or, on the contrary, be accumulated in lenses, whose structure is completely destroyed, and marking out locally the major abnormal contacts or forming the core of diapirs. It is the third décollement zone Ø 3, whose extension is quasi-general in Provence.

The yellow Rhaetian limestones are often shelly (with *Rhaetavicula contorta*), and are sometimes rich in crustacean coprolites, some of them having been described for the first time in Provence (BRÖNNIMANN et al. 1972a,b).

**Invertebrate fauna, biostratigraphy, and paleobiogeography  
of the marine *Trias Carbonaté* of SE-France,  
compared to the *Upper Muschelkalk* of Central Europe**

Hans HAGDORN

The striking similarity of the Middle Triassic carbonate and evaporite succession in SE-France with the classic Upper Muschelkalk in SW-Germany and NE-France (Alsace, Lorraine) has been treated by French and German workers since more than 150 years. A good deal of this research was focused on biostratigraphic correlation and aimed at understanding Middle Triassic palaeogeography and at reconstructing scenarios of faunal migration within the northwestern Peri-Tethys realm.

Lithofacies and the abundance of the brachiopod *Coenothyris vulgaris* and the crinoid *Encrinurus liliiformis* in the fossiliferous carbonatic middle units gave evidence for correlation with the Upper Muschelkalk and the “Lettenkohle” (Lower Keuper) of NE-France and SW-Germany. Therefore, its subdivision was transferred to the Middle Triassic of SE-France (HAUG 1925, THÉOBALD 1952, RICOUR 1962). The Upper Muschelkalk in the region of Toulon (Lagoubran) became especially well known because of excellent outcrops in vast limestone quarries that yielded complete sections. According to THÉOBALD (1952) the Middle Triassic of Toulon is approximately 100 m thick, comprising :

- ca. 16 m of marls and red dolomitic sandstones that he correlated with the Wellenkalk,
- ca. 30 m of limestones with silex nodules, and yellowish dolomitic marls, corresponding to the “marnes grises et marnes bariolées” of the Middle Muschelkalk,
- ca. 20 m of gray and yellowish limestones plus additional ca. 20 m marls with terebratules (*Coenothyris*) and ceratites correlated with the Upper Muschelkalk,
- ca. 10 m of marls and marly limestones equivalent to the Lettenkohle.

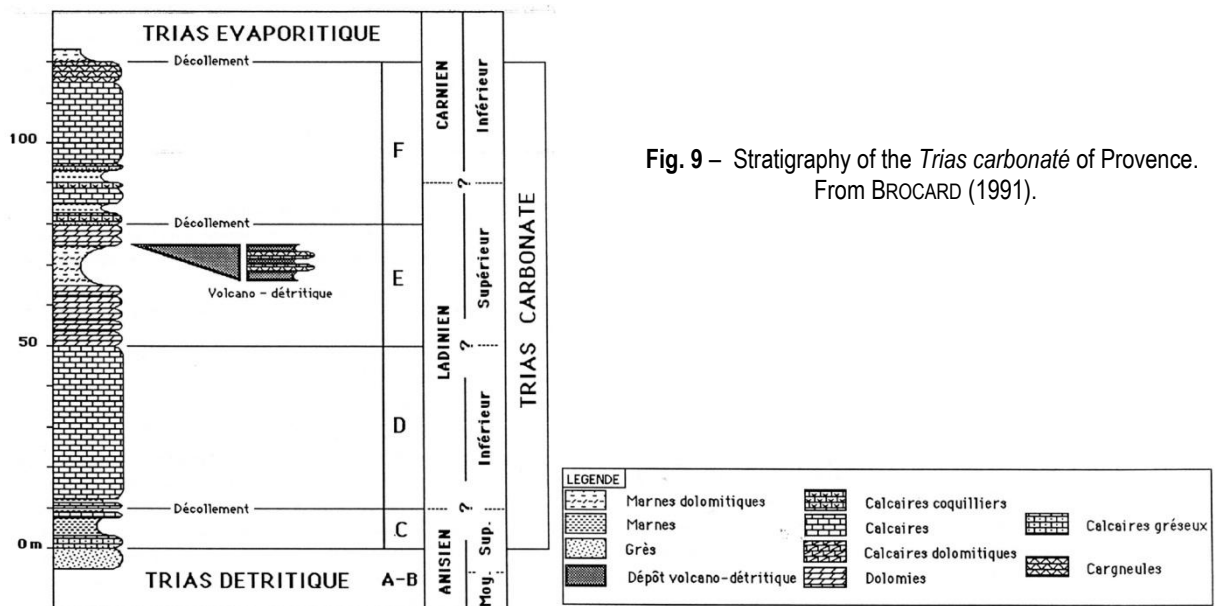
THÉOBALD (1952: 55) emphasizes that the Muschelkalk of SE-France does not contain any fossils that are unknown in the typical Germanic Muschelkalk of Lorraine and Germany. However, a first marine cycle – the Lower Muschelkalk of Central Europe – is not represented by marine sediments in SE-France. Detailed lists of macroinvertebrate and vertebrate fossils were added by CHARLES (1948) and CORROY (1933).

Later, CARON (1967a,b), GLINTZBOECKEL & DURAND (1984) and BROCARD & PHILIP (1989a) established independent lithostratigraphic subdivisions of the marine Middle Triassic in SE-France, avoiding correlations with the Central European germanotype Muschelkalk. According to BROCARD (1991), the “*Trias carbonaté*” of late Anisian through early Carnian age is subdivided in the units C, D, E, and F (Fig. 9). Downsection, the sandstones of Units A and B represent the “*Trias détritique*”. The late Carnian and younger Triassic up to the marine Rhaetian is called “*Trias évaporitique*”. For Muschelkalk and Lower Keuper stratigraphy in SW-Germany see figures 10 and 11.

This informal subdivision is used in the following notes on common and important invertebrate fossils most of which were collected during a field trip in 1996 in the fossiliferous Unit F (for locality data and profiles see CARON 1965c, 1967b and BROCARD 1991). Unfortunately, the large limestone quarries



of Lagoubran, which are nowadays situated within the outskirts of Toulon, are covered with buildings or vegetation or used for deposition or incineration of rubbish.



### Depositional environment

According to BROCARD (1991), the shallow marine carbonates and marls were deposited on two successive homoclinal ramps settled in a semi-enclosed area, partly surrounded by structural highs. Due to relative sea level fluctuations the connection to the open sea was changing. The earlier ramp is characterized by tide-controlled packstones and wackestones with small sized gastropods, bivalves, ophiuroid sclerites, and ostracods (Unit D). After a barren evaporitic interval (Unit E) with volcanic ash beds near its top, the second ramp (Unit F) was formed. Storm controlled sediments with *Placunopsis*- and Crinoid-bioherms and abundant brachiopods indicate a change of similarly restricted and more open marine environments.

### Fauna

The macrofauna of Units A – D is relatively poor compared to that of Unit F. BROCARD (1991) provides detailed faunistic data including microfauna for the measured sections. None of the faunal elements allows statements about the chronostratigraphic position of these units or about paleobiogeographic relations with the Germanic Basin. Unit E is unfossiliferous. For these reasons, the focus is laid on the fossiliferous Unit F that yielded the ceratites and other typical Muschelkalk macrofauna. Micropalaeontological data of importance for chronostratigraphic correlation are reported from the literature, mostly from BROCARD (1991).

### Ceratites

Internal moulds (*Steinkerns*) of germanotype ceratites from South-East France were mentioned for the first time by PHILIPPI (1901, 1905) and identified with the south-alpine *Ceratites tornquisti*. In his description of *Ceratites toulonensis*, RIEDEL (1916) emphasized that the lateral nodes of his specimens

are positioned above the mid of the flank. Accordingly, WENGER (1957) diagnosed his new subgenus *Austroceratites* as follows: Germanotype ceratites with lateral nodes above mid of the flank. Simple ribs are developed by gradual shifting of the lateral nodes close to the external margin, and original marginal nodes disappearing. *Ceratites* (*Austroceratites*) *toulonensis* RIEDEL, 1916 is diagnosed as follows: Juvenile sculpture dichotomous. During growth, lateral nodes gradually confluent with the umbilical margin by a shallow fold. Lateral nodes shifting to an external position maintaining this fold that finally forms the adult rib. Original marginal nodes forming an edge that disappears towards the body chamber. The size is less than 12 cm.

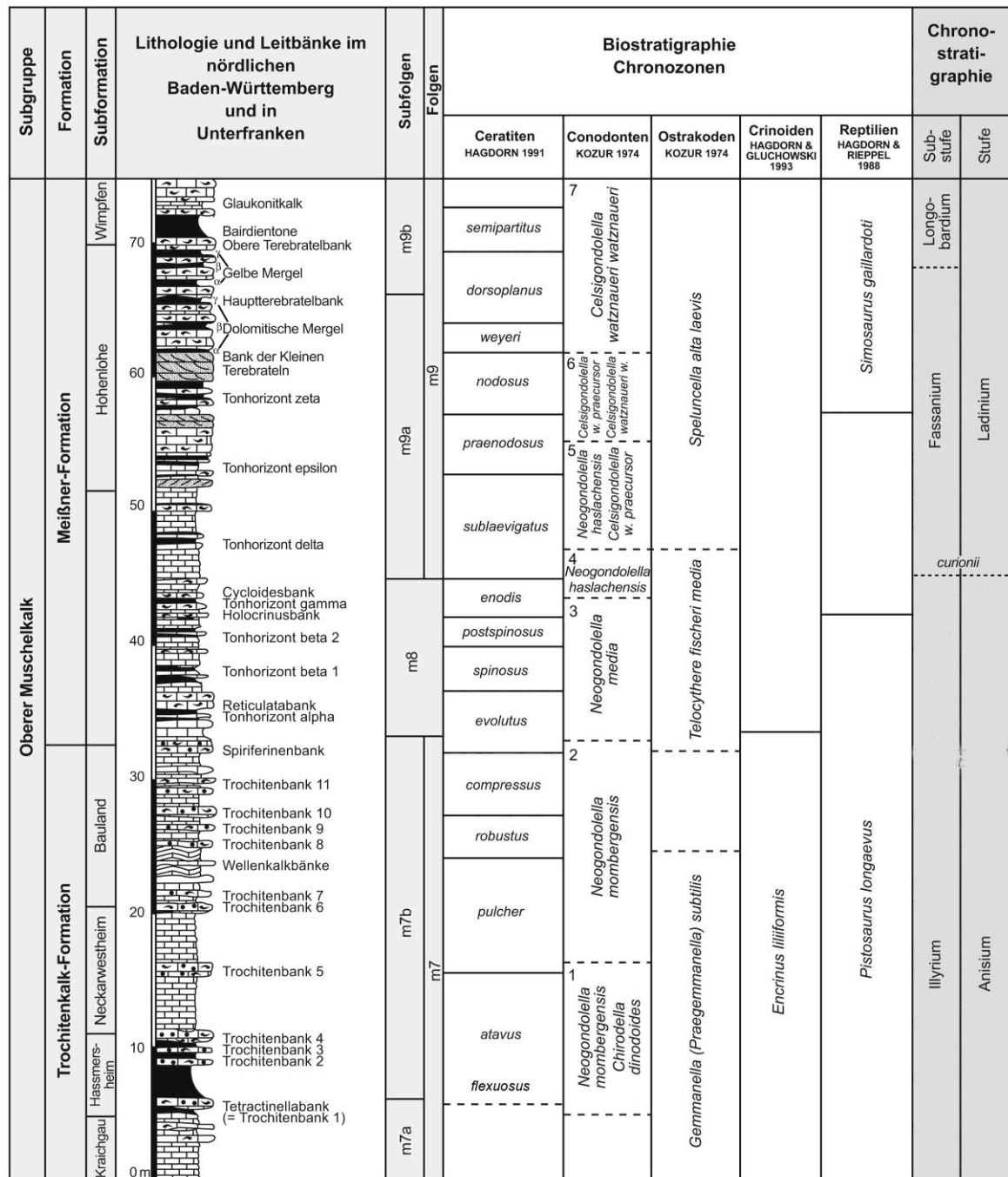
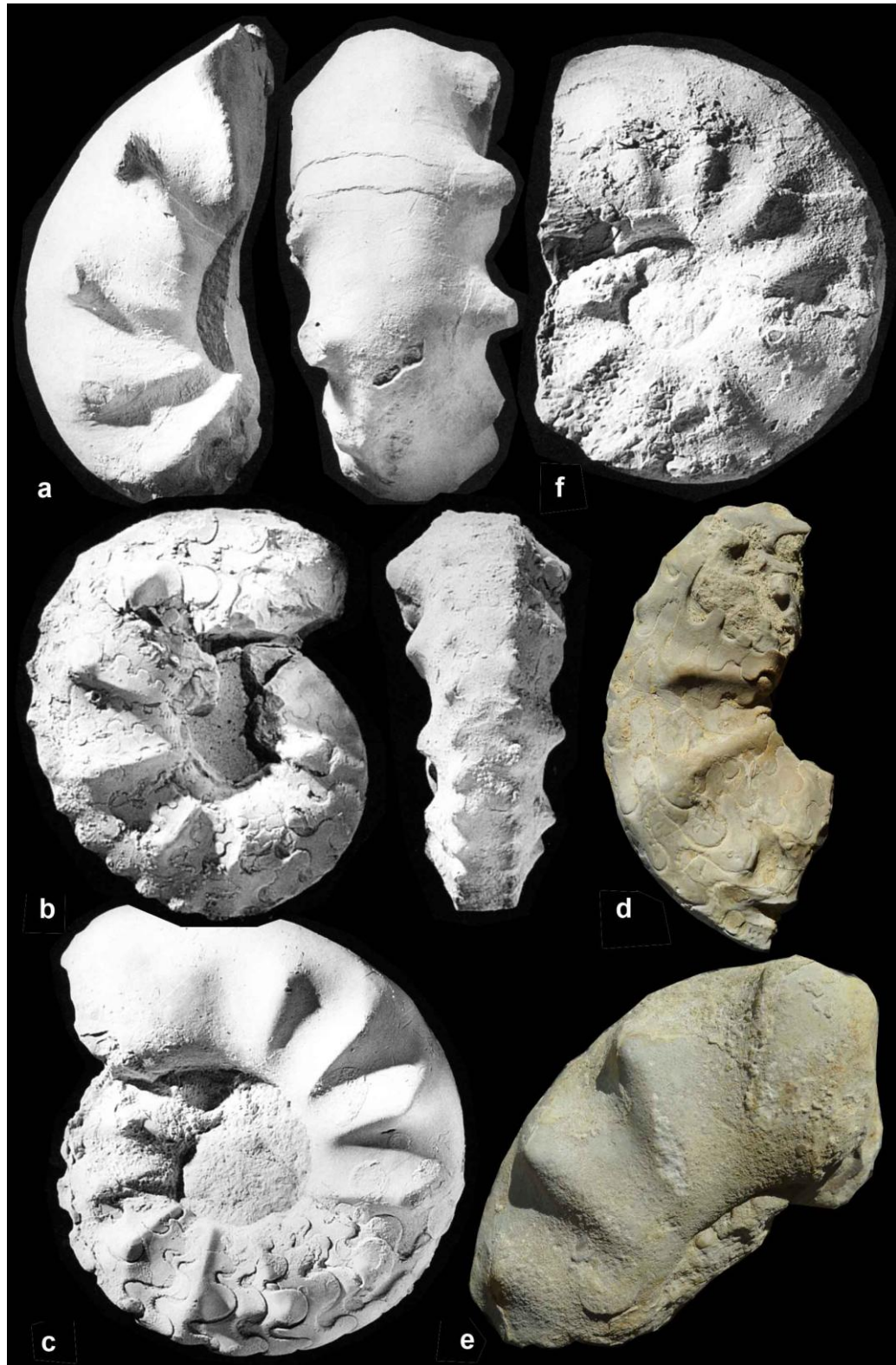


Fig. 10 – Stratigraphy of the Upper Muschelkalk in SW-Germany. From HAGDORN (2004).



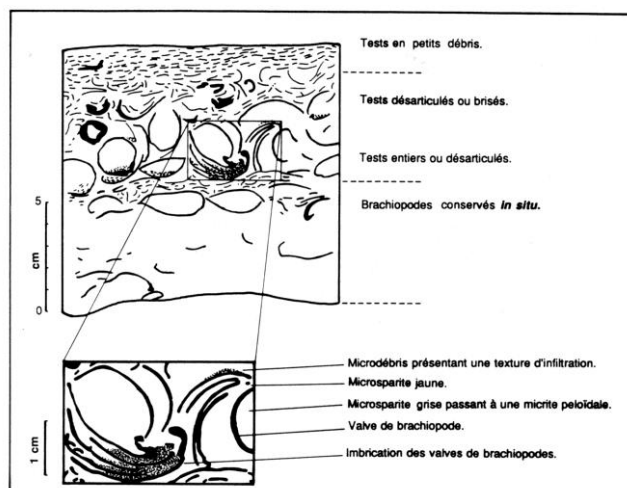


**Fig. 12 – Ceratites.** **a-e** *Ceratites* (*Austroceratites*) *toulonensis* RIEDEL, 1916 (from URLICHS 1997). **a** Body chamber, from lateral and from ventral; Lagoubran; Lab. Géol. Univ. Marseille; height 8,5 cm. **b** Phragmocone, from lateral and from ventral; St. Jean-du-Var; Lab. Géol. Univ. Marseille; height 6 cm. **c** Adult individual from lateral; Lagoubran; Lab. Géol. Univ. Marseille; height 10,5 cm. **d** Fragment of phragmocone from lateral; La Roquebrussanne; Muschelkalkmuseum Ingelfingen (MHI); height 7,8 cm. **e** Body chamber, from lateral; La Roquebrussanne; MHI; height 8,6 cm. **f** *Ceratites* (*Gymnoc.*) cf. *laevigatus* PHILIPPI, 1901 (from URLICHS 1997) from lateral; La Blaque near Tourves; Lab. Géol. Univ. Marseille; height 8,2 cm.

From these data, URLICHS (1997) reconstructed a phylogenetic and paleobiogeographic scenario for genus *Ceratites*, stating that after the extinction of the large spinose ceratites (*C. (Acanthoc.) postspinosus* and *penndorfi*), the Germanic ceratites survived in an unknown area within the Germanic Basin. From this area, ceratites re-occupied their former area and diversified there as *enodis* group (*C. (Gymnoc.) enodis* and *laevigatus*) and as *Austroceratites* in SE-France.

## Brachiopods

The articulate brachiopod *Coenothyris vulgaris* (V. SCHLOTHEIM, 1820) is an abundant faunal element in Unit F. Large specimens are concentrated within marl-dominated sections in up to 20 cm thick lensoid shell beds reaching several meters in diameter. These lenses display a typical vertical structure of a micritic base covered by double valved specimens in situ followed upsection by isolated imbricating and interlocking shells (Figs. 13, 14 a). Towards the top of the bed, debris of brachiopod shell fragments indicates tempestitic accumulation.

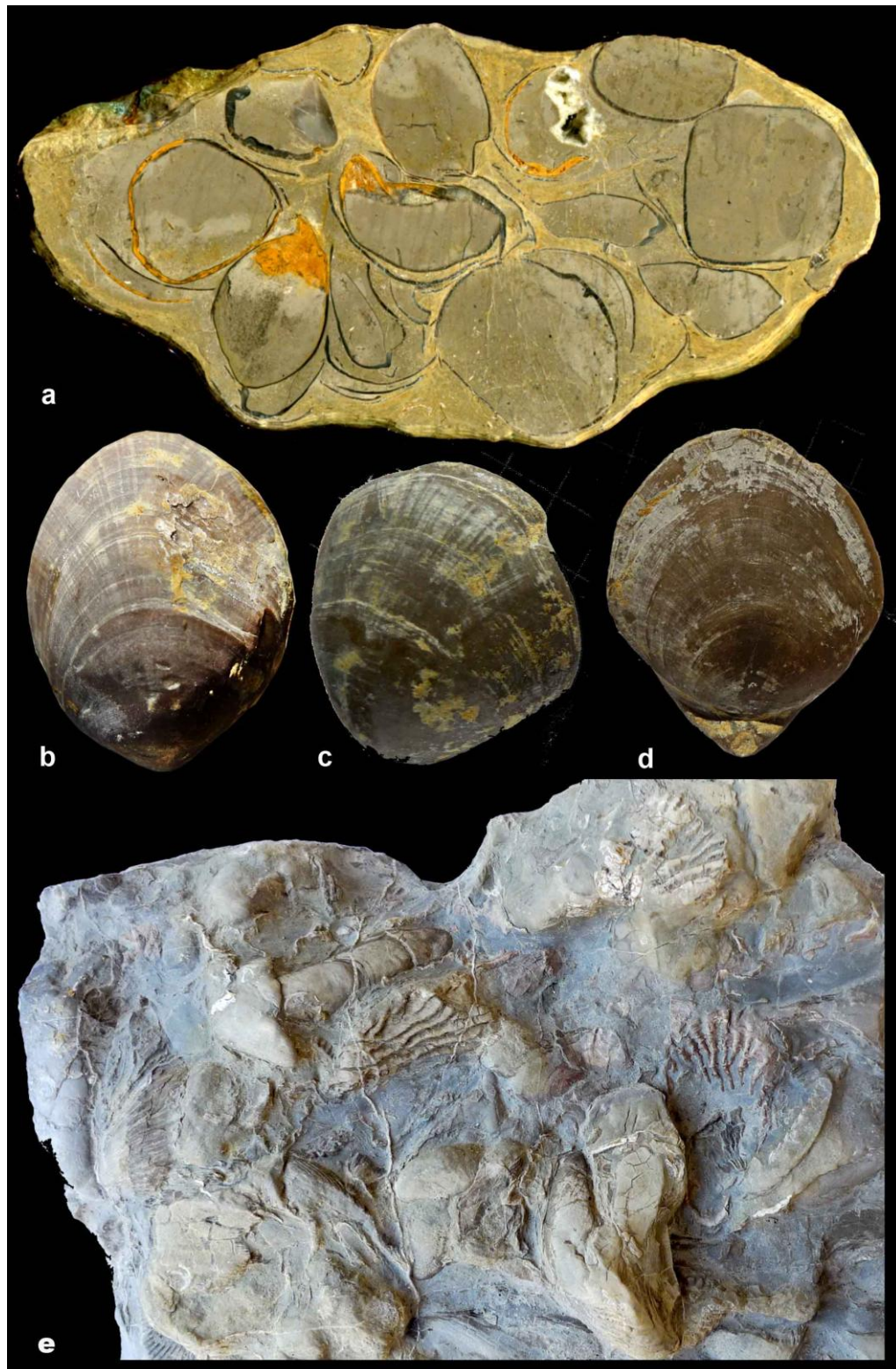


**Fig. 13** – *Coenothyris coquina* from Unit F (Flassans-sur-Isssole). From BROCARD (1991).

In well preserved *Coenothyris* shells the attachment trace *Podichnus centrifugalis* has been observed. It was produced by the brachiopod pedicle that was attaching to other individuals by etching small holes into their calcitic shells. The marls may contain clusters of double valved specimens in life position settling on one another with the pedicle hole directed downward towards the substrate.

According to the stratigraphic correlation proposed by URLICHS (1997), the large *Coenothyris* of SE-France would be time-equivalent to the much smaller *Coenothyris cycloides* of the Central European Muschelkalk Cycloidesbank (*enodis* zone). However, the Cycloidesbank being the most widespread marker horizon of the Upper Muschelkalk has not been identified west of River Rhine (HAGDORN & SIMON 1993). Moreover, the specimens from SE-France are most similar in shape and size to the *Coenothyris* individuals from populations in the Hauptterebatelbank (*dorsoplanus* zone), the most important ecostratigraphic marker horizon in the Southwestern part of the Upper Muschelkalk Basin. This bed can be traced from the southwestern margin of Vosges Mountains to Central Germany (DURINGER 1982, HAGDORN & SIMON 1993). In this bed and in the upsection following “Gelbe Mergel 1”, *Coenothyris* lumachelles similar to those of SE-France are very common. However, the *Coenothyris* from Unit F have rather narrow color bands, whereas the color bands of the Hauptterebatelbank *Coenothyris* are wider (HAGDORN & SANDY 1998).

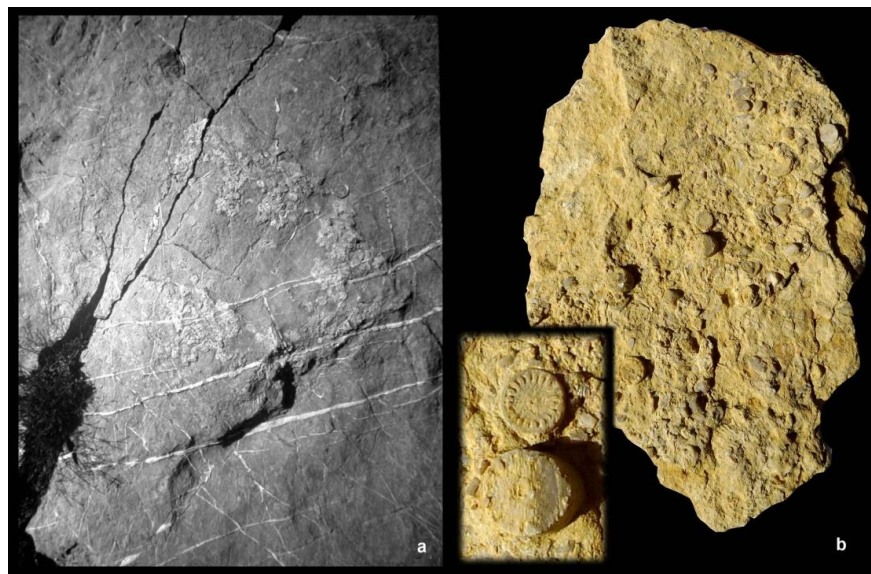




**Fig. 14 – Brachiopods and bivalves.** **a-d** *Coenothyris vulgaris* (v. SCHLOTHEIM, 1820); **a** Vertical section of coquina with double valved specimens in life position; Lagoubran; MHI; width 12,5 cm. **b-c** Double valved individuals with radial color bands; Lagoubran; MHI; height 3 - 2,6 cm respectively. **d** Uncolored double valved individual; Lagoubran; MHI; height 2,8 cm. **e** Shell bed with *Enantiostreon spondyloides* (v. SCHLOTHEIM, 1820); Bastide de la Blanque near Tourves; MHI; width 14 cm.

## Crinoids

Disarticulated sclerites of encrinid crinoids occur abundantly in bioclastic limestone beds of Unit F forming encrinites (crinoidal limestones) (BROCARD 1991). A few arm fragments from Le Pradet allow their assignment to genus *Encrinus*. This genus is best known by the large *Encrinus liliiformis*, indicative of the late Anisian *liliiformis* Zone of the Central European Upper Muschelkalk, which is correlated with the *flexuosus* through *evolutus* ceratite biozones. A very poorly preserved and as yet undescribed crown of an *Encrinus* from the early Ladinian dolomitic Rottweil Formation (former Trigonodusdolomit) of SW-Baden-Württemberg gives evidence for occasional immigration of stenohaline crinoids into the Germanic Basin (HAGDORN 1985). However, search for the early Ladinian *Holocrinus doreckae*, which immigrated into the Germanic Basin in the *enodis* Zone, remained without success in SE-France (HAGDORN 1983).



**Fig. 15 – Crinoides.** a-b *Encrinus* cf. *liliiformis* LAMARCK, 1801. **a** Clusters of encrinid holdfasts forming the frame of a crinoid bioherm; Le Pradet; Photo 1996. **b** Crinoidal limestone with encrinid columnals and brachials; Montferrat; MHI; width of slab 11,5 cm.

Clusters of in situ preserved encrinid holdfasts were discovered in Unit F of Le Pradet in 1996 but remained as yet undescribed (Fig. 15 a). Such encrinid-bivalve bioherms are common in the late Anisian Trochitenkalk Formation of Germany and are indicative of autochthonous occurrence of *Encrinus liliiformis* and the characteristic *Encrinus/Enantiostreon* fossil community (HAGDORN & OCKERT 1993). The presence of such bioherms in Unit F of Ladinian age indicates an autochthonous encrinid occurrence in SE-France that is definitely younger than the mass occurrence of *Encrinus liliiformis* in Central Europe.

The following two scenarios may explain this data: (1) The encrinid from SE-France is conspecific with *Encrinus liliiformis*. In this case, the crinoid survived in SE-France into Ladinian times, while it disappeared in Central Europe by the end of Anisian and re-immigrated occasionally via the Burgundy Gate. However, there is no evidence for an *Encrinus* in the Anisian part of the marine Middle Triassic in SE-France. (2) The encrinids from SE-France represent a species of its own that immigrated rarely into the SW-German Muschelkalk Sea after the decline of *E. liliiformis*. This scenario seems to be



more realistic because the provençal encrinid could also be assigned to an as yet undescribed *Encrinus* represented by some complete and articulated individuals from other parts of the Ladinian Muschelkalk of the western Peri-Tethys (Catalonia and Israel) and possibly also to encrinids from the Sardinian Muschelkalk.



**Fig. 16 – Bivalves**

**a-** Coquina with *Plagiostoma striatum* (v. SCHLOTHEIM, 1820), *Promysidiella eduliformis* (v. SCHLOTHEIM, 1820), *Bakevella substriata* (CREDNER, 1851), *Enantiostreon spondylioides* (v. SCHLOTHEIM, 1820), and infaunal *Myophoria intermedia* SCHAUROTH, 1856; Bastide de la Blanque near Tourves; MHI; width of slab 12,5 cm. **b-** Ausschnitt from with *Bakevella substriata* (CREDNER, 1851). **c-** Double valved individual of *Promysidiella eduliformis* (v. SCHLOTHEIM, 1820); Bastide de la Blanque near Tourves; MHI; width 4 cm. **d-** Shell bed with isolated valves of *Hoernesia socialis* (v. SCHLOTHEIM, 1820); Lagoubran; MHI; width 17 cm.

## Bivalves

Many shell beds in Unit F contain a fossil association of bivalves and the brachiopod *Coenothyris* that is very common in the upper part of the Upper Muschelkalk in NE-France and SW-Germany (*dorsoplanus* through *semipartitus* zones), and also in certain carbonate beds of the Lower Keuper. The following bivalves from Unit F belong to this association:

***Hoernesia socialis*** (v. SCHLOTHEIM, 1820) (Fig. 16 d). This typical Muschelkalk bivalve with a strongly twisted left valve reaches up to 80 mm. The individuals from SE-France correspond in size and shape with large individuals that lack an anterior wing and have a posterior wing devoid of a pointed tip. This morphotype is most abundant in the Muschelkalk of NE-France and SW-Germany from the *nodosus* zone to up to the *Linguladolomites* of the Lower Keuper.

***Bakevella (Bakevella) substriata*** (CREDNER, 1851) (Fig. 16 a, b). is an elongated bivalve with radial ribs and a distinct edge that runs from the beak to the posterior margin. In the Upper Muschelkalk of Central Europe, this bakevelliid bivalve does not appear earlier than *weyeri* Zone and reaches its maximum abundance in the Hauptterebatelbank (*dorsoplanus* Zone). It is commonly found in carbonate beds of the Lower Keuper up to the Grenz dolomit.

***Placunopsis ostracina*** (v. SCHLOTHEIM, 1820). The systematic assignment of this small oyster-like bivalve to a certain family is still under discussion. The individuals from SE-France can morphologically not be separated from the Upper Muschelkalk and Lower Keuper specimens that constructed the well

known *Placunopsis* bioherms of SW-Germany and NE-France (BACHMANN 1979, HAGDORN & MUNDLOS 1982, DURINGER 1982). Primarily, *Placunopsis ostracina* is very common as an incruster of hard substrates, e.g. mollusk shells or hard grounds (Fig. 17 b). Germanotype *Placunopsis* bioherms were also reported from Unit F (BROCARD & PHILIP 1989b) but do not reach the dimensions of the bioherms in the Hauptterebratelbank. In this marker bed they had their widest geographical distribution covering an area from the southwestern margin of the Vosges Mountains through Lorraine and to the Eifel-North-South-Zone and through SW-Germany to northern Franconia. Relatively small *Placunopsis* bioherms also occur in the Lower Keuper Anthrakitbank South of Stuttgart and in the Linguladolomite of Bayreuth (BACHMANN 1979, 2002).

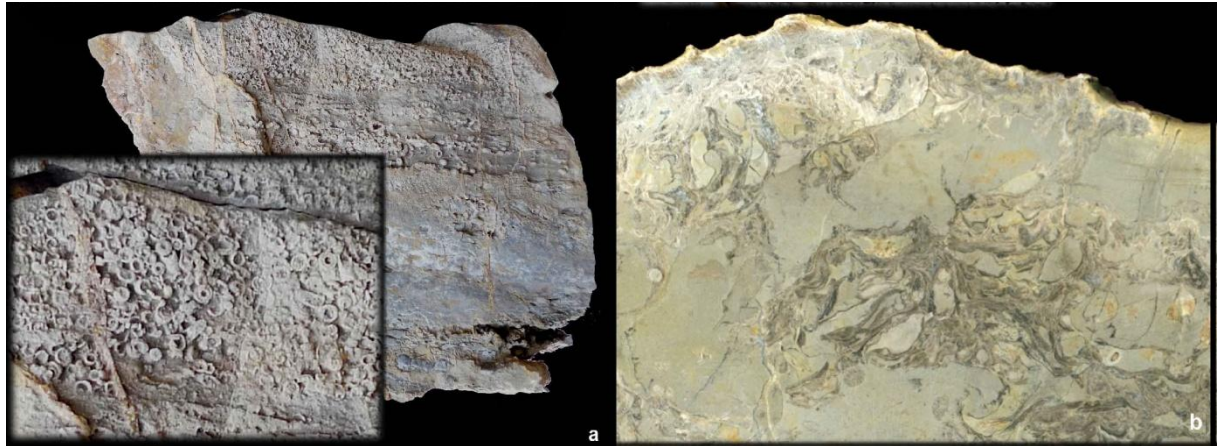


Fig. 17 – **Dasycladaceans and bivalves from Unit F.** **a** Undetermined dasycladacean algae; Le Pradet; MHI; width of slab 18 cm. **b** Polished section of *Placunopsis* bioherm; Carcès; MHI; width 10 cm.

***Enantiostreon spondylioides*** (v. SCHLOTHEIM, 1820) (Figs. 14 e, 19 f) is another oyster-like bivalve that contributed to the solid frame of the *Placunopsis* bioherms, however, it has not yet been found in the Lower Keuper. In NE-France and SW-Germany, it reaches its maximum abundance in the *Placunopsis* bioherms of the Hauptterebratelbank and the Upper Terebratelbank (*dorsoplanus* through *semipartitus* zones).

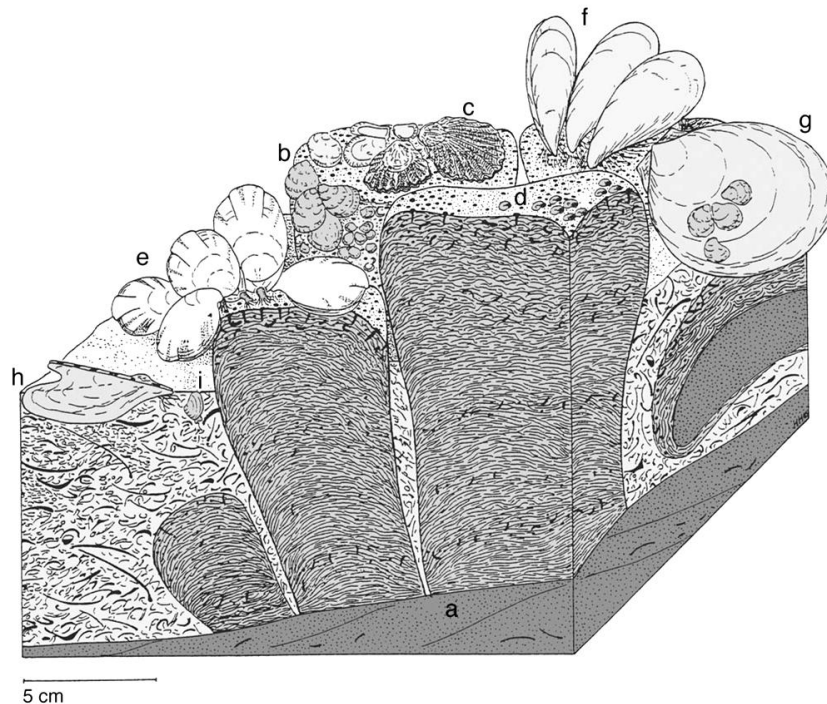
***Promysidiella eduliformis*** (v. SCHLOTHEIM, 1820) (Fig. 16 a, c) – the *Mytilus* of the older literature – has its maximum abundance also in the *dorsoplanus* and *semipartitus* zones of NE-France and SW-Germany. It was attached with byssus-threads to solid substrates such as *Placunopsis* bioherms or large cephalopod shells. Like *Bakevella substriata* its latest occurrence is in the Lower Keuper Grenzdolomit.

***Plagiostoma striatum*** (v. SCHLOTHEIM, 1820) Large individuals of this common Upper Muschelkalk bivalve occur in SW-Baden-Württemberg and the Swiss Jura up to the Lower Keuper Grenzdolomit, which is to be correlated with the Linguladolomite of Central Württemberg. Individuals from SE-France are generally smaller (Fig. 16 a).

***Pleuronectites laevigatus*** v. SCHLOTHEIM, 1820 is a common bivalve throughout the Upper Muschelkalk and has not been reported from the Lower Keuper. Specimens from SE-France (Fig. 19 a) may display radial color bands (FISCHER 1925, HAGDORN 1995) that may be fluorescent (pers. comm. Dr. K. Wolkenstein, Stuttgart).



These bivalves make up the trophic nucleus of the *Placunopsis*/*Coenothyris* fossil association which is typical for the Hauptterebratelbank and the Upper Terebratelbank. They are epibenthic suspension feeders and needed solid substrates for anchoring either by cementation, or by byssus or pedicle attachment. This association is unknown from the Cycloidesbank region. The reconstruction of this fossil association from the Muschelkalk in SW-Germany (Fig. 18) can easily be applied to this association in Unit F. However, there are crinoids to be added.



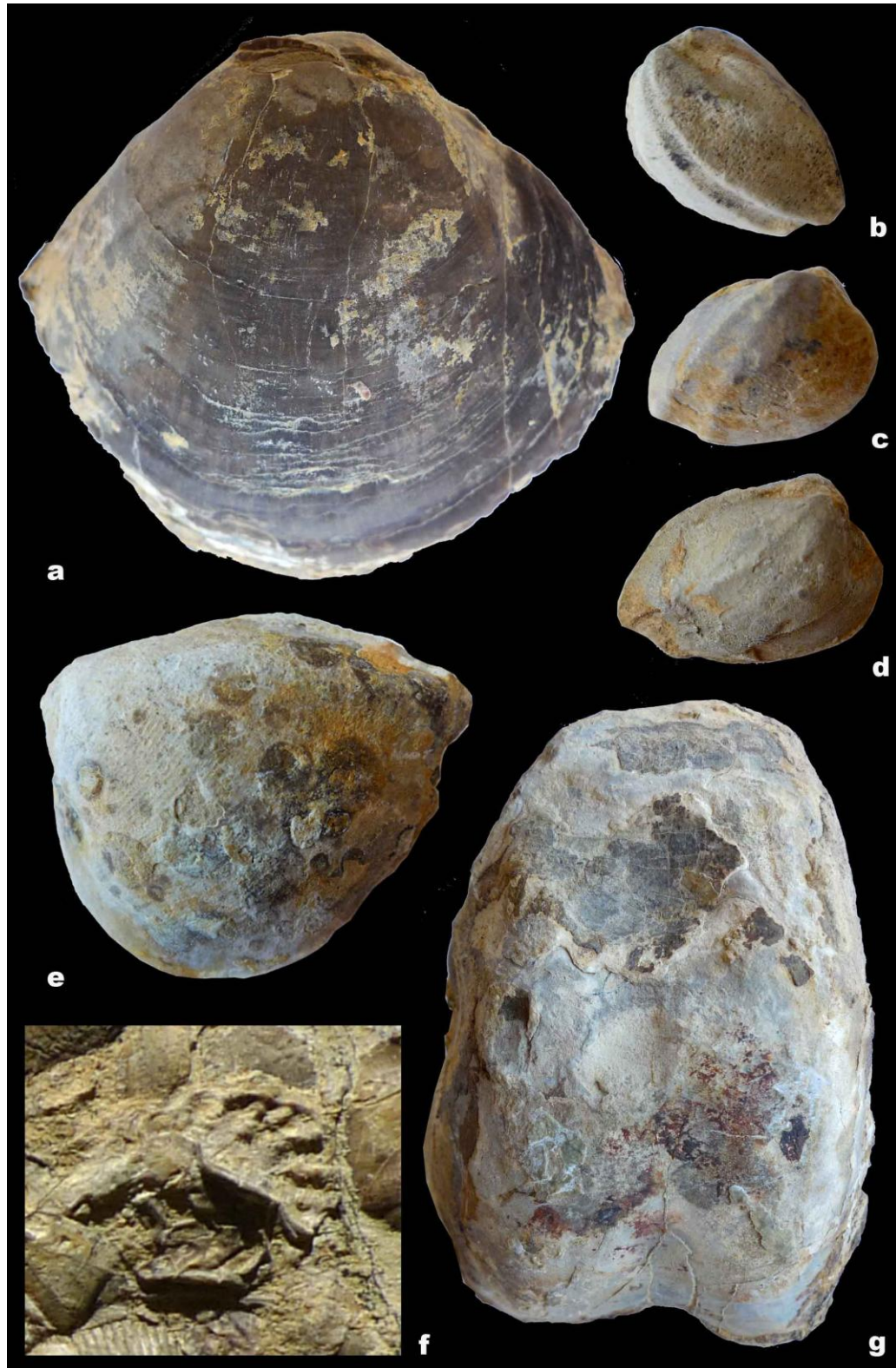
**Fig. 18** – *Placunopsis* association from the Hauptterebratelbank (Upper Muschelkalk) of NE-France and SE-Germany with the epibenthic cementers *Placunopsis ostracina* (a, b), *Enantiostreon spondyloides* (c), *Microconchus valvatus* (d), the flexibly attached *Coenothyris vulgaris* (e), *Promysidiella eduliformis* (f), *Pleuronectites laevigatus* (g), the endobyssate *Bakevella substriata* (h), and the burrowing *Nuculana excavata* (i). Each of these species is also a common faunal element of Unit F. From HAGDORN (2004).

The following bivalves are endobenthic filter-feeders and were burrowing in muddy bottoms.

***Myophoria intermedia*** V. SCHAUROTH, 1856 is typical for the Upper Muschelkalk from the *nodosus* Zone up to the Lower Keuper Grenzdolomit and has its maximum in the *semipartitus* Zone. Double valved steinkerns are quite common in Unit F (Fig. 19 b - e).

***Costatoria goldfussi*** (V. ALBERTI, 1834) is the index fossil of the Lower Keuper and has its maximum northward distribution in the Grenzdolomit. However, its earliest occurrence is in the *nodosus* zone. In Unit F it is present (Fig. 45, right) but not really common. This may be explained by its tolerance to changing salinity which made it less well adapted to constant salinity compared to euryhaline organisms. However, *Costatoria goldfussi* is widely distributed in Ladinian times in the western Peri-Tethys realm and has been reported from the Muschelkalk of Spain and Sardinia.





**Fig. 19 – Bivalves and *Germanonautilus*.** **a** Double valved individual of *Pleurnectites laevigatus* v. SCHLOTHEIM, 1820 with indistinct color bands; Lagoubran; MHI; width 8, 7 cm. **b - d** , Small double valves individuals of *Myophoria intermedia* SCHAUROTH, 1856; Bastide de la Blanque near Tourves; MHI; width ca. 2,5 cm. **e** Very largel double valved individual of *Myophoria intermedia* SCHAUROTH, 1856 with encrusting *Placunopsis*; Lagoubran; MHI; height 4 cm. **f** *Enantiostreon spondyloides* (v. SCHLOTHEIM, 1820); Bastide de la Blanque near Tourves; MHI; width 2,5 cm. **g** *Germanonautilus* sp.indet., vertically embedded; Lagoubran; MHI; width 9 cm.

### Ichnofauna

In Unit F, the soft ground trace fossil *Rhizocorallium irregulare* is occasionally found. Much more abundant are large *Thalassinoides* burrows. At Le Pradet *Thalassinoides* occurs one burrow next to the other in several subsequent beds (Fig. 20). Due to the overturned section, the burrows at the bed bases are naturally prepared and provide an impression of the rich endobenthic fauna. The burrows are usually filled with shell and echinoderm debris. There is evidence from similar burrows in SW-Germany that the producer of *Thalassinoides suevicus* in the Upper Muschelkalk was the lobster *Pemphix sueuri*, which was also reported from SE-France by CHARLES (1948).



Fig. 20 – *Thalassinoides suevicus* burrows at lower side of bed. Unit F (Le Pradet). Photo 1996.

### Biostratigraphy and age

As demonstrated above, URLICHS (1997) correlated the ceratite-bearing Unit F of the Muschelkalk in SE-France with the *enodis* Zone of the Muschelkalk in the Central European Basin and concluded an early Ladinian (Fassanian) age. After BROCARD (1991) Unit E and the lower part of Unit F has late Ladinian (Longobardian) age and the upper part of Unit F is already early Carnian.

BROCARD's (1991) correlation is based on

- occurrence of *Budurovignathus truempyi* in CARON's (1967b) Formation II, which corresponds to the early to late Ladinian *curionii* to *archelaus* zones HIRSCH (1971) or to the late Ladinian (HIRSCH 1972).
- occurrence of spores and pollen of late Ladinian age.

URLICHS's (1997) assignment of Unit F into early Ladinian is based on

- occurrence of *Germanonautilus bidorsatus* in Unit F. In the Germanic Muschelkalk, this species occurs up to the *postspinosus* Zone of early Ladinian age.
- occurrence of *Germanonautilus suevicus* in Unit F. In the Germanic Muschelkalk, this species appears in the *enodis* Zone of early Ladinian age.
- according to KOZUR (1980), the *truempyi* zone has early Ladinian age. The index conodont *Budurovignathus truempyi* is common in the West Mediterranean faunal province and is rarely found in the *Gondolella haslachensis* Zone of the Germanic Basin, which corresponds with the *postspinosus* and *enodis* ceratite-zones.
- the ranges of the spores and pollen mentioned by BROCARD (1991) already appear in the early Ladinian.

For a new discussion of the correlation of the Muschelkalk in SE-France and SW-Germany, more detailed micropaleontological data (conodonts, spores, pollen) are required and the position of the Anisian/Ladinian boundary within the Germanic Basin has to be discussed. Moreover, as demonstrated above, the macrofauna, especially the bivalves have to be included into consideration. From this viewpoint, Unit F would be isochronous with the upper part of the Upper Muschelkalk (*nodosus* through *semipartitus* zones) and probably also with the Lower Keuper. Taken this isochrony for granted, the following paleobiogeographic scenario would explain the faunal distribution:

- The strictly stenohaline encrinids give evidence for fully marine conditions in the depositional area of SE-France. Their immigration into the Germanic Basin was prevented by a salinar barrier along a salinar gradient. Only very rarely, single individuals managed to invade the southwestern part of the basin (cf. the *Encrinus* from Rottweil).
- The brachiopod *Coenothyris* and the above discussed bivalves of the *Placunopsis/Coenothyris* fossil community were distributed from SE-France following the Burgundy Gate to SW-Germany during *nodosus* to *semipartitus* zones.
- During Lower Keuper times, the salinar gradient prevented the immigration of *Coenothyris*, while most of the bivalves and even *Germanonautilus* still occur in some of the Lower Keuper carbonate beds.
- The Grenzdolomit is the horizon of maximum northward expansion of the Lower Keuper sea. For the last time, the above described fossil community spread northward, however, its faunal diversity decreased towards the North. Ceratites and nautiloids reached the Central German area of Thuringia, either as living animals or as empty shells.

This scenario is not contradictive to URLICHS's (1997) correlation if one assumes that the sedimentation rate was higher in the Germanic Basin than in SE-France and that the Lower Keuper has still early Ladinian age. *Ceratites* (*Austroceratites*) *toulonensis* is clearly different from any other Germanic Muschelkalk ceratite subgenera. A typical germanotype ceratite has not necessarily to be found in SE-France <sup>(1)</sup>. It would be worthwhile to compare *C. (Austroc.) toulonensis* again with the rare Lower Keuper ceratites from the Grenzdolomit.

<sup>(1)</sup> More in the west than the Provence-Nurra area, Middle Triassic ammonoids are well diversified in Balearic Islands - especially Minorca - and Catalonia (Goy 1995), with morphs unknown in the Germanic Basin. Those formerly assigned to the genus *Ceratites* are actually *Gevanites*, and, despite some morphologic similarities, no direct family relationship between Iberic *Gevanites* and Germanic *Ceratites* exists. Hypothetically a common Anisian ancestor of both may have lived in the eastern parts of the Sephardic province (Rein 2008) [M.D.].

## THE FIELD-TRIP

Monday, 5 Sept. 2011

### Stop 1 – Le Pradet I

#### Buntsandstein of La Garonne

Between the beaches of La Garonne and Les Bonettes, the coastal path makes it possible to go through the whole Buntsandstein, about 60 m thick (Fig. 22) with a dip which is close to the vertical.

The thin basal conglomerate (1 m) contains pebbles of the same types as those of the 'Poudingue de Port-Issol' (among which some reworked ventifacts), but it is undoubtedly more recent, since it does not rest directly on the Permian, but on a dolomitic crust, of pedological origin, characteristic of the main formation : 'Grès de Gonfaron'. However, less than 1.5 km SE, the 'Cap Garonne' old copper mine (GUILLEMIN 1952) was opened in a true equivalent of the 'Poudingue de Port-Issol', forming a lens up to 8 m thick, whose materials came from the southeast.

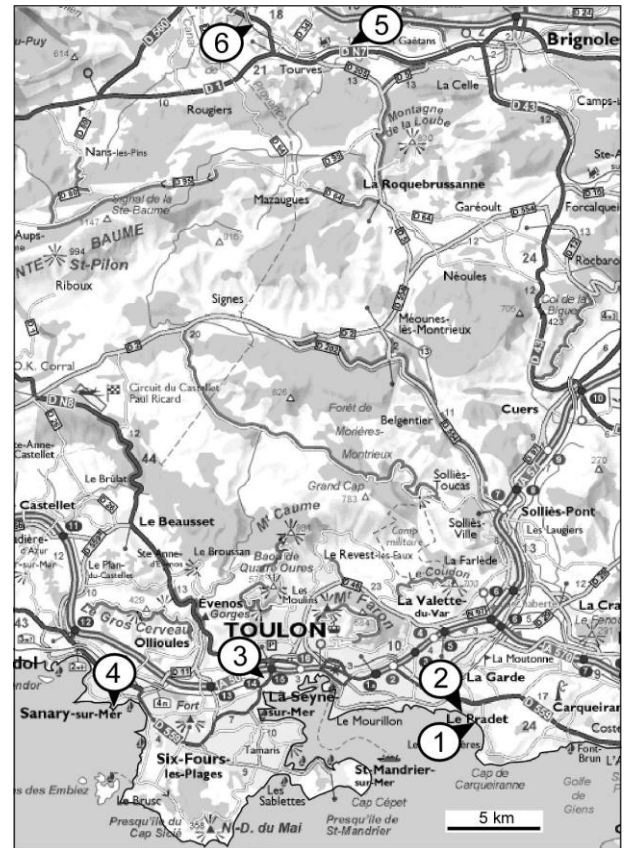


Fig. 21 – Location of the stops of the first day.

As in most sections in the area of Toulon, the 'Grès de Gonfaron' Formation can be divided into three informal units :

The lower sandstones (7 m with conglomerate included), often very coarse, make it possible to reconstitute paleocurrents flowing towards the SW, in conformity with the general direction highlighted in the other parts of the basin. Some wind-ripple deposits, HUNTER's (1977) 'SCTS', call to mind sand wedges along ephemeral-river banks.

The middle zone (26 m) usually corresponds in the Toulon area to silto-argillaceous facies deposited in a playa environment; here it is partly invaded by sandy sequences laid down by terminal splays (Fig. 23). This intermediate episode could correspond to a disturbance of the drainage system, which is perhaps the expression of a certain tectonic mobility. Paleosols occur (Fig. 24) but are less evolved than in the following unit

The upper sandstones (24 m), coarser and where small extraclasts reappear, mark the return to the initial system of drainage. They were particularly affected by the weathering processes related to a semi-arid paleoenvironmental context: most types of paleosols likely to be met in the Trias of Provence, including dolocretes and silcrettes (DURAND et al. 1989b, DURAND & MEYER 1982) can be studied there.

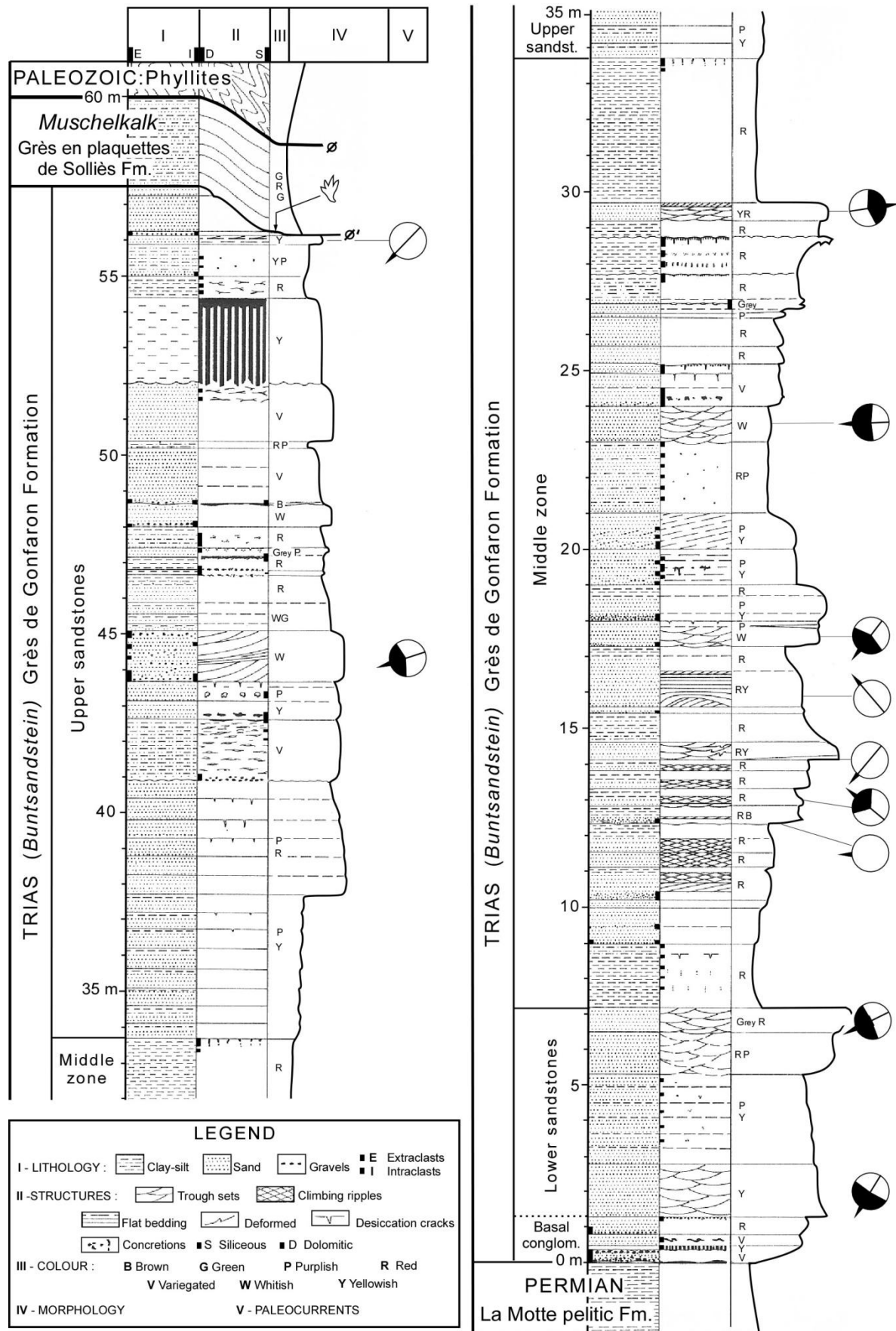


Fig. 22 – Sedimentologic section of the Triassic Buntsandstein west of La Garonne Beach. From DURAND et al. (1989b).



In the numerous sandy sequences, generally less than 1 m thick, inserted within the silty-clay playa facies of the middle zone, the most prominent structures are plane lamination and *kappa* cross-stratification (ALLEN 1963) (Fig. 23). Each of these sedimentary units: SEILACHER's inundite (1982), expresses the waning-flow stage ending a flood event. Exceptionally, one thicker sequence shows a washed-out dune structure (see below) having recorded the rise in flood.

	LITHOLOGIC ELEMENTS	GENETIC CONDITIONS
I <sub>f</sub>	Silt to clay <i>Massive</i>	Settling
I <sub>e</sub>	Fine to very fine sandstone <i>Kappa cross-stratification</i>	Decreasing Lower flow regime
I <sub>d</sub>	Medium to fine sandstone <i>Large-scale trough sets</i>	
I <sub>c</sub>	<i>Plane lamination</i>	Upper flow regime
I <sub>b</sub>	Medium grained sandstone <i>Washed-out dune</i>	Transition lower-upper flow regime
I <sub>a</sub>	Intraformational congl./breccia	Washing and/or overpassing

Fig. 23 – Idealized inundite sequence for the terminal-lobe deposits from Le Pradet (La Garonne beach) and Sanary (Bau Rouge cliffs). From DURAND et al. (1989b), modified.

The only evidence of animal activity on this section consists in a tetrapod track (preserved in positive epirelief upon the uppermost bed of the Grès de Gonfaron) from which was defined the ichnospecies *Chirotherium mediterraneum* DEMATHIEU & DURAND, 1991.

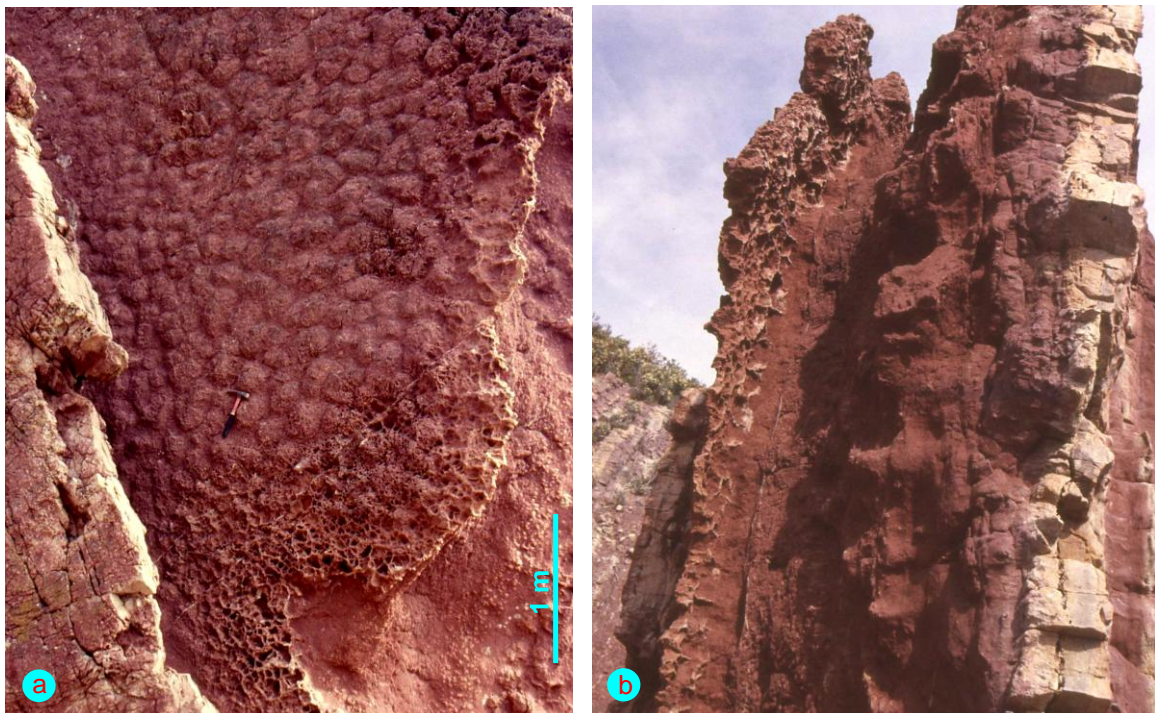


Fig. 24 – The main paleosol in the upper part of the medial zone of La Garonne section. **a** - Upper surface with gilgai micro-relief, witness to a vertisol stage. In the lower part, recent erosion has reached the honeycomb internal structure of this dolomite. **b** - Vertical section showing, on the left, the previous paleosol from below. On the right, sandstones have been converted to quartzite (gray) on both sides of a former intraformational sulphate-breccia (hollows).



## Stop 2 – Le Pradet II

### Upper Muschelkalk of Les Bonnettes

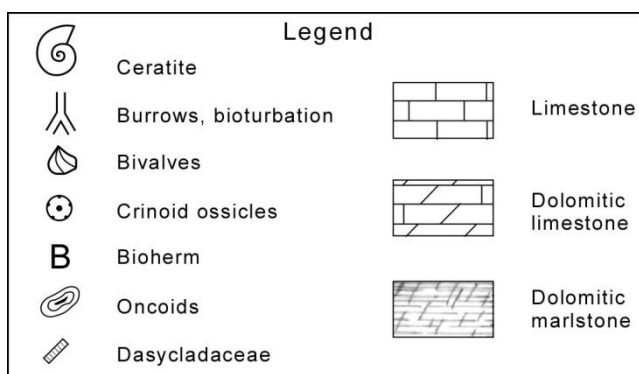
West of Les Bonnettes Beach, the path along the rocky part of the coast goes first through the same allocthonous basement unit as that of the top of the previous section visible on the other side of the bay. After a short course at the top of cliffs consisting of laminated or vermiculated gray limestones (Lower Muschelkalk t3 in normal position), it gives access to very good outcrops of Upper Muschelkalk fossiliferous limestones (t3d Formation II: CARON 1967a,b ; Unité F: BROCARD 1991) which are there upside down (Fig. 25).

The overturning of the layers is clearly shown by at least two types of features: the polarity of burrows, mainly *Thalassinoides* occurring one next to the other in several subsequent beds (especially large in bed 5: Fig. 20), and *Coenothyris* buried in life position, but now with foramen turned upwards.

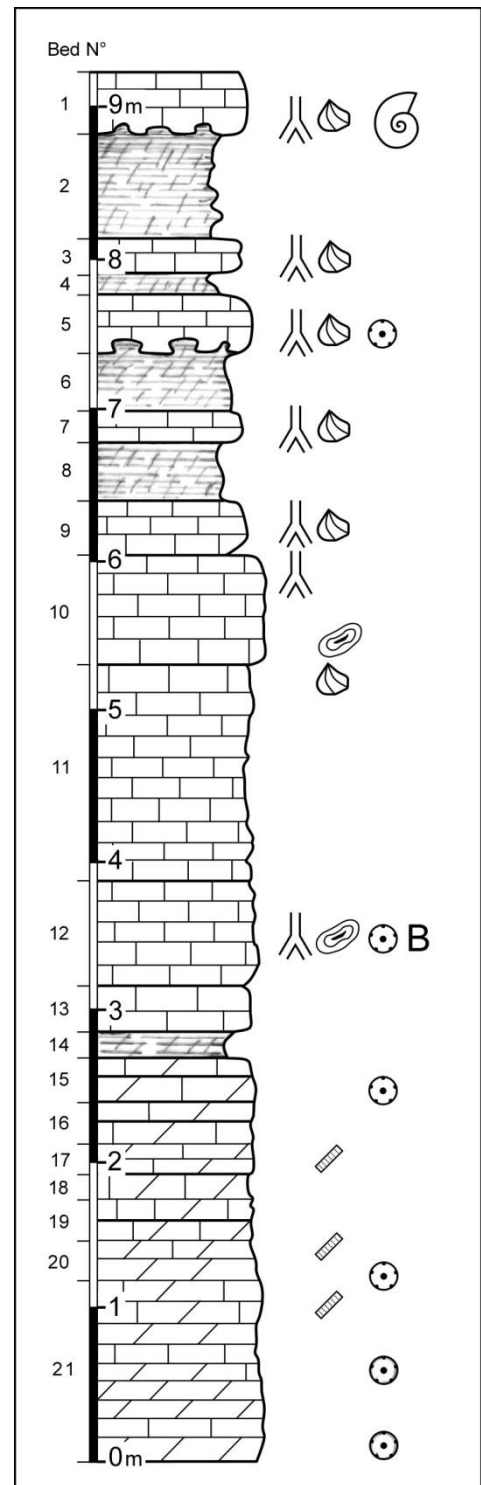
In bed 12, with abundant crinoid and bivalve debris, and large *Girvanella* oncoids <sup>(1)</sup>, a 40 x 30 cm big cluster of in situ encrinid holdfasts forms the frame of a small crinoid bioherm (Fig. 15 a), deepening up to 5 cm into the substrate. Crinoid holdfasts are extensively bored (*Calciroda kraichgoviae*, *Talpina gruberi*).

Dasycladacean algae are especially well preserved, and densely packed in bed 17 (Fig. 17 a).

<sup>(1)</sup> They could be actually *Solenopora* rhodoids which are very common in Provence at this level (CARON 1966). Such large coated grains were also reported southwest to the Vosges massif (NE France), but in the basal part of the Upper Muschelkalk ('Calcaire à entroque') (DURAND & JURAIN 1969, DURAND et al. 1989a)



**Fig. 25** – Section of the eastern (stratigraphically uppermost) part of the Upper Muschelkalk outcrop at Le Pradet (Les Bonnettes) in original position. Measured by H. Hagdorn (1996 and 2011). Beds are numbered from base to top of the outcrop.



### Stop 3 – Toulon (Lagoubran)

#### 3a – Lower Muschelkalk of Giraud Hill (ramp to Villa Helvétia)

This outcrop makes it possible to observe the upper part of compact dark limestones of **t 3b**, whose base is cut by the trench of the railroad, inaccessible. No notable fossiliferous layer is visible, except rare recrystallized biocalcarene beds, of a few centimeter thickness. The bedding surfaces are generally plane or slightly corrugated, and present only exceptionally some sedimentary structures susceptible to be used as up-down criteria confirming their normal structural position. However, at the top of this pure limestone unit, argillaceous and brecciated, the trench shows a karstic morphology (Fig. 26), filled with argillaceous and marly facies extremely deformed. They could represent the base of the Middle Muschelkalk **t3c**. Very comparable karstic structures were described in the Lower Muschelkalk of the Barcelona region, in Catalonia (RAMON & CALVET 1987). This tectonic unit is separated from the old quarries of Lagoubran by a N-S accident.

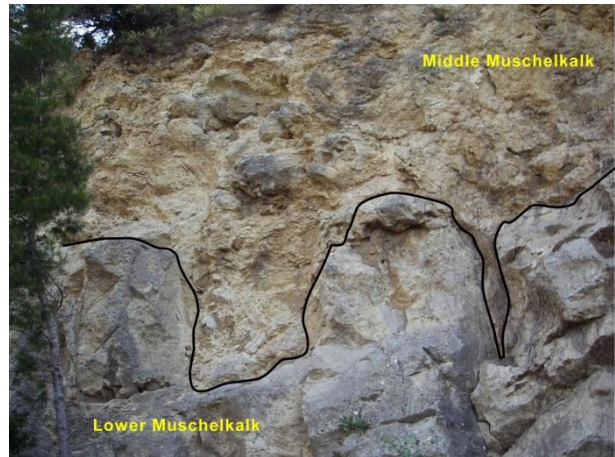


Fig. 26 – Karstic features at the upper part of the old quarry along the ramp to Villa Helvétia.

#### 3b – Upper Muschelkalk of the old quarries of Lagoubran

The old quarries 'Andréoni' and 'Fournier' constituted one of the most important fossiliferous spot of the region, having fed of many collections, public and private. The great excavation work of the zone of Lagoubran resulted in to make disappear the 'Fournier' quarry. The two 'Andréoni' quarries were open in the limbs of a pinched syncline of Upper Muschelkalk, rectified to the vertical and in contact one with the other by a faulted axial plane, still visible in the trench which linked the two quarries. The opening of D958 B1 road, through the eastern quarry, strongly reduced the outcrops. Nevertheless a rather good section of Formations I, II and III is still visible on the eastern wall of this road, from the roundabout of the incineration center in the NE, towards the roundabout of Lagoubran in the SW, where they are cut by a transverse accident. From the western wall of the road one reaches the western quarry, used as waste deposit, by the trench (Fig. 27) where can be observed part of Formation IV of the eastern limb, whose uppermost beds were removed by the axial fault, quite visible. From the fault westwards the Muschelkalk of the western limb lets appear the uppermost part (with bedded cherts) of the Formation IV. The Keuper, which should occupy the heart of the syncline, does not crop out there: extruded by compression, or never deposited ?

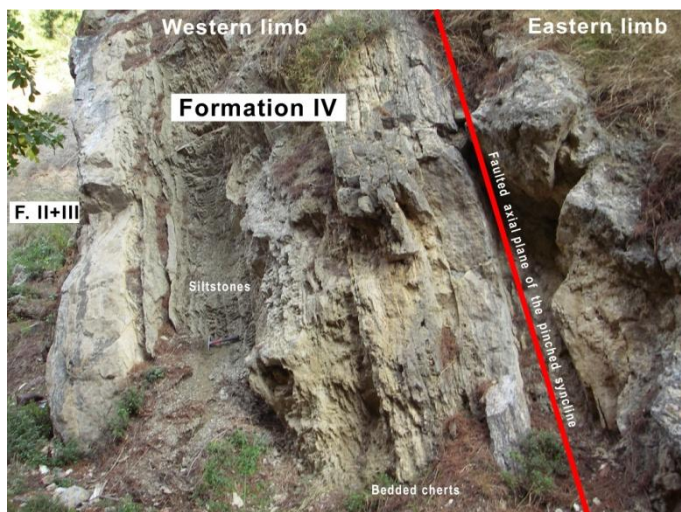


Fig. 27 – Northern wall of the trench to the former 'Andréoni' quarry.



## Stop 4 – Sanary

### Buntsandstein and Lower Muschelkalk of the Bau Rouge Point – Portissol

The coastal cliffs on the southern side of Bau Rouge Point (west of the city of Sanary-sur-Mer) provide one of the best continuous sections (ca. 80 m thick) of the Buntsandstein in Provence (Fig.28). The basal part was chosen as the type section of the *Poudingue de Port-Issol* because it is here that it reaches its maximum thickness: 8 m.

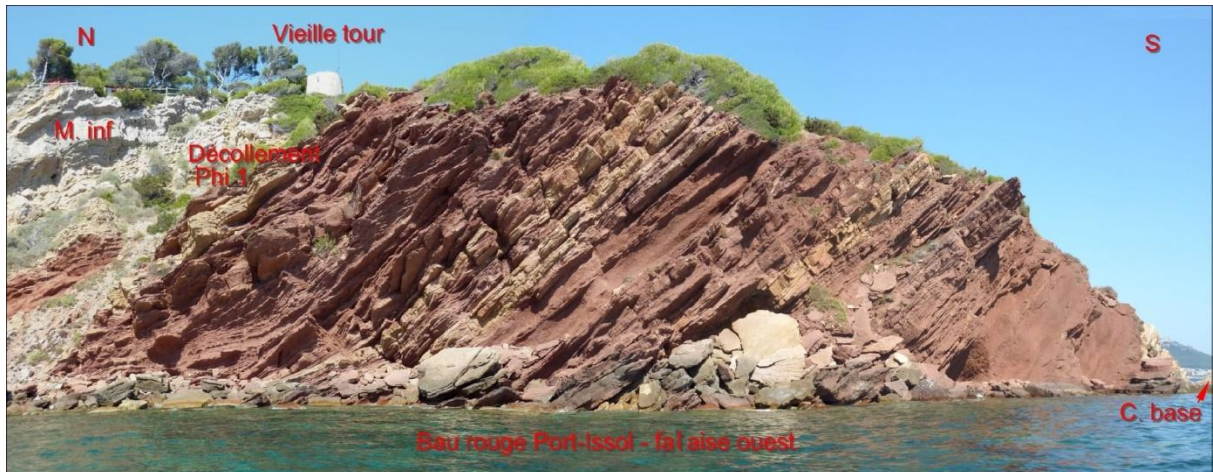


Fig. 28 – The Bau Rouge Point outcrop viewed from the southwest.

The paraconformable contact of the Triassic upon the local uppermost Permian unit, which can be seen in the surrounding area (e.g. Fabregas near Six-Fours), is here below sea level, but the lowermost bed of the basal *Poudingue de Port-Issol* emerges (Fig. 29). It is an oligomictic orthoconglomerate composed of only siliceous pebbles and small cobbles (mainly vein quartz, scarce lydites and quartzites) bound with a quartz-sand matrix. Sedimentary structures evoke longitudinal bars with lateral sand-wedges in a shallow braided-channel river, and indicate palaeocurrents flowing to the southwest.

Above a sharp truncation surface marking an abrupt change in depositional style, the *Grès de Gonfaron* Fm. begins here with 12 m of coarse-to-medium grained lower sandstones (Fig. 29) with caliche nodules, mostly reworked (Fig. 32 e,f). These concretions, as well as many trace fossils, are indicative of a marked climatic change from (hyper)arid to semi-arid. The depositional units, less than 1 m thick, are sheet-like in the lower part, and tend to narrow and to take a biconvex lens shape in the upper part (Fig. 32 c,d). The rest of the section is rich in red floodplain-to-playa deposits, similar to those seen at La Garonne (Figs. 23, 32b). Sandstone lenses become plano-convex (Fig. 29) and can be interpreted as terminal-fan lobes (DURAND 1991).

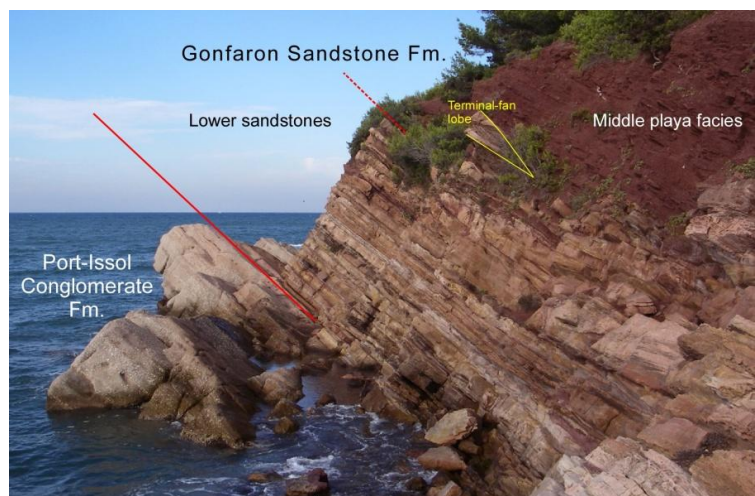
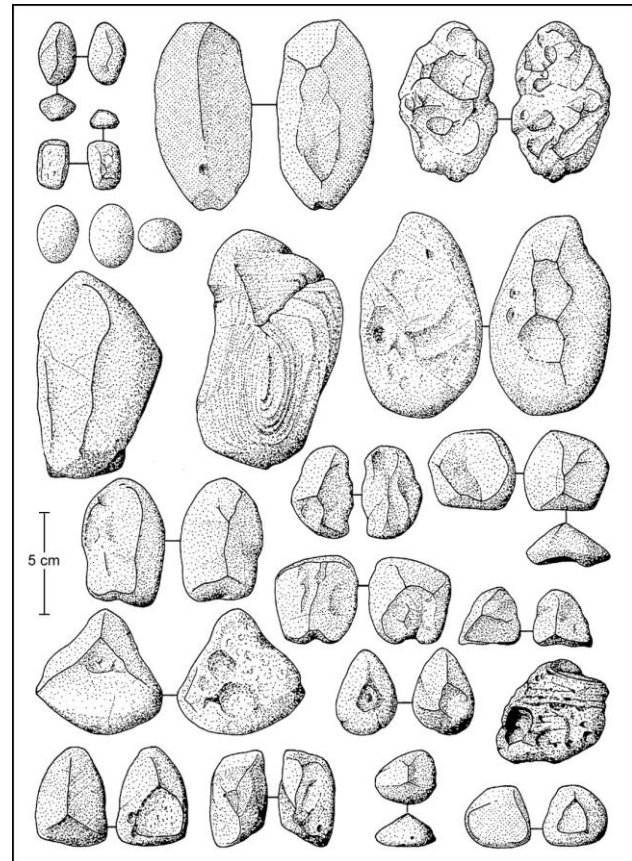


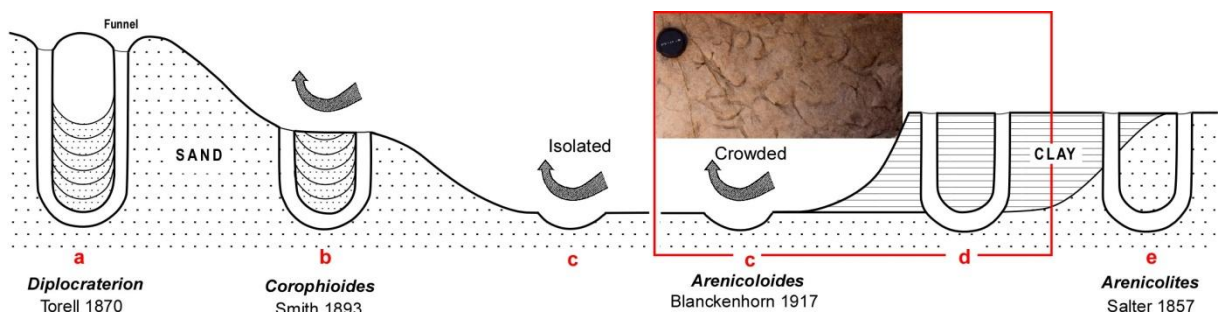
Fig. 29 – Lower part of the Bau Rouge outcrop viewed from the northeast.

In the Conglomerate, most phenoclasts are well rounded because of a long (probably polycyclic) fluvial transport, but many display secondary edges fashioned by aeolian sand-blasting shortly before their last reworking (Fig. 30). Such clasts are usually known by the German term 'dreikanter', which refers to a specific shape that is never dominant, and furthermore can form in a different environment; this is why the term 'ventifact' (EVANS 1911), which can apply to all wind-worn pebbles whatever their shape, should be used in preference (DURAND & BOURQUIN 2011). These ventifacts, which testify to a clearly arid period, allow to consider a Smithian age for the first Triassic deposits in that part of Provence BOURQUIN et al. (2007, 2011),



**Fig.30** – Examples of ventifacts from the Buntsandstein of Provence. Most of them from the Poudingue de Port-Issol Fm. From DURAND et al. (1989b)

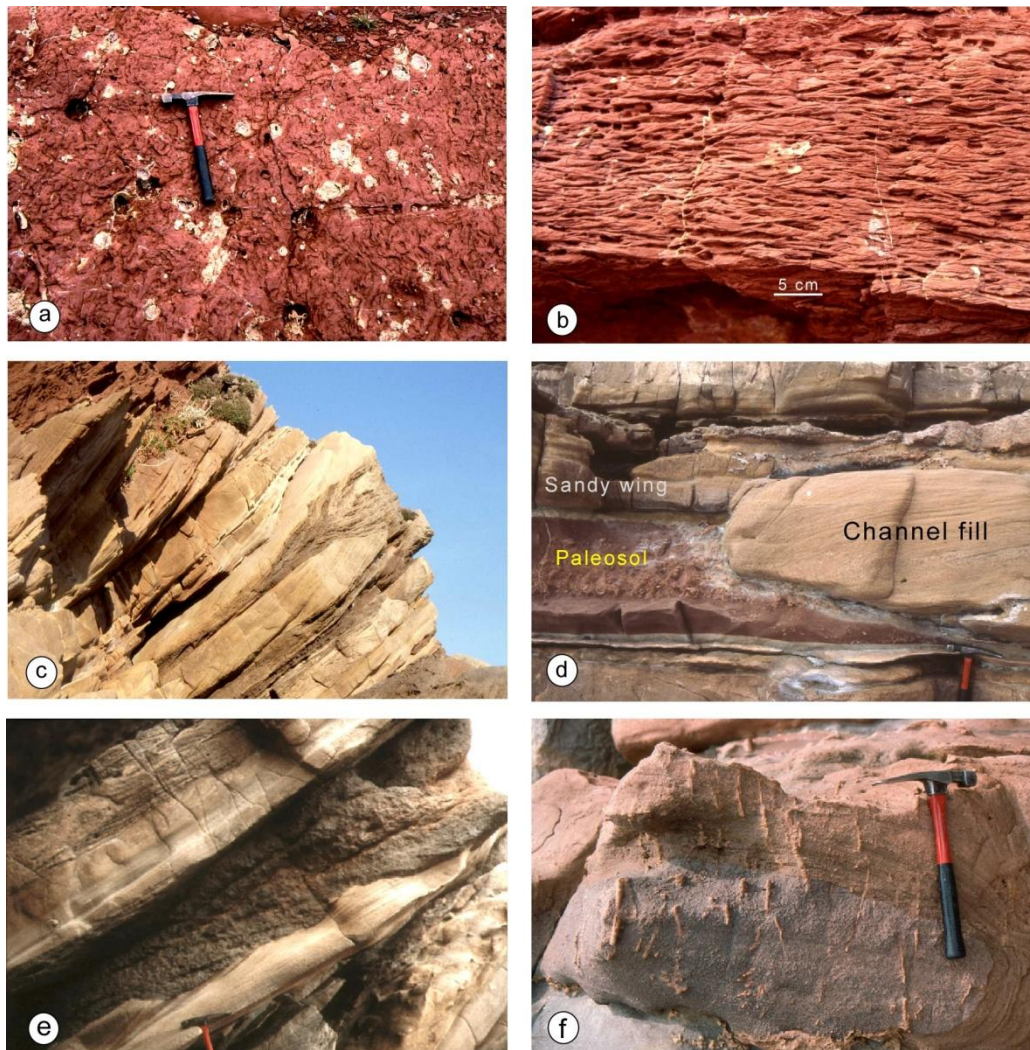
Within the Gonfaron Sandstone Fm., animal activity is shown here only by burrows: mainly *Soyenia*, occasionally *Phycodes*, *Beaconites*, and a large undetermined gamma-shaped ichnotaxon. As on other outcrops, the first traces appearing above the conglomerate top are basal parts of U-burrows that we are advocating to designate as *Arenicoloides* BLANKENHORN, 1917 instead of *Arenicolites* SALTER, 1857, as usually used (see fig. 31 for explanation). Plant growth in the depositional environment is confirmed by various vegetation-induced primary sedimentary structures (RYGEL et al. 2004), particularly many cases of centroclinal cross-stratification (UNDERWOOD & LAMBERT 1974) (Fig. 33). It is very likely that the 'tetrapod footprints' reported by ELLENBERGER (1965) were such structures appearing in plan view. Moreover, bed surfaces of the uppermost part of the Buntsandstein section show casts left by *Equisetites* taproots, more or less connected by creeping stems or stolons (Fig. 32 a).



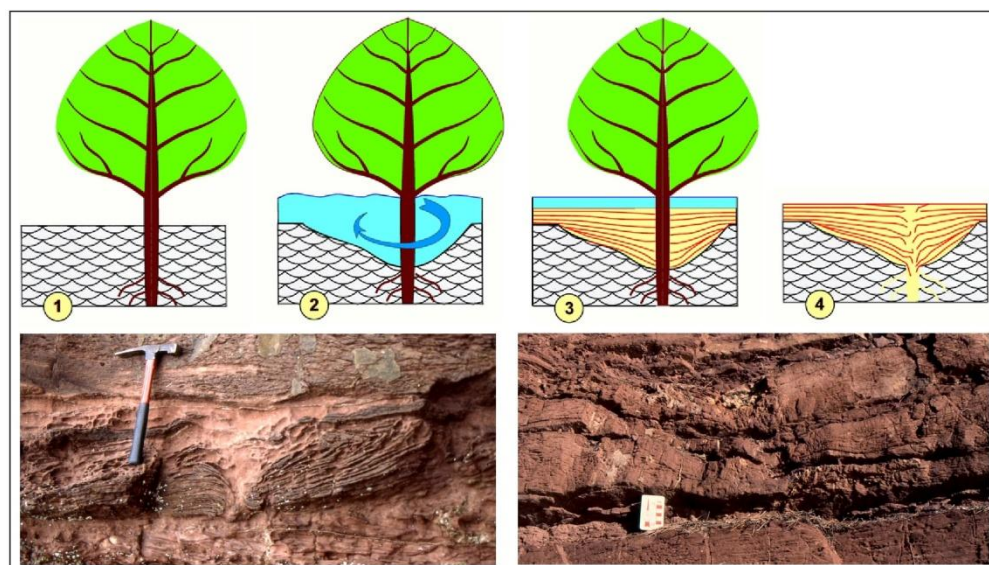
**Fig.31** – Influence of erosion on the morphology of vertical U-shaped burrows. Inspired by FÜRSICH (1974).

A single trace type c may result from the partial erosion of a burrow type a, b, d or e. But such traces crowded on a sandstone slab can come only from the truncation of burrows type d, preferentially dug in clay, indicating a trace-maker behavior very different from that of the authors of burrows a, b and e, digging in sand.





**Fig. 32** – Sedimentary structures from the Gonfaron Sandstone Fm. **a** Traces of *Equisetites* roots and creeping stems, in plan view. **b** Climbing-ripple structure: Kappa cross stratification. **c-d** Biconvex sandstone lenses : proximal lobes. **e** Channel side filled with a breccia of reworked pedogenic nodules. **f** *In situ* Rhizolites (root sleeves).



**Fig. 33** – Centroclinal cross-stratification. Mode of formation and two examples from the Bau Rouge outcrop.



## Stop 5 – Tourves I

### Upper Muschelkalk of La Bastide de la Blanque, with basalt.

About 500 m west of the Bastide de la Blanque, the trench of the narrow road along the railway cut deep the Triassic limestones (Fig. 35), overturned and dipping 50° N. This section is the type locality for the conodont species *Gladigondolella truempyi* HIRSCH, 1971, subsequently referred to the genus *Carinella*, *Budurovignathus* or *Sephardiella*, and which, in Provence, is only known so far in the Formation II of the Upper Muschelkalk. The same beds yielded two specimens of *Ceratites* {*Cycloceratites*} cf. *laevigatus* (URLICH 1997).

Formation II is divided into a lower and an upper parts by a weathered basalt flow (6 m thick) for which a first radiometric dating was proposed by CARON (1970):  $224 \pm 9$  Ma. However, subsequent datings performed on the 'Volcan de Rougiers' (Poulagnier hill = Puy Runnier, ca 7 km WSW from Tourves) provided younger ages for the Middle Muschelkalk older volcanism (see Boulon outcrop): 197 Ma (BAUBRON 1974), then  $220 \pm 7$  Ma (BAUBRON et al. 1982) which would correspond to a Carnian (GRADSTEIN et al. 2004) or even Norian age (BRACK et al. 2005).

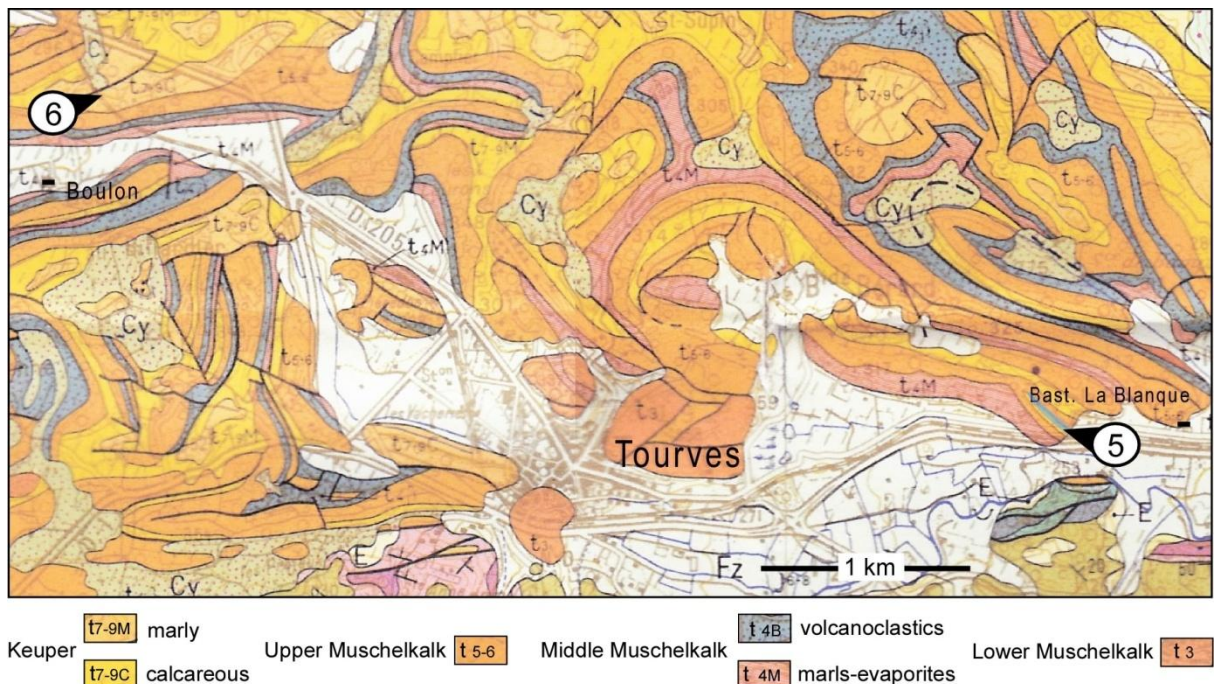


Fig 34 – Geological map of the Tourves area. From CARON in MENESSIER et al. (1979).

## Stop 6 – Tourves II

### Upper and Middle Muschelkalk of Boulon

The depression of Boulon corresponds to the core of Middle Muschelkalk of an anticlinal structure, partly masked by the alluvium. The northern limb corresponds to the crest limiting this depression to the north. It is crossed by the trench of the disused Gardanne-Carnoules railway. There one can observe the beds, nearly vertical, of the uppermost part of the Middle Muschelkalk and of the calcareo-dolomitic Upper Muschelkalk (Fig. 35). In the lower (southeast) part of the section, mafic pyroclastics and/or volcanoclastics, quite weathered, are well exposed (CARON 1970).



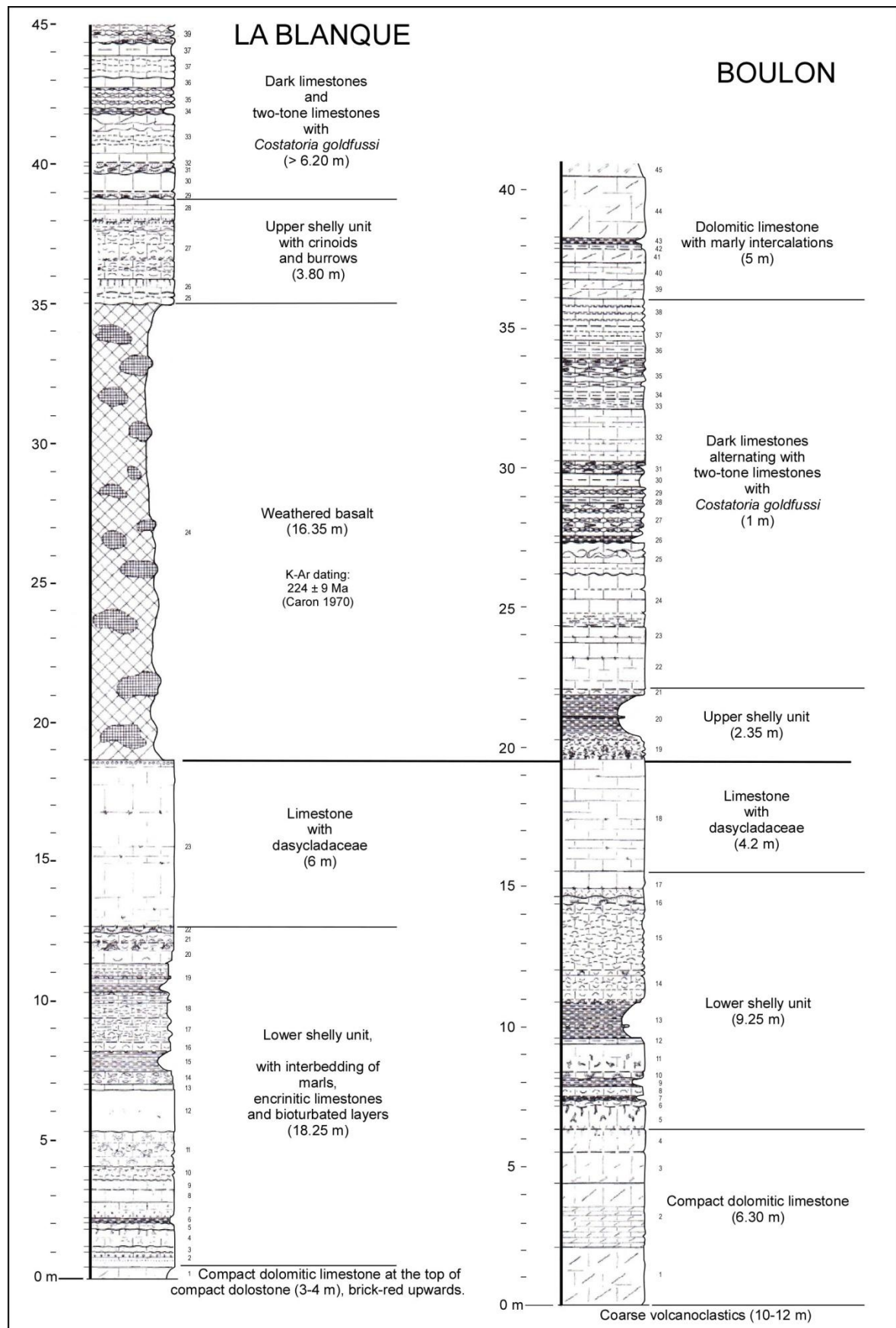


Fig. 35 – Comparison of the sections of Bastide de la Blanque and Boulon. After CARON (1969).

Tuesday, 6 Sept. 2011

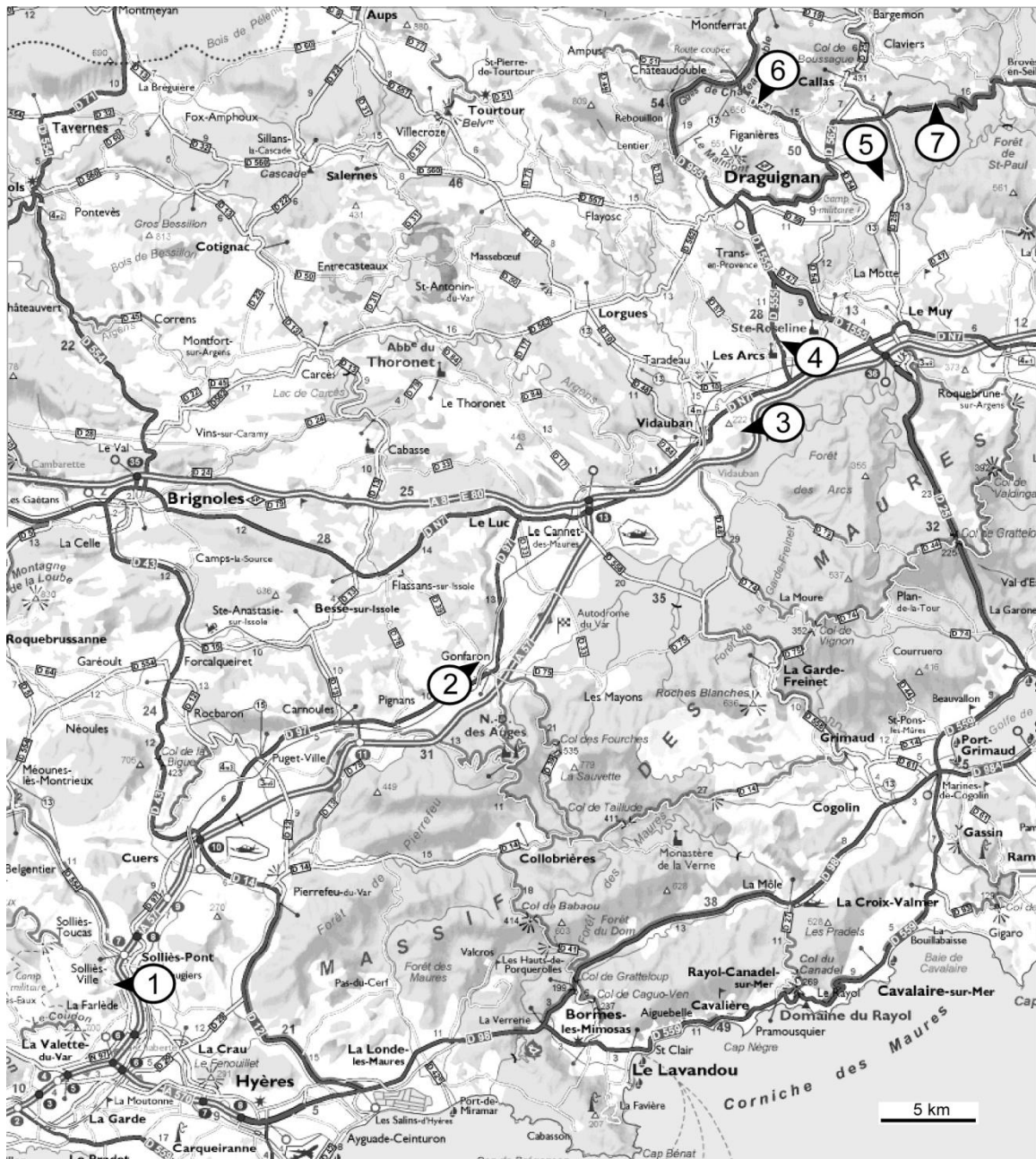


Fig. 36 – Location of the stops of the second day.

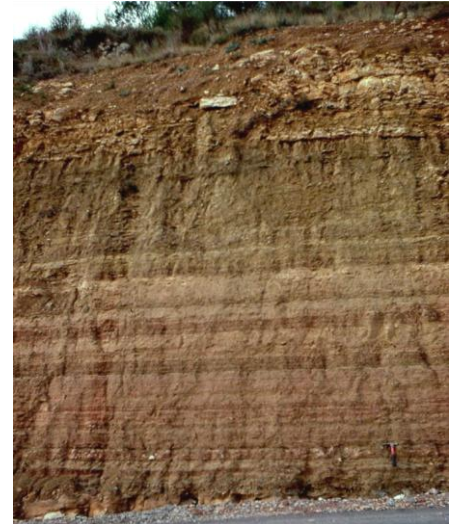
## Stop 1 – Solliès-Ville

### Transition from Buntsandstein to Muschelkalk

The trench of the D67 road, that goes from La Farlède up to Solliès-Ville, was, despite of tectonic complications, the most interesting section through the Buntsandstein of the interior (see DURAND et al. 1989b ) before it was almost completely obscured by a spreading of pink concrete. However, it is still possible to study in fairly good conditions the upper part of the Gonfaron Sandstone Formation and the transition to the Muschelkalk (Fig. 37).

In the upper part of the Gonfaron Sandstone Fm., a paleosol is covered by stromatolitic dolostone lenses where was described the freshwater alga species *Toutinella bifurcata* FREYTET et al., 2000. Thin clay lenses yielded a palynoflora assemblage of low diversity allowing only to assume an Anisian age, without further details (ADLOFF in DURAND et al. 1989b). Therefore we do not know yet if the overlying formation (barren) is coeval with the Röt or with the Middle Muschelkalk (Heilbronn Fm.) of the Germanic Basin. Further studies are in progress (J. B. DIEZ).

The contact with the 'Grès en plaquettes de Solliès' Formation (GLINTZBOECKEL & DURAND 1984), of which it is here the type section, is rather sharp. They consist of alternating thin layers of fine-grained yellow sandstone and reddish to greenish clay strata. Some sandstone platelets shows cubic-hopper casts (halite "pseudomorphs", see fig. 47) which are characteristic of this unit, and indicating the first marine ingression in the area. Notice that the thin rhythmic deposits are thickening-upwards, suggesting a transgressive system-tract.



**Fig. 37** – The 'Grès en plaquettes de Solliès', 5-6 m thick.

## Stop 2 – Gonfaron

### The Permian-Triassic boundary and the 'Grès de Gonfaron' Formation



**Fig. 38** – Permian and Triassic outcrops north of Gonfaron village.

The 'Gonfaron type' of Permian-Triassic relationship corresponds to an apparent transition because of a lack of any conglomerate. On these outcrops a 'precursory' sandstone facies ((b on fig.38) typical of the 'Buntsandstein' seems to be inserted in Upper Permian red silt-clay deposits ('Intra-Permian Grès bigarré' of COURNUT 1966). For a time, the regional PTB was believed to be located at the top of the uppermost thick silty unit (c) because of the development at this level of a spectacular palaeosol with long, drab-haloed root traces and yellowish subvertical caliche nodules (COURNUT 1966; TOUTIN-MORIN 1986). Subsequently, a careful examination of finegrained facies revealed significant



differences between lower playa sediments (a) and upper floodplain deposits (c). On the other hand the sandstone units b and d are clearly related; they contain particularly subspherical (wind-worn) coarse quartz grains, concentrated mostly at the very base of the lower unit. This is why it is currently believed that this level is actually the base of the Triassic Series (DURAND et al. 1989b). It must be emphasized that a flat erosional unconformity, which may correspond to a hiatus of several million years, is likely to pass unnoticed much more easily than a variegated palaeosol, even though it is rather moderately developed, such as that described above. Incidentally, one can also note that skeletal remains of tetrapods, poorly preserved, were found in units a (M.D.) and b (J.-P C.).

### Stop 3 – Vidauban

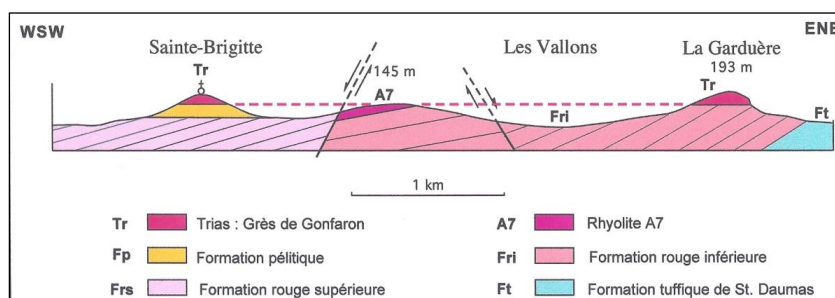
#### The Permian-Triassic angular unconformity of La Garduère

**Fig. 39** – The angular unconformity between the Permian and the Triassic at La Garduère.



The 'Vidauban type' of Permian-Triassic stratigraphical contact is characterized by an angular unconformity and the lack of any basal conglomerate; the Gonfaron Sandstone Formation rests directly on different Permian units. As here well preserved ventifacts may appear scattered on the paleosurface.

At this outcrop, in the Escarayol massif SE of Vidauban, the angle between Permian strata and Triassic sandstones approximates  $20^\circ$ , and the truncation reached a rather deep level of the Permian Series: 'Formation rouge inférieure' (see fig. 50). Such an unconformity is not the expression of some latest Permian or earliest Triassic tectonic movements; it results from intra-Permian tilting (BAUDEMONT 1985, 1988) followed by deep truncation. There, on the Vidauban swell between the Bas-Argens and Le Luc basins, transtensional deformations generated progressive unconformities, some of which, at a very short distance, are sealed by the uppermost Permian unit in this region ('Formation péltique' = La Motte Formation).



**Fig. 40** – Structure of the Vidauban area. From BAUDEMONT (1988).

## Stop 4 – Les Arcs

### Les Arcs Formation (Permian or Triassic ?)

The Les Arcs Formation (AREVIAN et al.1979), of very limited extension, is visible only along a ca. 4 km belt, at the foot of the Triassic cuesta, between the Permian basins of Le Luc to the west and Bas-Argens to the east (see figs. 4 and 50). A maximum thickness of 78 m was reported from a bore-hole for mining research. It cropped out in very poor conditions before the excavation of the bypass road of Les Arcs (D555) towards end of the 90ies.

In its lower part it is composed in half of floodplain red-brown siltstones and illitic clays, with some pedogenic dolomite nodules, and of large pinkish sandstone lenses (channel fills) the base of which is sometimes marked by a thin conglomeratic bed, with varied small pebbles: mainly crystalline basement fragments, with Permian volcanites and isolated remorked nodules (TOUTIN 1980). Upwards sandstone bodies tend to spread laterally and to predominate, making it difficult to put finger on the contact with the Gonfaron Sandstone Fm., without basal conglomerate and of facies very similar, apart from the presence of coarser and more rounded grains.



**Fig. 41** – Aspects of the Les Arcs Fm. near the type locality. Right: Lower part of the D555 trench. Left: Around the middle part. The slightly angular relationship is between lateral accretion (point bar) and aggradation (channel axis) deposits.

The period during which the sub-‘Buntsandstein’ pediplanation surface developed is very loosely appraised. On one hand some discrepancies persist between dating elements from the Permian series, and on the other hand only Mid-Triassic palaeontological data were obtained from the ‘Buntsandstein’ so far, in its upper part. Nevertheless, the very local occurrence of the Les Arcs Fm. – the Permian or Triassic age of which is debatable – provides evidence that the sub-‘Buntsandstein’ unconformity probably corresponds to a major hiatus. In this connection, it is perhaps useful to report that two independent methods (geometric extrapolation and organic matter study) show that, above the rather nearby Lodève Basin (about 100 km WNW of Toulon), nearly 1500 m of Permian sediments could have been eroded before the firsts Triassic deposits (Middle Anisian) (LOPEZ et al. 2005).

Nevertheless, during the Late Permian most areas in France, and elsewhere in SW Europe, experienced a more or less deep erosion forced by exceptional drops of global sea level and became only bypass-zones for sediments during the earliest Triassic. Therefore, the time gap corresponding to the sub-Triassic unconformity actually encompasses the PTB, and this gap is increasingly long as one approaches the edges of the basin. For the Provence realm, it cannot be excluded that Les Arcs Formation results from the earliest Triassic infilling (early transgressive system tract) of a palaeovalley incised during the Late Permian.

## Stop 5 – Callas

### Muschelkalk quarry of La Catalane

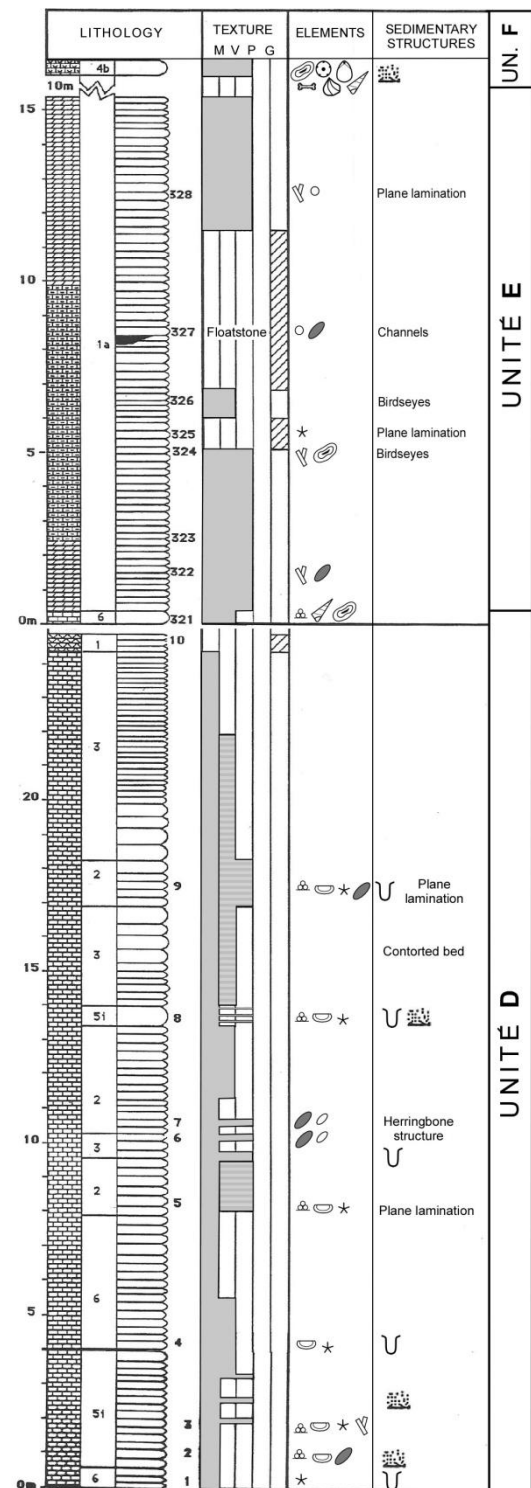
This vast quarry is actively operated in 'Unité D' (BROCARD 1991, TOUTIN-MORIN et al. 1994,) or 'Muschelkalk inférieur t3b' (CARON 1968) by the SOMECA company (Société Méridionale de Carrières) since 1981, supplying granulates for road construction, house building, concrete production and civil engineering. The overburden corresponds mainly to Unit E, and Unit F crops out sparingly.

Unit C (20 to 30 m thick) whose base rests on the Triassic siliciclastics but was not reached in the quarry, is mainly characterized by a brecciated structure and its compactness. The white to yellowish limestones are often dolomitic, with pseudomorphs after sulphates. This unit contains interbedded layers of clay-marly gypsum. The transition to the next unit, progressive, is manifested by the gradual appearance of stratification, without significant change in limestone facies.

Unit D (35 to 45 m thick), which constitutes the bulk of the working faces, consists of decimeter-thick beds (Fig. 43 b) of dark gray limestones, finely laminated (Fig. 43 d), and very hard. Breccias occur in the bottom half, some of which were 'dedolomized' by circulation of meteoric waters enriched in sulfates (see AYORA et al. 1998), and then partially dissolved (Fig. 43 a). Sedimentary structures and textures, as well as paleontological content are indicated on figure 42 and 43 c.

Unit E (20 to 25 m) begins with light-coloured dolostones, sometimes brecciated and/or showing pseudomorphs after sulphate, with intercalated black clay lenses. They are topped by gray-green laminated marls, with fine quartz grains, which constitute most of the overburden of the site.

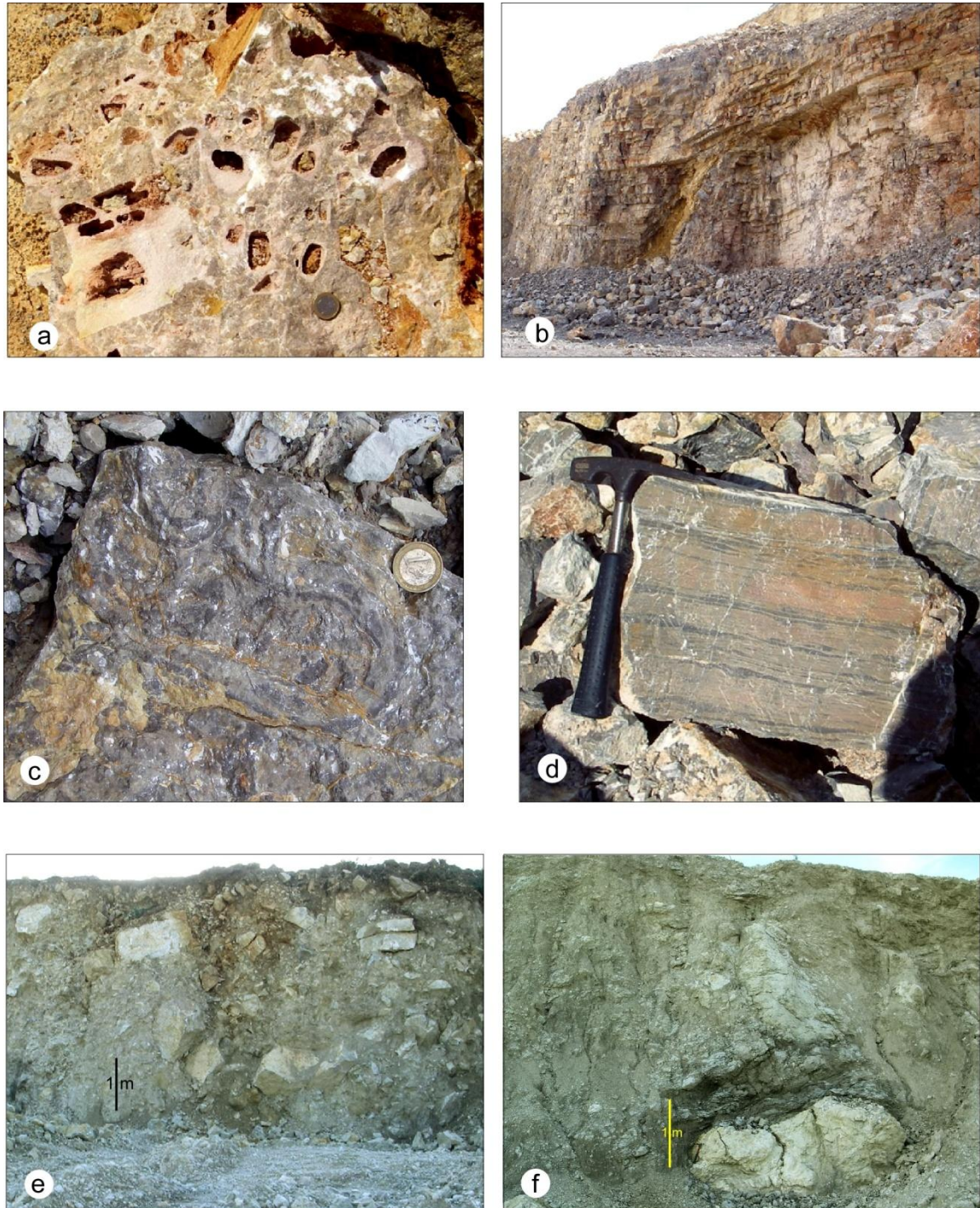
The black clays (see fig. 42: sample # 327) yielded a palynoflora with, among others: *Triadispora aurea*, *T. staplini*, *T. epigona*, *T. crassa*, *Ovalipollis ovalis*, *Paracirculina granifer*, *P. tenebrosa*, *Enzonalosporites tenuis*, *Verrucosiporites remyanus* and *Camerosporites secatus* (FAUCONNIER in BROCARD 1991). The presence of that taxon, generally regarded as a Carnian indicator (CIRILLI 2010, KÜRSCHNER & HERNGREEN 2010) below Unit F, of Ladinian age, poses



**Fig. 42** – Sedimentologic log of La Catalane quarry. From BROCARD (1991). See fig. 44 for legend.



a problem. Given the chaotic aspect of Unit E (Fig. 43 e,f) it would not be impossible that the fossiliferous level be located stratigraphically above Unit F, locally returned. Indeed, the tectonic style with recumbent isoclinal folds has long been known in the region, even in the Jurassic (BERTRAND 1888).



**Fig. 43** – Aspects of the Triassic carbonates in La Catalane quarry. **a-** Dedolomitization structures in the lower part of the section (C-D transition); **b-** Stratification of Unit D, in the middle part of the section; **c-** *Rhizocorallium* from Unit D; **d** and **e** - Chaotic aspect of Unit E. On the right, a block of fossiliferous limestone (from Unit F) is wrapped within gray-green laminated marls, intensely deformed.

## Stop 6 – Figanières

### Upper Muschelkalk of the Saint-Andrieu Pass

There are several sections in the fossiliferous Muschelkalk near Figanières. Points visited are located NW of the village, along the D54 road to Châteaudouble, shortly before the pass of Saint-Andrieu.

These outcrops allow to realize that, contrary to the assertions of ancient authors (e.g. RICOUR 1962), there is no significant stratigraphic or sedimentological variations in the '*Trias carbonaté*', between the regions of Toulon and Draguignan. The trench of the road reveals a BROCARD's (1991) *Unité F* – CARON's (1967) *Formation II* – almost as fossiliferous (see figs. 44 and 45 left) as on Le Pradet outcrop. Unfortunately the foraminifer assemblage, with *Ophthalmidium?* and *Triadodiscus eomesozoicus*, is not stratigraphically conclusive, the latter taxon ranging from Spathian to Carnian (RETTORI 1995).

The old quarry, overgrown with vegetation, west of the road, provides the opportunity to identify Formation III (two-tone limestones with *Costatoria goldfussi* (Fig. 45, right), and Formation IV with bedded cherts.

LEGEND (Figs. 42 and 44)			
	Pseudomorphs after sulphate		Brachiopods
	Tepee structure		Bivalves
	Event deposit		Gastropods
	Burrows		Serpulids
	Micrite intraclasts		Crinoid columnals
	Oncoids		Other echinoderm remains
	Peloids		Dasycladaceae
	Faecal pellets		Ostracodes
	Ooids		Conodonts
	Fish remains		Benthic foraminifera
	Rauwacke		Marly limestone
	Dolostone		Marl
	Dolomitic limestone		Homogeneous texture
	Limestone		Alternating texture
	Shelly limestone		Recrystallized texture

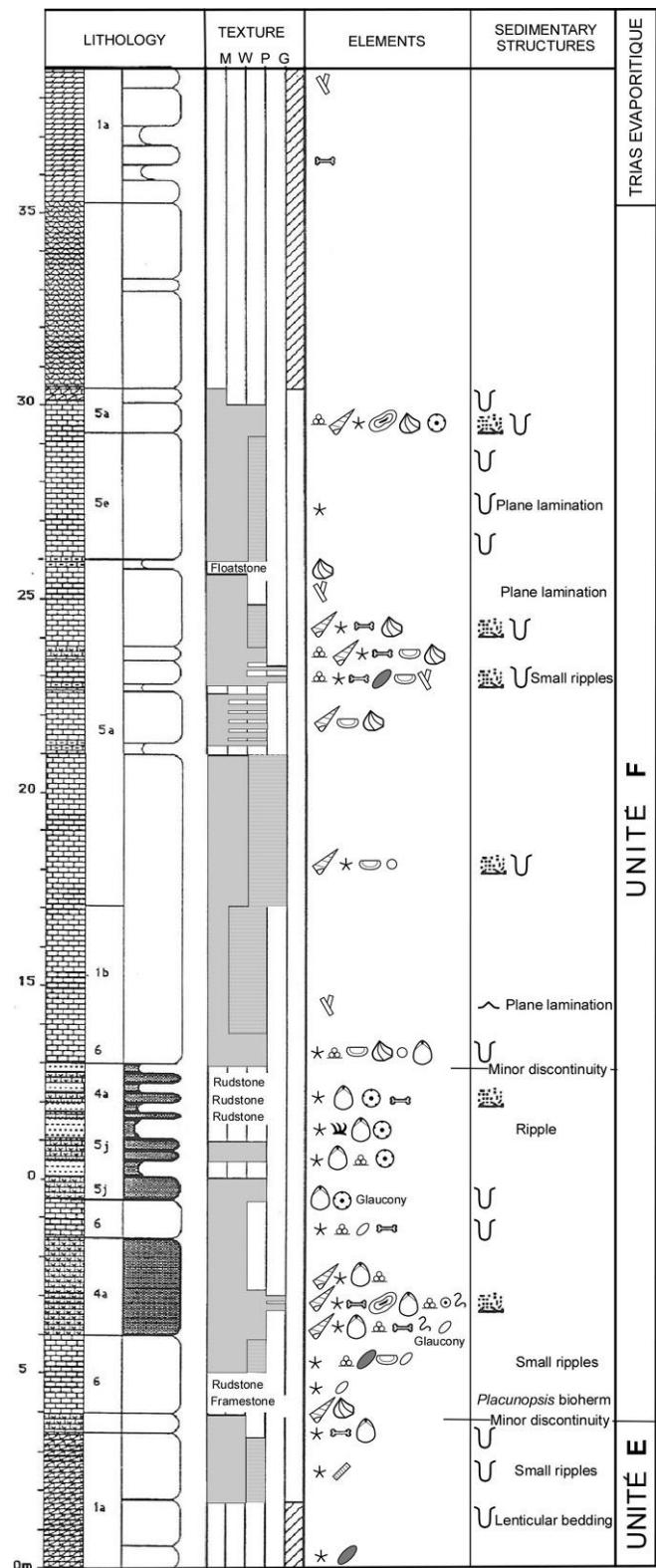


Fig. 44 – Sedimentologic log of Unit F along the road NW of Figanières. From Brocard (1991).





**Fig. 45** – Fossiliferous limestones from the Figanières section. Left: Crinoid wakestone-packstone in Formation II. Right: Two-tone limestone with *Costatoria costata* in Formation III .



## Stop 7– Callas

### Buntsandstein of La Joyeuse.

Below another huge quarry operating in the same Muschelkalk limestones as at La Catalane, about 25 m of the Buntsandstein series (45 thick in this area) is well exposed along the trench of the D 562 road, in four tectonic blocks limited by minor faults. In the eastern part, the 'Poudingue de Port-Issol', reduced in thickness (1 m) is resting on the weathered gneissic basement of the Tanneron Massif, showing a sub-vertical foliation (Fig. 46, right). Pebbles and cobbles, exclusively quartz, are well rounded mostly, but some have a well preserved ventifact shape.

Another compartment shows a columnar paleosol, with large vertical dolomitic rhizocretions, and the next three silcrete lenses, a few decimetres thick for several meters of horizontal extension. In the upper (western) part of the section grain size grows sharply from a thin polygenic conglomerate where pebbles of Permian volcanites are dominant (Fig. 46, left). These petrographic changes, and paleocurrents as well, show the arrival of a new detrital input, coming from an area further south (Corso-Sardinian massif ?), via a depression between the Maures crystalline massif and the Esterel volcanic massif (see fig. 5). Finally, the Buntsandstein is topped by fine red sandstones passing to the classical 'Grès en plaque de Solliès' Formation, with halite 'pseudomorphs' (Fig. 47).



**Fig. 46** – The two types of Triassic conglomerates in the Joyeuse area. Right : Basal quartz conglomerate, bimodal, resting on the weathered gneissic basement of the Tanneron Massif. Left : Polymictic and poorly sorted conglomerate marking the base of the upper (coarse) sandstones.

**Fig. 47** – Cubic-hopper halite casts, underside of a sandstone slab . 'Grès en plaquettes de Solliès Fm.' on the Joyeuse outcrop.



Wednesday, 7 Sept. 2011

Fig. 59

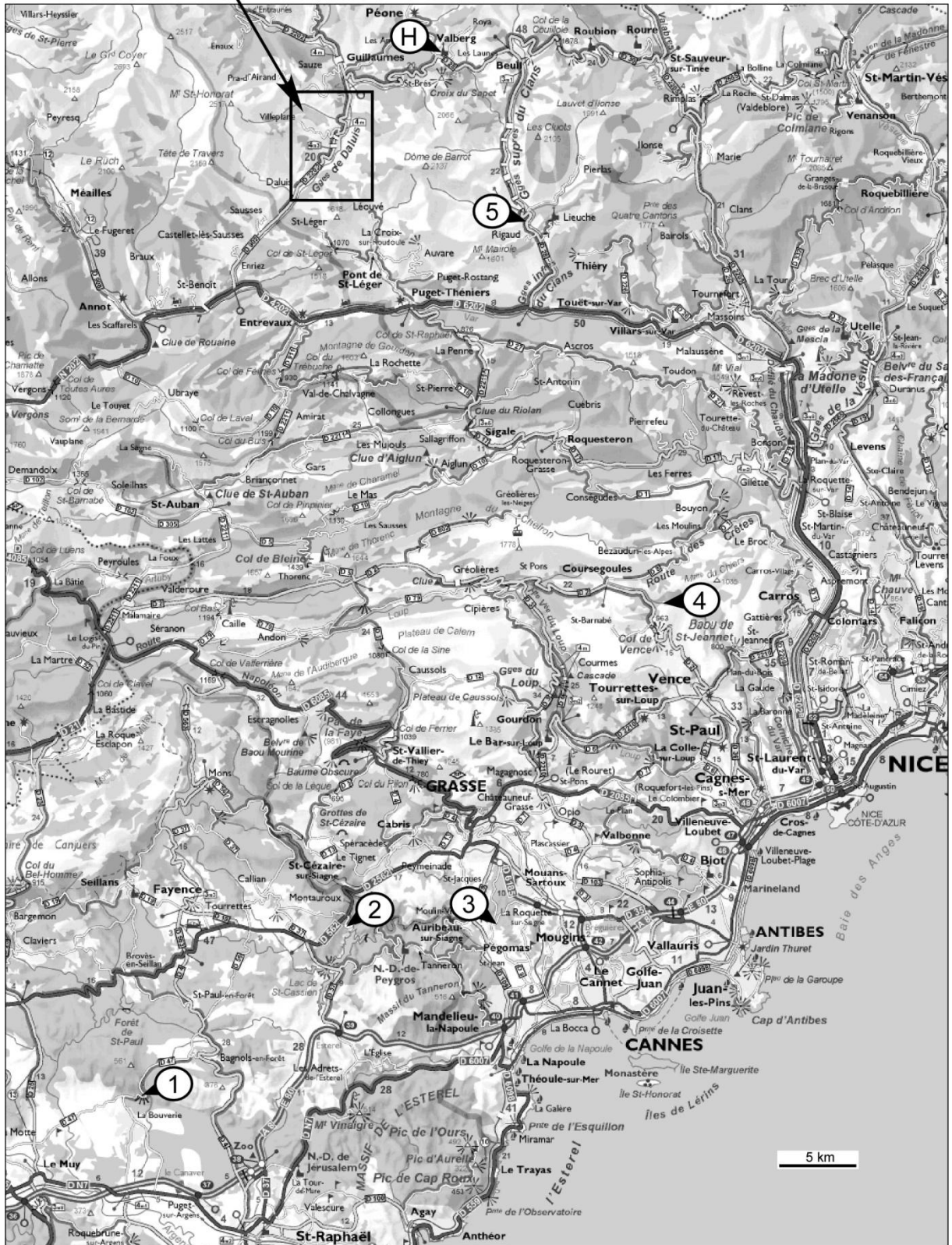


Fig. 48 – Location of the stops of the third day.



## Stop 1 – Roquebrune-sur- Argens

### Panorama on the Bas-Argens Permian Basin

From the hotel along the mythic Road N7, near Le Muy, the morning route crosses the Bas-Argens Permian basin northwards (i.e. transversally) before climbing its bordering stepped fault-scarp. In this area, the long ledge that dominates the landscape corresponds to the 'A7 Rhyolite' which is the main stratigraphic marker through the Permian basins of Provence (Figs. 49, 50). The first stop, on the rhyolite flow, offers a broad panorama of the Bas-Argens basin, from the summits of the Estérel (to the east) to the Vidauban swell (to the west). The prominent rocky relief in the background to the south is a huge alluvial-fan: 'Rocher de Roquebrune'. Its geomorphological inversion is due to the (rather) recent preferential erosion of the source area: Plan-de-la-Tour granite, in the Maures Massif.

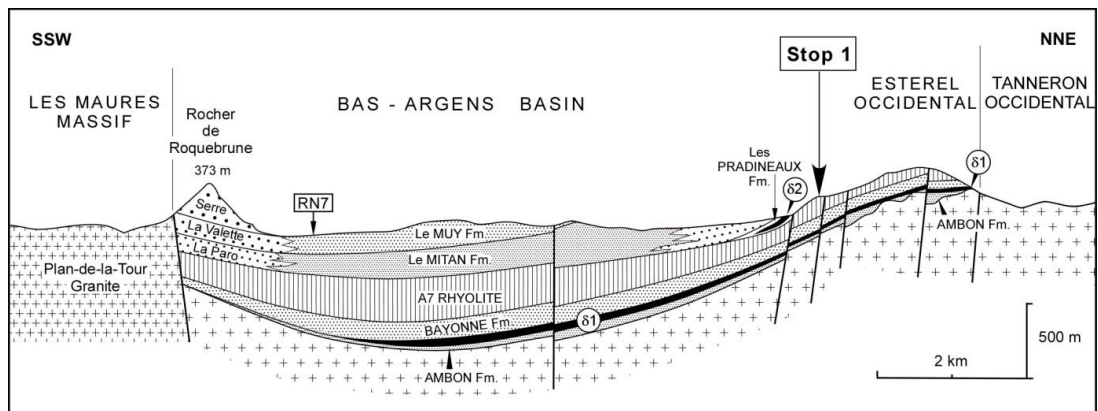


Fig. 49 – Geological section across the Bas-Argens Permian basin. Modified after TOUTIN-MORIN et al. (1994).

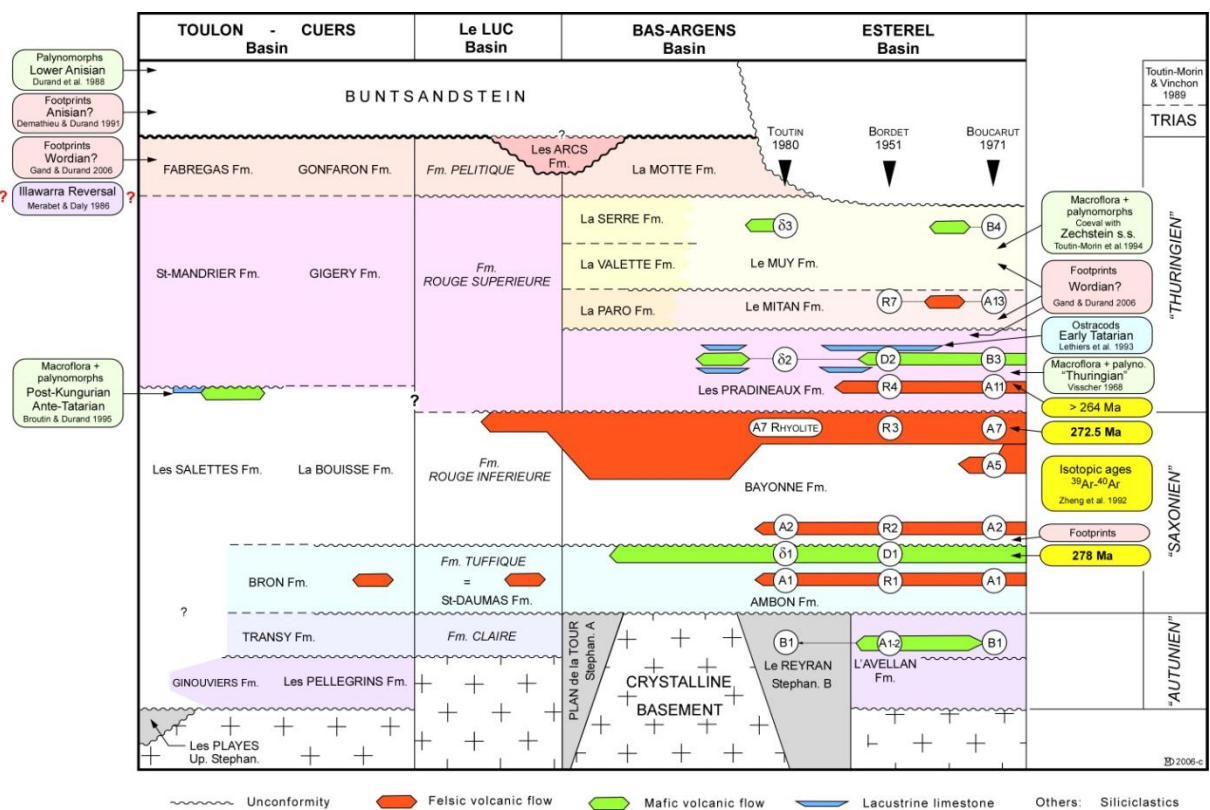


Fig. 50 – Correlations through the Permian basins of Provence, with location of the dating elements. From DURAND (2008).



## Stop 2 – Montauroux (Tournon)

### Relationship of the Buntsandstein and the Stephanian of the Reyran Basin

On the northern side of the Lake of Saint-Cassien, along the road D94 from Tournon to Tanneron village at the top of the massif, the route cuts across the Stephanian siliciclastic deposits of the Reyran Basin (see figs 4, 7). One can see there that well developed polymictic conglomerates contain white quartz gravels already almost so well rounded than those of the 'Poudingue Port-Issol', and comparable in sizes. This basin could thus be the main source of quartz pebbles of the Provence Buntsandstein. The first Triassic deposits, above a slightly angular unconformity, are rather sandstones, and more rich in quartz pebbles, whose smaller ones exhibit a pill morphology: 'dragées' (see fig. 30).

## Stop 3 – Pégomas

### Buntsandstein of Les Canebiers

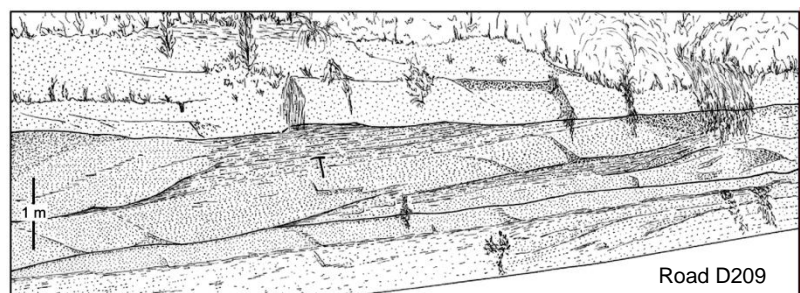
From Pégomas, the road D209 goes up the valley of the Mourachonne river. At the entrance to the 'Les Maures' forest track, it runs along an outcrop showing the base of the Triassic series resting on the highly altered Variscan basement (Fig. 51). It is marked by the succession of two beds rich in pebbles whose ventifact morphology is often perfectly preserved. The first is dominated by gray quartz of local origin, while the second by rhyolites. East of the Reyran Swell, we are indeed here on the edge of a new basin (see fig. 7).

**Fig. 51** – Basal Buntsandstein conglomerates resting on weathered metamorphic basement at the entrance of 'Les Maures' forest track, north of Pégomas.



About one hundred meters further, facing the access road to the old Canebiers Mill, sandstones of the upper Buntsandstein exhibit lateral accretion deposits that yielded well preserved palynomorphs: *Triadispora staplini*, *T. falcata*, *Alisporites grauvogeli*, *Microcacrhya fastidoides*, *M. sittleri*, *Pityosporites* sp., *Angustisulcites klausii*, *Voltziacaesporites heteromorpha*, *Illinites kosankei* and *Hexasacites muelleri* (syn. *Stellapollenites thiergartii*). This assemblage, very close to those found in the 'Grès à Voltzia' Fm. of NE France, allows assignment of an early Anisian age (ADLOFF in DURAND et al. 1989b).

**Fig. 52** – Lateral accretion (point bar) deposits in the Buntsandstein of Pégomas. From DURAND et al. (1989b).



## Stop 4 – Coursegoules

### Keuper of the Vescagne anticline

In the mountainous areas north of Grasse-Cannes (Castellane Arc and Nice Arc), Triassic formations crop out very locally, in the heart of four anticlines incised by deep valleys: Bar-sur-Loup, Gillette and Vescagne, west of the Var River, and Levens to the east. In this last, the erosion has reached the fossiliferous Muschelkalk and even the Buntsandstein (CARON & ROUX 1966).

The famous 'Keuper of Vescagne' it is located at the bottom of the deep valley of the Cagne river, in the municipality of Coursegoules. It can be reached, from the Vence Pass, by a path 5 km long (round trip) for 300 m difference in level, or from Le Gourbel, near Bezaudun-les-Alpes, by a 4x4 trail through private property. It takes its name from the 'Bastide de Vescagne', a fortified farm. Coal has begun to be exploited there probably in the early 19th century, and the last period of operation dates back to 1939-1953.

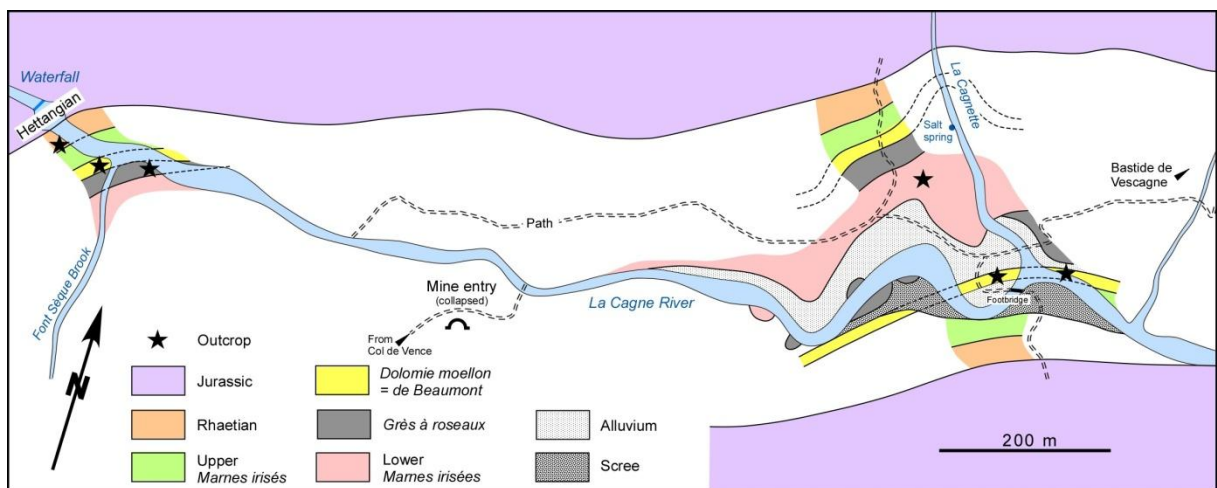


Fig. 53 – Map of the Keuper outcrops of Vescagne. From Ricour (1962) modified and completed.

The heart of the pinched anticline shows very contorted gypsum, black, red or white (Fig. 54). Then appears a set of gray siltstones and black shales, where coal was mined. It is topped by beds of cream-colored dolomite (about 10 m), then gray to green marls with conchoidal fracture. This series strongly suggests that of the Keuper of Lorraine (see legend of fig. 53). The Rhaetian consists of alternating yellow limestone beds, black shales, and gray shelly limestones with *Rhaetavicula contorta*.

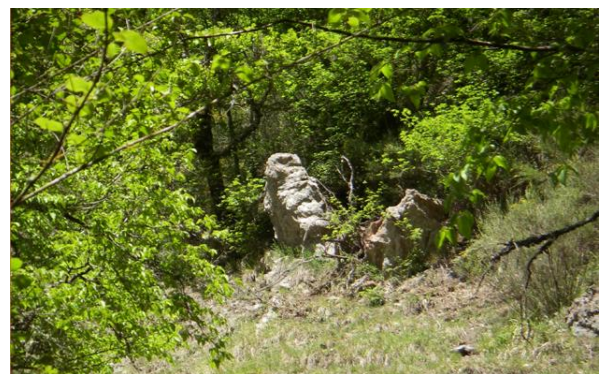


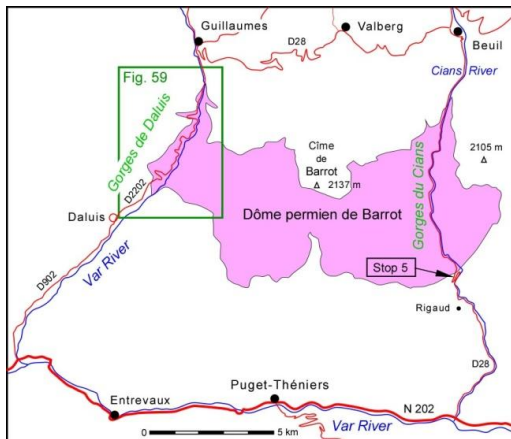
Fig. 54 – Vescagne eastern outcrops. Left: Old gypsum quarry in Lower 'Marnes irisées'. Right: Dolostone unit supposed to be the equivalent of the 'Dolomie de Beaumont'.



## Stop 5 – Rigaud

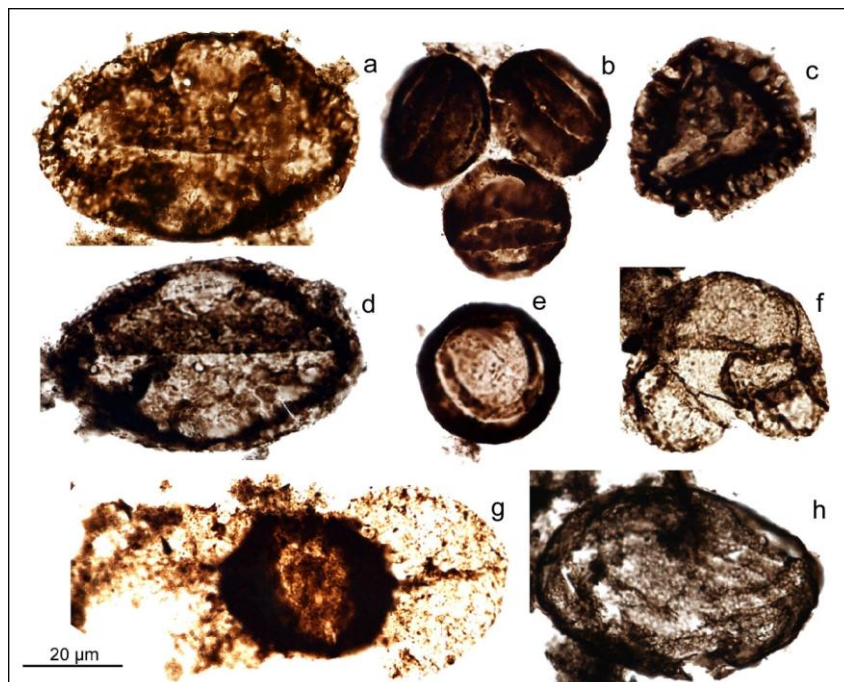
### Rhaetian of Pra d'Astier

This first outcrop of the Dôme de Barrot area is located at the south entrance of the Cians Gorges (Fig. 55). It is not very spectacular but that is the only one which allows to observe a part of the Upper Triassic near a paved road. It can also make aware of the stratigraphic problems posed in this region by tectonic deformations, since here the Rhaetian, in subvertical attitude, follows directly upon the Buntsandstein in apparent conformity.



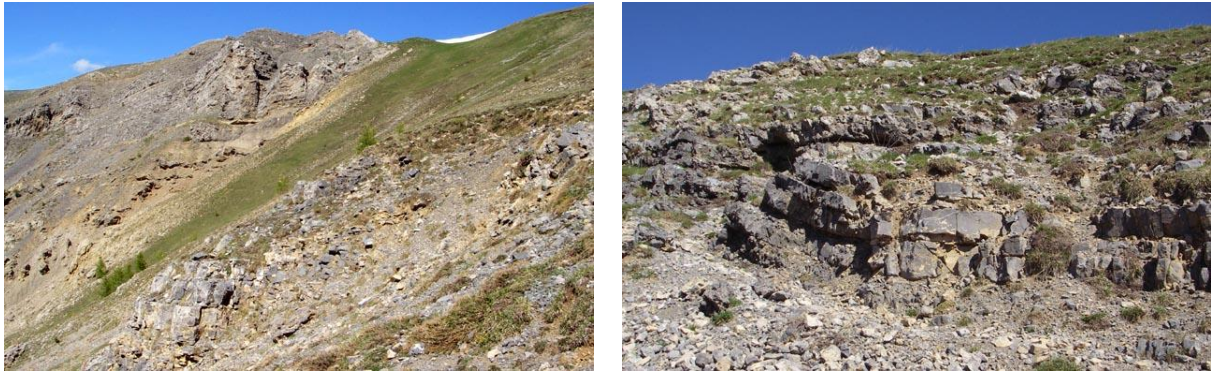
**Fig. 55** – Location and aspect of the Pra d'Astier outcrop.

The facies exposed is not very different from the Rhaetian of Vescagne: alternation of yellowish limestones and black shales. The palynological assemblages are still under investigation (J.B. DIEZ), but the appearance of *Ovalipollis ovalis* and *Classopollis* sp. already allows to assign this unit to the Upper Triassic: Norian-Rhaetian. The presence of *Classopollis* tetrads indicates a well preserved autochthonous deposit.



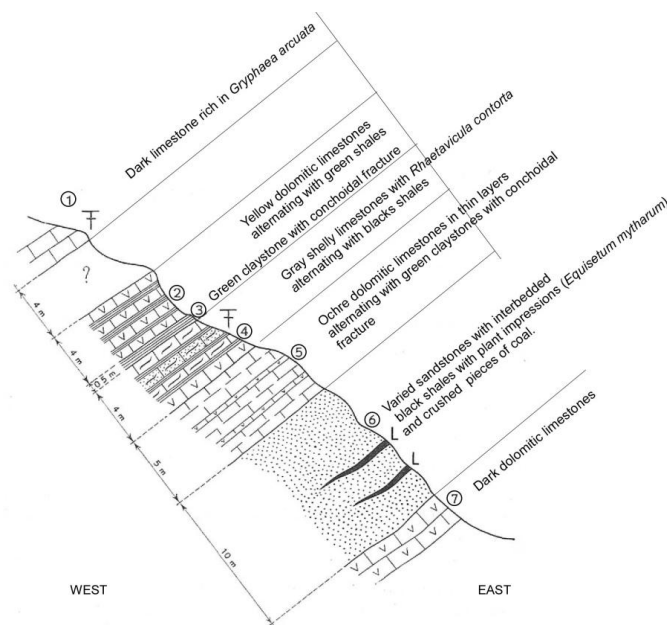
**Fig. 56** – Palynomorphs from the Pra d'Astier outcrop. **a** and **d**) *Ovalipollis ovalis*, **b**) Tetrad of *Classopollis* sp., **c**) *Rewanispora* sp., **e**) *Classopollis* sp., **f**) *Microcachrydites* sp., **g**) *Platysaccus* sp., **h**) *Concentricisporites* sp.

The main part of the Upper Triassic of the Dôme de Barrot is very poorly known. It seems that the best outcrops are located in a zone of difficult access, about 2000 metres a.s.l.: Cîme de Prat, north of the Barrot summit. In that area, BORDET (1950) reported the occurrence of two fossiliferous limestone units (Fig. 57) a few metres thick, isolated within *rauhwackes*, between the typical *Muschelkalk* limestones, nearly devoid of fossils, and the yellow Rhaetian limestones.



**Fig. 57** – Aspect of the two limestone units in the Keuper of Cîme du Prat. Left: Lower unit in the foreground. *Muschelkalk* *rauhwackes* of La Courbaisse in the background, separated by a fault. Right: Upper unit.

Recent observations showed the presence of plant remains in the upper limestones, and black clays above, with pieces of coal. This succession is very different from that of Vescagne, located 34 km SE, on the south margin of the 'Moyen Verdon - Estéron' Swell (Fig. 7). It could be characteristic of the 'Domaine Pré-briançonnais', as suggested by the section below (Fig. 58), measured 23 km to the east, along the Mercantour-Argentera edge. The level with coal seams has been likened by RICOUR (1962) to the German *Schilfsandstein* (Carnian), especially based on the presence of *Equisetum mytharum* (HEER), 1876. This binomial is probably a junior synonym of *Equisetites arenaceus* (JAEGER) SCHENK, 1864 (KELBER & VAN KONIJNENBURG-VAN CITTERT 1998). However, the hypothesis of a more recent age should not be rejected a priori because coal deposits of Rhaetian age are known in regions so diverse as Sweden, Germany, Hungary, Turkey or Viet-Nam.



**Fig. 58** – Section of Upper Triassic on La Raia mountain, Saint Dalmas-en-Valdeblorre. From RICOUR (1962).



Thursday, 8 Sept. 2011

Dôme de Barrot

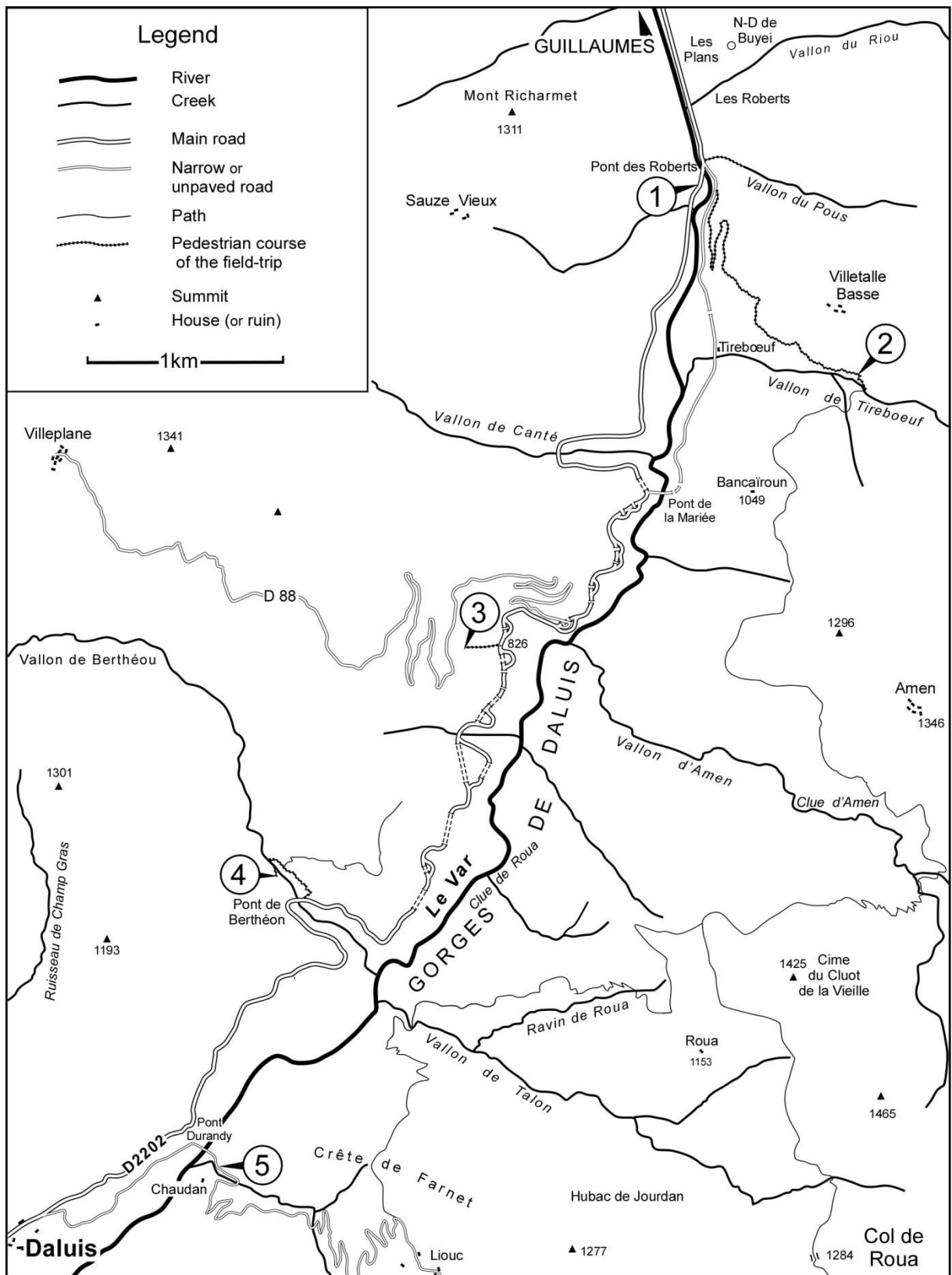


Fig. 59– Location of the stops of the fourth day: Western part of the Dôme de Barrot.

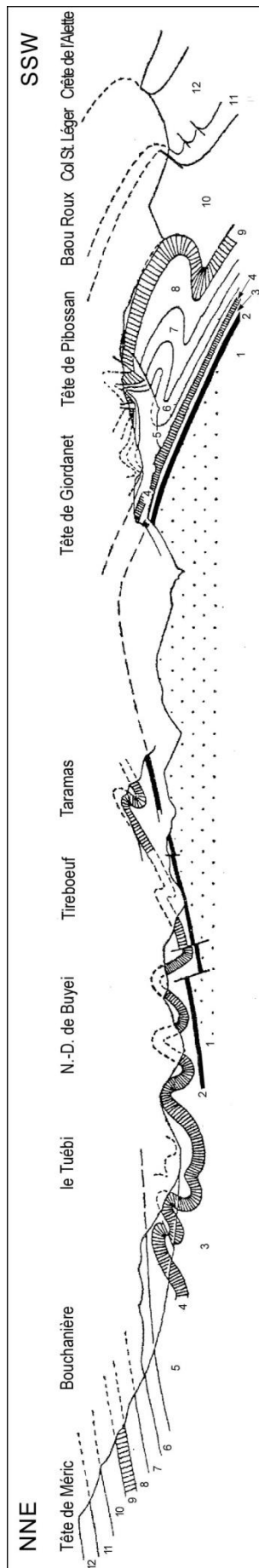


Fig. 60 – Geological cross-section of the Dôme de Barrot east of the Daluis Gorges. After Bordet (1950).

1- Permian, 2- Buntsandstein, 3- Lower Carnegneules, 4- Calcareous Muschelkalk, 5- Upper Carnegneules, 6- Lias, 7- Dogger, 8- Oxfordian, 9- Malm, 10- Lower Cretaceous, 11- Aptian, 12- Upper Cretaceous.

The Dôme de Barrot constitutes a unique window (Fig. 7) allowing to study the Triassic of the huge palaeogeographic entity called 'Domaine pré-briançonnais' (DURAND et al. 1988). The Buntsandstein is there much less disturbed by the Alpine events than that of Argentera-Mercantour implied in a vigorous folding and more or less affected by schistosity.

It is a brachyanticline, trending E-W, about 15 km length on 5 km broad (Fig. 55), and limited to the west by a system of wrench faults NNE-SSW. The major tectonic characteristic of this area is the structural independence which exists between three superimposed elements: a basement comprised of the Permian substratum and its siliciclastic Triassic '*revêtement*' (Buntsandstein), a very deformed intermediate series, including Muschelkalk and Keuper, and finally a Jurassic, Cretaceous and Cenozoic cover whose thickness exceeds 2000 m (Fig. 60). The Permo-Triassic tectonic basement forms a regular bulge, neither folded nor affected of reverse faults. A study of the fracturing led SCHUILLING (1956) to conclude that the dome would be due only to a vertical push. Thus a hypovolcanic origin may be suspected.

In the north and the west of the dome, the calcareous Muschelkalk is affected by tight and overturned folds, verging towards the south, whose axes tend to be moulded on the contour of the dome. BORDET (1950) estimates at nearly 10 km the shortening of the cover at this level. This *intercutanée* tectonics is due to the initial presence, on both sides of the affected formation, of an unit rich in plastic evaporites, which allowed a decollement and played the part of lubricant; and is now transformed into *rauhwackes* (*carnegneules*). On the other hand, in the south of the dome, the calcareous Muschelkalk remained interdependent of its Permo-Triassic substratum and its Jurassic cover (see fig. 60), and shows rare practically undeformed outcrops, as at Stop 5.

Contrary to the calcareous Muschelkalk, the Jurassic-Cretaceous cover has kept a nearly tabular structure in the north, whereas in the south it draws the large recumbent fold of Pibossan, whose axis shows, in the area of Daluis, a direction completely different (NW-SE) from that of the adjacent anticlines of Muschelkalk (BORDET 1950).

In Argentera, recent work highlighted the effects of synsedimentary distensive tectonics, primarily Permian in age (faults N100°E and N125°E) and rarely Triassic (DELTEIL et al. 2003). In

the Dôme de Barrot, comparable phenomena (progressive angular unconformities) seem to be detectable in the Permian series, with the observation of landscapes and air photographs; on the other hand the Buntsandstein did not still deliver any clue making it possible to suppose the occurrence of syndimentary movements of Triassic age.

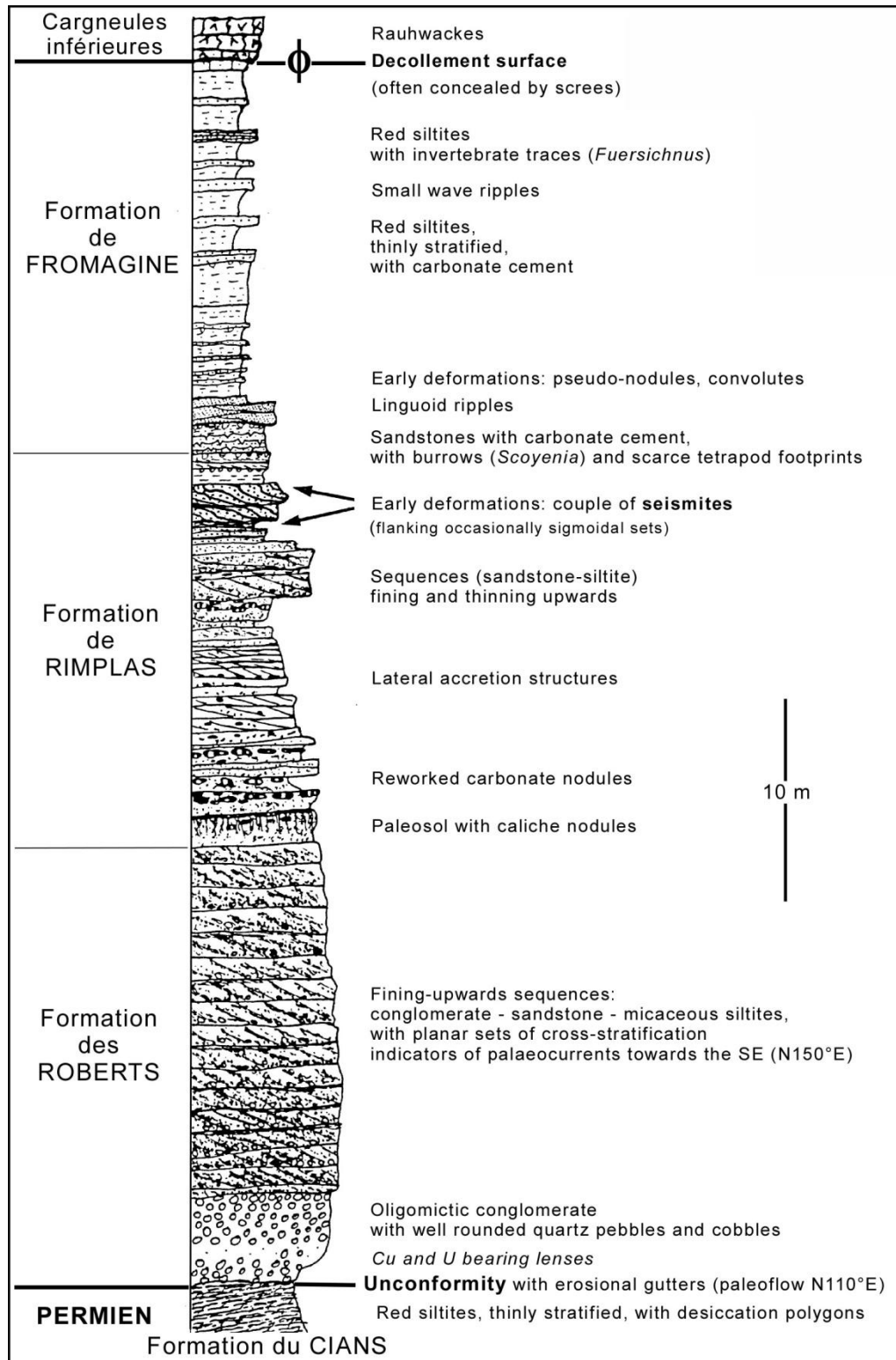


Fig. 61 – Synthetic section of the Buntsandstein of the Dôme de Barrot .  
From AVRIL in DURAND et al. (1989b)

## Stop 1 – Pont des Robert

### Permian-Triassic unconformity and Les Roberts Fm.

A same siliciclastic succession (Buntsandstein), 70 m thick on average, overcomes the unconformity marking the top of the Permian series in the entire region Barrot – Mercantour-Argentera (FAURE-MURET 1955). It is currently divided into four formations (AVRIL et al. 1987, AVRIL 1989, DURAND et al. 1989b) (Fig. 61). At the basal part, the Berthéou Formation (incised-valley fill ?) was recognized only very locally (see Stop 4), on the western edge of the Dome. For the two last units, the type locality was chosen on the Mercantour, where vegetation is sparser.

A marine origin was sometimes claimed for these siliclastics, from wave-dominated beach barrier to tide-influenced offshore bars (RICHARDS 1981, 1983, 1986, 1994), but no convincing evidence was provided. However, sedimentological and even more paleontological data advocate clearly for a continental origin, mainly fluvial (DURAND et al. 1989b). The traces of invertebrates and tetrapods, appearing since the lower part of Les Roberts Fm. up to within Fromagine Fm. (AVRIL, 1989; DEMATHIEU & DURAND, 1991), are particularly significant.



Close-up on casts of attritional gutters dug in hard rock along the unconformable surface.



**Fig. 62** – The Permian-Triassic unconformity downstream of 'Pont des Roberts', seen from the path to Tireboeuf.

Just downstream of Les Roberts bridge on the Var River, the Permian-Triassic boundary crops out largely on both sides of the valley, marked by a slightly angular unconformity on the playa facies of the Cians Fm. It is at this site that **Les Robert Formation** (15 to 35 m) was defined. The unit appears in the landscape usually as cliffs (Var and Cians valleys). It always starts with the 'basal conglomerate' of ancient authors, made of well-rounded quartz pebbles and cobbles, up to 20 cm long. At the sole of the conglomerate appear, overhanging, casts of deep erosion grooves, more or less sinuous, indicating paleocurrent direction (N120°E here). The fact that this conglomerate passes gradually to sandstones showing evidence of pedogenesis, and that the few ventifacts that can be meet show traces of a major reworking, suggests that it is more recent than the Poudingue de Port-Issol (see fig. 6).

The transition to the overlying light-gray quartzitic sandstones, often coarse grained, is usually very gradual, seldom sharp. They form lenticular beds, metric in thickness, with significant lateral extension, showing mainly tabular cross-bedding. Mudrock intercalations are scarce. The deposition of this formation reflects a profound change in flow conditions, related to tectonics and/or climate. Removal of residual materials from a raised peneplain was followed by the development of a braided-channel network, with numerous bars, first longitudinal to linguoid, then essentially transverse.

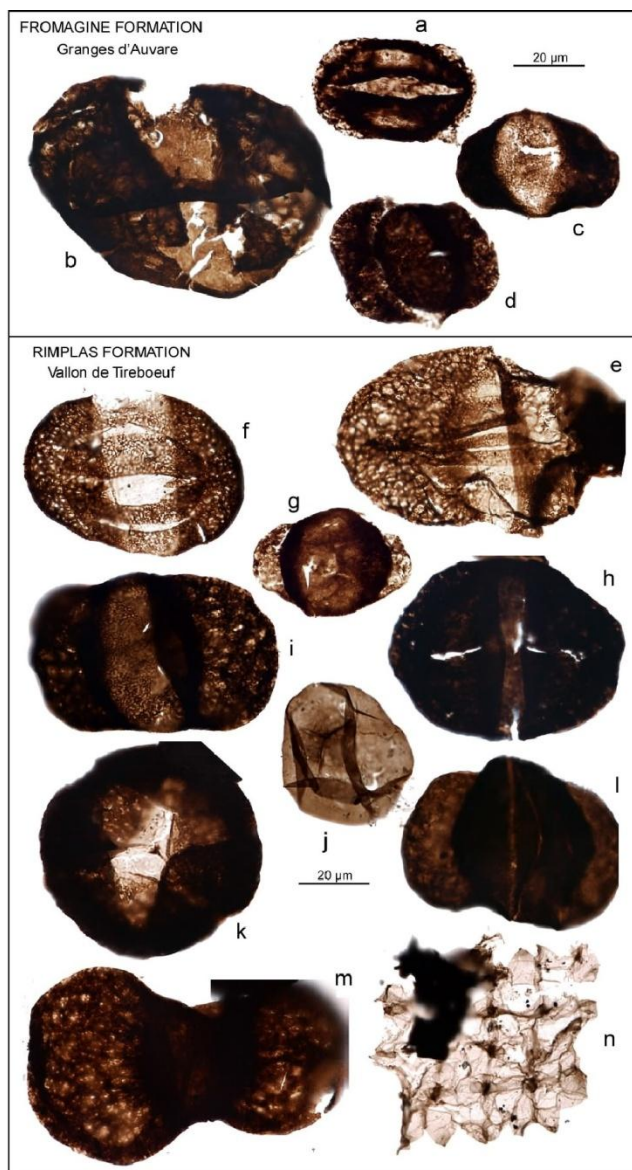


## Stop 2 – Vallon de Tirebœuf

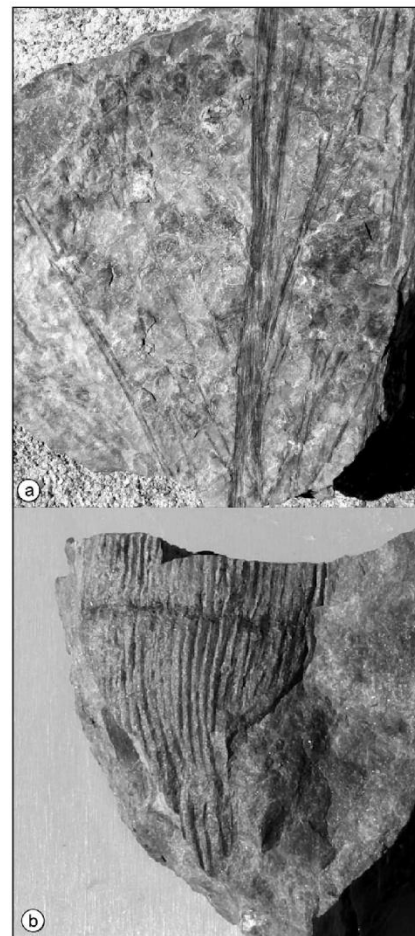
### Rimplas Formation and Fromagine Formation

The walk to the Tirebœuf valley, 3 km long (round trip), is not so steep as that leading to Vescagne, because the access trail (which starts from the bridge along the sub-Triassic unconformity) is none other than the old mule track leading to Puget-Théniers by the Roua Pass; it was still the main access route to Guillaumes from the Var valley until 1878, when was open the road by the gorges.

Just at the unconformity one can see few entrances of gallerie. The Dôme de Barrot has indeed acquired a certain notoriety because of its copper mineralizations, of which the only of economic interest are related to the contact Permian-Triassic (VINCHON 1984, MARI 1992). Then the trail, climbing on the Cians Fm., allows (in the morning) to have a beautiful view on the cliffs of Stop 1 (Fig. 62). Further, in the scree at the foot of the cliffs, most of the Muschelkalk facies (rauhwackes and limestones) can be



**Fig. 64** – Palynomorph assemblages from the Buntsandstein of the Dôme de Barrot. **a)** *Ovalipollis ovalis*, **b)** *Illinites kosankei*, **c)** *Triadispora staplinii*, **d)** *Triadispora suspecta*, **e)** *Lunatisporites acutus*, **f)** *Striatoabieites ayugii*, **g)** *Triadispora staplinii*, **h)** *Illinites kosankei*, **i)** *Voltziaceasporites heteromorpha*, **j)** *Calamospora tener*, **k)** *Hexasaccites muelleri*, **l)** *Alisporites grauvogeli*, **m)** *Platysaccus papilionis*, **n)** *Plaesiodyctyon mosellanum*. Photos J.B. DIEZ



**Fig. 63** – Macrofloral elements from Rimplas Fm. (Tirebœuf deposit).  
a) *Aetophyllum*, b) *Equisetites*  
From DURAND & GAND (2007)

sampled. After a long crossing on Fromagine Fm., whose red clay-sandstone facies appear in the slope, the trail reaches the top of the Rimplas Fm., a hundred metres before the bridge on the Tirebœuf creek.

**The Rimplas Formation** (12 to 35 m) is characterized by a change in architecture of the deposits as well as the development of carbonates in the form of concretions or diffuse impregnations in more or less direct relationship with paleosols. Sandstone bodies may pass laterally to silty-clay units, variegated to gray, sometimes containing plant remains which are the only biostratigraphic elements available for dating the Buntsandstein in the Alpes-Maritimes. These deposits show a marked increase in the sinuosity of the channels, always shallow, which tended to stabilize, leaving between them areas emerged a long time, subject to pedogenesis under semi-arid climate. Periods of low water, allowing the installation of *Scoyenia* ichnocoenoses to the edge of permanent water bodies, were interrupted by flood events spreading sandy deposits with current ripples. Near the top of the formation, an isochronous stratigraphic marker is represented by a couplet of seismites (DURAND et al. 1989), 0.1 to about 1 m in thickness and vertically spaced from 1 to 2 m according to the outcrops. It has been observed in several places, from the western edge of the Dome to the margin of the Mercantour.

**The stop** before returning presents four main points of interest. The main path trench shows a carbonate crust of pedogenic origin (dolocrete) especially developed; such features are generally not so thick in the rest of the Rimplas Fm. A few meters down below the path, at the foot of a small sandstone cliff, a thick lens of gray claystone (oxbow-lake deposit linked with point bar) is preserved, which provided some macrofloral elements (Fig. 63) and, more recently, a rich palynoflora (Fig. 64). The Lower Anisian age proposed by ADLOFF (in DURAND et al. 1989b) for the Rimplas Fm. from a sample taken at Stop 3 (see below) is here confirmed by *Hexasaccites muelleri*, *Illinites kosankei*, *Triadispora staplinii* and *Voltziaceasporites heteromorpha* (DIEZ, in progress). The third interesting point is located again along the main path, a few steps from there. This is a seismite bed whose aspect is different from that of Stop 3, because generated within a heterolithic facies: sand and clay layers.

Finally, ascending the ravine to the north, it is possible to study in detail various aspects of **the Fromagine Formation**. Between 20 and 40 m in thickness, it consists mainly of red siltstones, often thinly bedded, differing from the Permian pelites practically only by the constant presence of mica. The trace fossils (AVRIL 1989, DURAND & GAND 2007), represented by *Fuersichnus* ichnocoenoses (BROMLEY & ASGAARD 1979), are also different. To the base, siltstones alternate with thin platy sandstone beds of the same color. Towards the top, color becomes yellowish and dolomitic thin layers are increasing; some halite “pseudomorphs” may appear. For the moment, the only palynological associations delivered in different places are rather poor (Fig. 64): of middle or upper Anisian age, so it is necessary to complete the analysis (DIEZ, in progress). This formation shows a total disorganization of fluvial systems. Under the influence of a probable elevation of base level, related to the Muschelkalk transgression, large permanent shallow lakes, favorable to the development of *Fuersichnus* ichnocoenoses, settled almost everywhere. The very slow flow of these sheets of water, between temporary islands with desiccation cracks, seems strongly deviated from the previous eastwards, perhaps under the influence of winds. The appearance of the first halite cubic-hopper casts, together with the development of dolostone layers, marked the end of the Permo-Triassic continental history of that domain.

The Buntsandstein in the whole region Argentera-Mercantour and Barrot has traditionally been considered "Werfénien" or "Lower Triassic" in age (Bordet 1950; Richard 1981;1986) on the basis of a cursory comparison with the 'Quartzites du Briançonnais'. Actually stratigraphic data obtained by study of the Var Valley outcrops lead to the conclusion to the presence of a single widespread sedimentary cycle of Triassic age, post-Smithian (without us knowing if it began as early as the Spathian) and mainly Anisian. Anyway, the basal detrital series of the 'Dôme de Barrot' and Argentera-Mercantour (autochthonous) is not synchronous with the basal quartzitic series of the 'Zône Briançonnaise' (allochthonous), since the latter ends before the basal Anisian (*Dadocrinus gracilis* Limestone) from which it is separated by an evaporitic unit responsible for a first detachment level of the cover (MÉGARD-GALLI & BAUD 1977).

### Stop 3 – Ravine above the 'height point 826' bridge

#### Seismites in Rimplas Fm.

To access the observation point it is necessary to go under the bridge from the height point 826, then to climb the steep narrow valley up to an outcrop of sandstones in the Rimplas Fm. lowered against the Cians Fm. by a fault.



Fig. 65 – The lower seismite of the couplet in the uppermost part of the Rimplas Fm., at Stop 3.

The seismite couplet is here well expressed in an entirely sandy facies (Fig.65). One can also notice the presence, close by, of cupriferous showings in connection with both the fault and the reducing environment associated with plant remains. This is also there that a small gray-green clay lens yielded a palynoflora almost as rich as that of Tirebœuf (ADLOFF in DURAND et al.1989).

### Stop 4 – Vallon de Berthéou

#### Cians Fm. (Permian) and Berthéou Formation

From the car park on the other side of the road, take the path to "Point Sublime" that winds on the Cians Formation (Fig. 66). At the fork near the bottom of the valley, turn to "Vallon de Berthéou". On the north side can soon be seen the basal conglomerate of Les Roberts Fm. resting on red Permian



silts. At the bridge, go down to the creek bed that sink quickly into a gorge (Les Roberts Fm.). At the exit, go along the right wall to have a look at the contact Les Robert Fm. on Berthéou Fm. (Fig. 67). The sand grains of the Berthéou Formation (greenish fine-grained sandstone beds here) have been reworked and mixed with the new input characteristic of Les Roberts Fm., implying that these deposits were not yet lithified, and inciting to place the Berthéou Fm. in the Triassic cycle rather than in the Permian. Only a very small part of the Bertheou Fm. is exposed; a few metres of laminated reddish sandstones are visible below.

**The Cians Formation** constitutes the bulk of the Permian Massif de Barrot. Its base is unknown, but it is in the bottom of the 'Gorges du Cians' that the older known terms, more massive and indurated, can be reached, while the upper terms, more brittle, are widely exposed in the 'Gorges de Daluis'. As a result of the presence of numerous faults, some of which seem to be synsedimentary (appearance of progressive unconformity), estimates of the total thickness of the outcropping part varies between 450 and 800 meters according to the authors (VINCHON, 1984). This formation, rather uniformly red coloured, is essentially composed of two types of facies. One, of massive siltstones, in beds metre thick, would be of aeolian origin according to VINCHON (1984), and would have been deposited in subaerial environment. The other, of silts and clays, is finely laminated and shows sedimentary surfaces with small wave ripples, often cut by a network of multiphased desiccation cracks; it results from deposition in a shallow water body, prone to drying: a playa-lake.



**Fig. 66** – Two types of sedimentary structures omnipresent in the Cians Fm. : Desiccation cracks and small wave ripples

The azimuth of ripples crests is relatively constant (around N140°E), very similar to that observed in the Salagou Fm. in the Lodève Basin (POCHAT et al. 2005), suggesting a same direction of prevailing wind, consistent with the global circulation system undisturbed by any mountain barrier. A third facies, occasional, is represented by fine-grained pyroclastics, in beds a few decimetres thick. Invertebrate trace fossils relatively uncommon, are still under investigation. They can all be reported to the *Scoyenia* ichnofacies and *Mermia* ichnofacies (BUATOIS & MANGANO 1995).

The Cians Fm. is not yet dated, but in south central massif, two other Permian formations are more or less preserved below the Triassic conglomerates (La Roudoule Fm. and Léouvé Fm.), the last of which yielded, in its upper member a palynological assemblage of 'Thuringian' age (VISSCHER et al. 1974), actually Guadalupian (see DURAND & GAND 2007).





**Fig. 67** – Close-up on the contact of Les Robert Fm. above Berthéou Fm.

## **Stop 5 – Durandy-Liouc Bridge**

### **Calcareous Muschelkalk**

Unlike the calcareous Muschelkalk of Provence, that of Dôme de Barrot can not be divided into two main unities. Near the north-east exit of Daluis village, a narrow road goes down north in the valley of the Var down to a frail bridge (limited to 1.5 t): Pont Durandy. From the other end of the bridge to an old quarry, one of the best section in Muschelkalk limestones can be studied along the dirt road leading to the hamlet of Liouc (Fig. 68). We are here below the Tête de Pibossan and, as can be seen on figure 60, this zone was relatively spared from tectonic deformation. The facies is very monotonous: dark gray mudstones, where levels with several bivalve and / or brachiopod fragments and / or encrinid columnal are spaced out. That section was never measured, and no search for conodonts has yet been undertaken across the whole region.



**Fig. 68** – Upper part of the Liouc outcrop in Calcareous Muschelkalk.

There is still much work to be done !

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