Synsedimentary collapse on a carbonate platform margin (lower Barremian, southern Vercors, SE France)

Grégory BIÈVRE
UMR 5561 Biogéosciences and UFR Sciences de la Terre et de l'Environnement,
Université de Bourgogne, 6 bd Gabriel, F-21000 Dijon (France)

Didier QUESNE
UMR 5561 Biogéosciences and UFR Sciences de la Terre et de l'Environnement,
Université de Bourgogne, 6 bd Gabriel, F-21000 Dijon (France)
didier.quesne@u-bourgogne.fr

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ABSTRACT
A large area of synsedimentary collapse covering about 25 km^2 has been identified within lower Barremian carbonate platform strata of the southern Vercors (Vocontian Basin, SE France). New observations of the prograding/aggrading strata of the Cirque d'Archiane and the Glandasse Plateau reveal the presence of a disturbed zone, showing tilted and imbricated blocks as well as slump features. Measurements and analysis on these synsedimentary distorted strata suggest that they compose a slide which slipped on the Barremian slope. The occurence of two coarse bioclastic grainstone beds on the eastern side of the Archiane Valley, in a distal hemipelagic context, suggests that this instability generated a tsunami that reworked proximal bioclastic material, previously transported out to the hemipelagic domain at the same time as the slide, rearranging it under the influence of tractive currents. The idea of high frequency sea-level variations to explain these strata is unlikely. They do not exhibit univocal sedimentologic evidence (such as bundles or herring-bone stratifications) that could indicate sea-level fluctuations. Furthermore, no evidence of major subaerial exposure on the platform top has been reported, neither acceleration of downward migration of platform facies is observed on the slope. It seems more appropriate, considering the palaeogeographical setting of this area, that these grainstone beds represent bioclastic deposits controlled by tractive currents. The origin of the slide could either be sediment loading or tectonics compounding sediment loading. These two events (slide and bioclastic beds) are proposed to be genetically linked, as well as with numerous tectonic activity evidence already reported at other sites in the region. The events observed in this work do not allow classical biostratigraphy dating methods to be applied. The various structures observed in these disturbed zones show that the material slipped in a direction wholly consistent with the unstable setting of the margin of the Vocontian Basin in Lower Cretaceous times.

KEY WORDS
Carbonate platform,
synsedimentary collapse,
lower Barremian,
Vercors,
SE France.

RÉSUMÉ

Glissement synsédimentaire à la bordure d'une plate-forme carbonatée (Barrémien inférieur, Vercors méridional, SE France).

Une zone de glissement synsédimentaire recouvrant une surface d'environ 25 km^2 est mise en évidence sur la plate-forme carbonatée du Barrémien inférieur du Vercors méridional (Bassin Vocontien, SE France). De nouvelles observations sur l'arrangement progradant/aggradant des dépôts du Cirque d'Archiane et du Plateau du Glandasse révèlent une zone perturbée qui comporte des blocs imbriqués et basculés de même que des figures de slump. Les mesures et analyses sur ces couches déformées suggèrent qu'elles résultent d'un glissement synsédimentaire sur la pente barrémienne. La présence de deux niveaux bioclastiques grossiers sur le flanc est du Cirque d'Archiane, dans un contexte sédimentaire hémipélagique distal, permet de proposer que le glissement ait généré un tsunami qui a repris du matériel bioclastique proximal, ayant précédemment été transporté en zone hémipélagique en même temps que le glissement, et l'a réorganisé sous l'influence de courants tractifs. Il apparaît peu probable que ces deux bancs sont le résultat de variations à haute fréquence du niveau marin. En effet, ils ne possèdent pas de critère sédimentologique univoque (*bundles*, stratifications entrecroisées en *herringbones*…) qui attesterait d'une variation du niveau marin. De plus, aucune preuve d'exposition subaérienne majeure au sommet de la plate-forme n'a été reportée à ce jour, de même qu'il n'existe pas d'accélération de la migration des faciès vers le large. Il semble plus approprié, au vu du contexte paléogéographique du secteur, que ces deux bancs représentent des dépôts bioclastiques mis en place sous l'influence de courants tractifs. Le mécanisme à l'origine du glissement pourrait être la surcharge sédimentaire ou bien la tectonique associée à la surcharge sédimentaire. Nous proposons que le glissement ainsi que les deux bancs bioclastiques soient liés génétiquement, de même qu'avec de nombreuses autres preuves d'activité tectonique déjà observées dans la région d'étude à cette période. Les événements observés dans ce travail ne permettent pas d'appliquer les méthodes classiques de datation par biostratigraphie. Les diverses structures observées dans ces niveaux à la sédimentation perturbée indiquent que le matériel a glissé dans une direction parfaitement concordante avec le contexte sédimentaire instable de cette bordure du Bassin Vocontien au Crétacé inférieur.

MOTS CLÉS
Plate-forme carbonatée, glissement synsédimentaire, Barrémien inférieur, Vercors, SE France.

INTRODUCTION AND GEOLOGICAL SETTING

The Alps are a mountain chain mainly built during the compressional phases that took place during Late Cretaceous and Cenozoic. The Vercors belongs to the external units of the subalpin chains. It is a palaeogeographic unit positioned on the northern edge of the Vocontian Basin where was located, during the Lower Cretaceous, the southeastern France basin (Stampfli *et al.* 1998). It is a large carbonate platform (Fig. 1) where bioclastic sand-shoals on the platform margin were reworked by tide and storm processes (Everts 1994).

Three main types of sediments can be encountered within this palaeomargin: 1) gravity flows (slumps, turbidites) which were generated from the upper-slope domain and fed turbiditic systems downslope. These deposits are characteristic of the

Vocontian Basin margins (Ferry 1976, 1978; Beaudoin 1977; Joseph *et al.* 1989); 2) hemipelagic series made of limestone-marls alternations developed at the shelf/basin transition (Ferry & Monnier 1987); and 3) platform bioclastic carbonate sands and rudistids beds were deposited on the paleomargin edge (Arnaud 1981; Arnaud-Vanneau *et al.* 1979) and correspond to the different platforms surrounding the Vocontian Basin (Jura-Vercors, Cévenole and Provençale platforms; see Fig. 1).

The Vercors carbonate platform is the southern extension of the Jura platform. Two main realms are distinguishable within this platform which are separated by the Isère Fault (Fig. 1). To the North of the fault (Jura platform) subsidence was low whereas to the South (Vocontian trough) subsidence was strong enough to allow the accumulation of thick carbonate formations (Arnaud 1988), like the 750 m thick Glandasse Limestone Formation.

The Vercors is often thought to represent a large carbonate platform where the sedimentary stacking patterns were barely affected by synsedimentary structural events. In the region of interest here, the Isère and Menée Faults break the platform into large downstepped blocks in its general transition towards the Vocontian Basin (Joseph *et al.* 1989). The Barremian formations of the southern Vercors (Figs 2; 3) are made of external and internal platform bioclastic carbonated sands (Borne and Glandasse Bioclastic Limestone Formations for the lower Barremian) and inner platform rudistidid limestones (Urgonian Limestone Formation, upper Barremian).

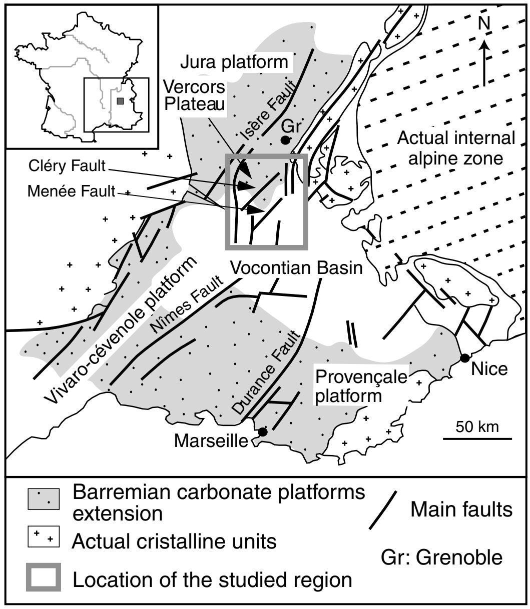

FIG. 1. — Palaeogeographic map of the Vocontian Basin and surrounding carbonate platforms during the Barremian times. Adapted from Jacquin *et al.* (1991).

Stratigraphically, the Glandasse Limestone Formation belongs to the lower Barremian (from

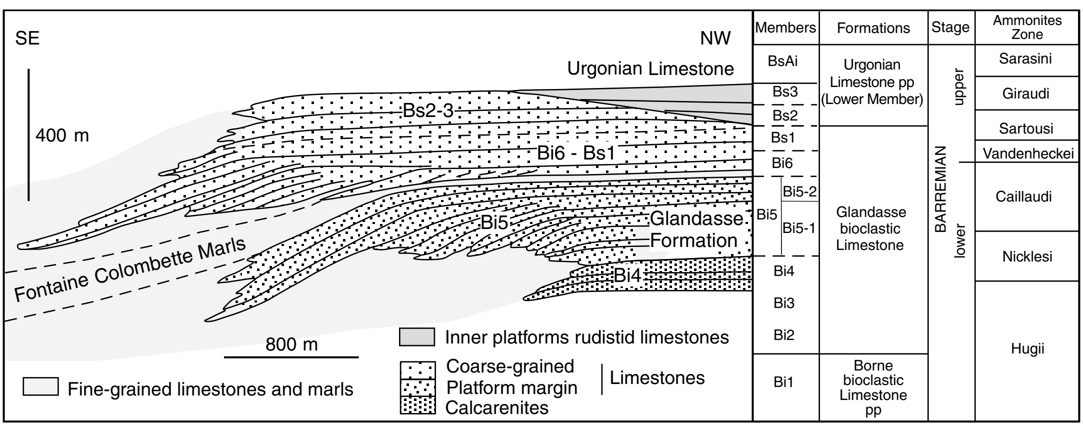

FIG. 2. — Schematic cross-section of the Barremian southern Vercors carbonate platform and its biostratigraphy. Adapted from Arnaud (1981) and Everts (1994); biostratigraphy after Rawson (1996).

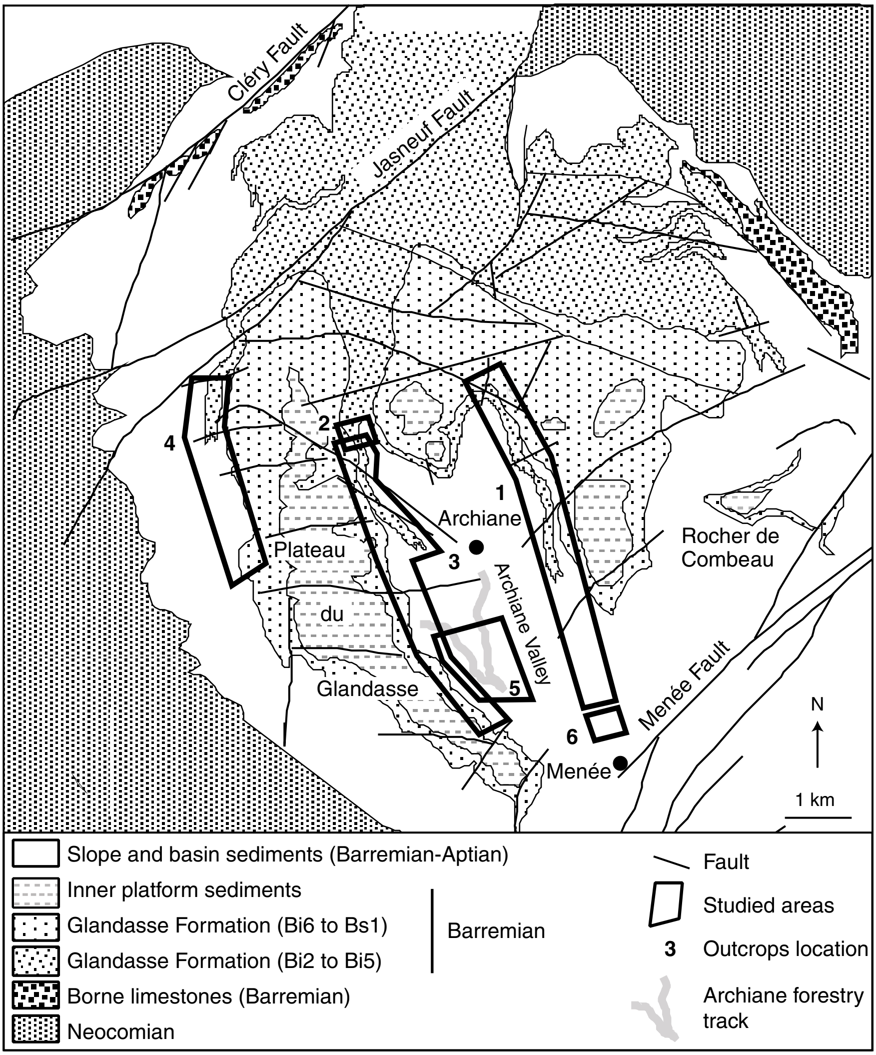

FIG. 3. — Geology of the Vercors region and location of the studied areas.

Hugii *pro parte* zone to Sartousi *pro parte* zone; Fig. 2) and is made of coarse bioclastic limestones depicting an external platform environment. It can be further divided into six parasequences labelled Bi2 to Bs1 (Arnaud 1981), arranged in clinoforms that prograde to the south (Figs 2-4). These high-energy deposits form the transition between the Urgonian deposits (in the broad sense) and the upper slope domain from where shelf-margin sands supplied material to sediment slides (Ferry 1976, 1978; Ferry & Flandrin 1979).

The cliffs of the southern Vercors (Archiane Valley and Glandasse Plateau; Fig. 3) are excellent sites for observing and analysing Barremian deposits, including the bioclastic sands of the Glandasse Limestone Formation, at a seismic scale. It is a location where the large-scale stratigraphic organisation and architecture can be studied in detail, explaining its interest for stratigraphers and sedimentologists (Arnaud-Vanneau *et al.* 1979; Arnaud 1981; Jacquin *et al.* 1991; Hunt & Tucker 1993; Everts 1994;

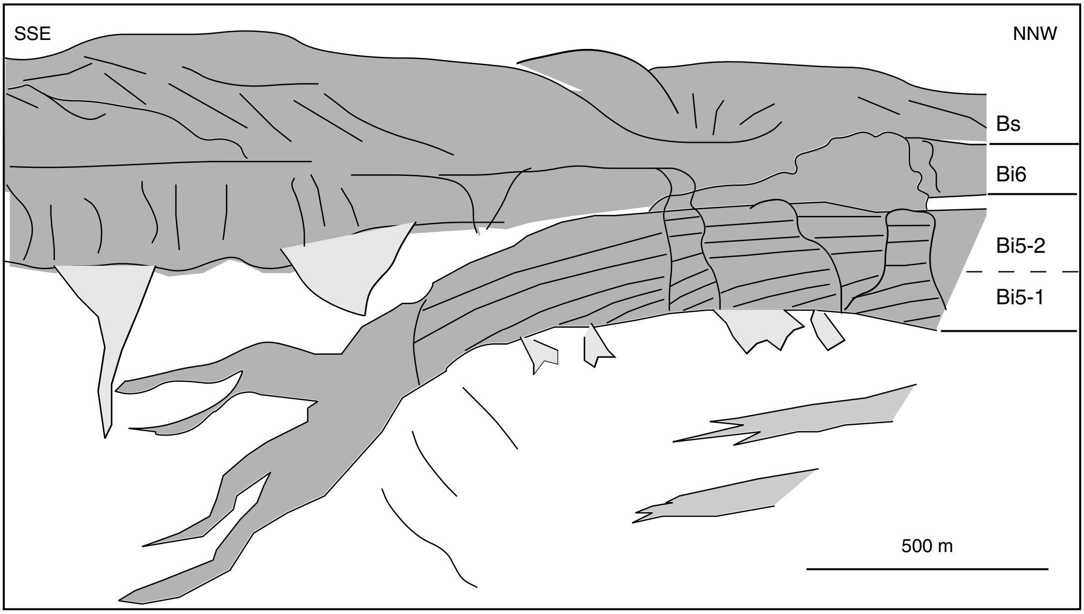

FIG. 4. — Prograding (Bi5-1) and aggrading (Bi5-2) geometry of the Barremian southern Vercors carbonate platform (see Fig. 3 for location, northern part of area 3).

Quesne 1996, 1998; McDonough 1997). Since the development of sequence stratigraphic concepts in the 1980s, more or less diverging interpretations have been proposed in terms of depositional sequences, depending on the type of approach: geometry and stacking pattern (Arnaud-Vanneau & Arnaud 1990; Jacquin *et al.* 1991), petrography and geochemistry of diagenetic surfaces (Fouke *et al.* 1995), sediment composition and stratal patterns (Everts 1994; Everts *et al.* 1995), facies sedimentology and genetic stratigraphy (Hunt & Tucker 1993; Quesne 1996, 1998). These diverging interpretations underline the difficulty of applying sequence stratigraphy concepts defined in siliciclastic environments to carbonate platform domains.
The influence of any reworking of already settled but incompletely lithified material has not been reported until now. Detailed examination of the Bi5 Member (as defined by Arnaud 1981) at various scales (panoramas, geometry and sediment stacking patterns, facies and microfacies analysis) yields new informations about the configuration and evolution of this platform margin during lower Barremian times. The aim of this work is to present new observations that may help to complement the understanding of the area as well as enhancing the application of sequential concepts to a carbonate platform margin.

STATE OF KNOWLEDGE OF THE BI5 MEMBER

The northern (platformward) part of the lower Barremian Bi5 Member consists in about 300 m of massive clinoforms composed of coarse bioclastic grainstone. The southern (basinward) part of Bi5 is made up first of fine slope sediments with slump and creep features (Everts 1994), these deposits being mainly sigmoidal clinoforms, before passing laterally into hemipelagic marly limestones (Jacquin *et al.* 1991; Everts 1994) showing laminations (vertical-stacked hummocky cross stratifications) that could reflect the distal effects of storms (Quesne 1996). The bedding planes bounding the clinoforms that make up Bi5 give way to marly horizons and then to marly beds towards the basin (Quesne 1996). Hunt & Tucker (1993), Everts (1994) and Quesne (1996) subdivided Bi5 on the basis of its geometry into two subunits: Bi5-1 and Bi5-2 (Figs 2; 4).

The first subunit (Bi5-1) consists principally of prograding clinoforms with an oblique sigmoidal arrangement (Everts 1994). Deposits are composed of rather coarse bioclastic grainstone, so intensely bioturbated at their base that all primary sedimentary structures have been destroyed (Quesne 1996). Hunt & Tucker (1993) further divided this subunit into three high-frequency cycles.

The second subunit (Bi5-2) has a more aggradational geometry, visible at several locations on the plateau in the NS and WE sense. Deposits change progressively downslope from grainstones to packstone-wackestones with gradual loss of shallow-water organisms (large bivalves, bryozoans, echinoderm debris, Orbitolinidae), which are progressively replaced by a fauna (Lenticulinidae, sponge spicules, small bivalves) typical of a hemipelagic environment (Quesne 1996). Hunt & Tucker (1993) distinguished three high-frequency cycles within Bi5-2, deposited at a time of rapid increase in accommodation, the second cycle marking the beginning of facies retrogradation.

Upslope, Bi5-2 was principally laid down in a shallow environment, revealed by the lack of clays within the deposits. The grainstones were deposited above wave base in the platform margin upper-slope area (McDonough 1997). Everts (1994) argued that the top of Bi5-2 is representative of an open sea shelf environment located below the fair-weather wave base.

DEPOSITIONAL GEOMETRY IN THE ARCHIANE VALLEY AND ON THE WESTERN EDGE OF THE GLANDASSE PLATEAU

ARCHIANE VALLEY

At the head of the Cirque d'Archiane (to the North), the geometry of Bi5 is clearly visible on the eastern side of the valley (Fig. 5; area 1 on Fig. 3 for location): Bi5-1 is rapidly prograding whereas Bi5-2 has a more aggrading geometry. On this side, the beds of Bi5 can be traced laterally in outcrops over long distances and they can be correlated from the end of the cirque at least as far as the village of Menée.

On the western side of the valley, the Bi5 Member is also visible with the same geometry as on the eastern side (Bi5-1 prograding, Bi5-2 aggrading; Figs 4; 6; respectively northern part of area 3 and area 2 on Fig. 3 for location). Nevertheless, this can only be seen over a very short distance. Southward, Bi5 beds can no longer be physically traced: there is no lateral continuity between the prograding (Bi5-1) then aggrading (Bi5-2) grainstones and the hemipelagic marl-limestones. Figure 7 (area 3 on Fig. 3 for location) shows the sudden lack of occurrence of Bi5 beds, whereas the Fontaine Colombette Marls and the Bi6 beds are easily visible and traceable. It is only some 2000 m farther on (to the South, at the hairpin bend in the Archiane forest road; Fig. 7) that Bi5 deposits can be seen again. They occur as hemipelagic marly limestones, similar to those on the eastern side of the valley opposite.

WESTERN SIDE OF THE GLANDASSE PLATEAU

The depositional geometry of the grainstone-packstone cliffs below the Roc de Peyrole (Fig. 8; area 4 on Fig. 3 for location) is unlike that of the eastern edge of the Archiane Valley. The very base of the cliff exhibits a progradational geometry but the overlying deposits display no prograding or aggrading arrangements of beds, but rather a massive organisation with no distinguishable stratal patterns.

DETAILED DESCRIPTION OF THE DISRUPTED ZONE

WESTERN SIDE OF THE ARCHIANE VALLEY

On the western side of the Archiane Valley, synsedimentary deformation features can be seen in the zone where the geometric pattern of Bi5 is disrupted. The cutting along the Archiane forest

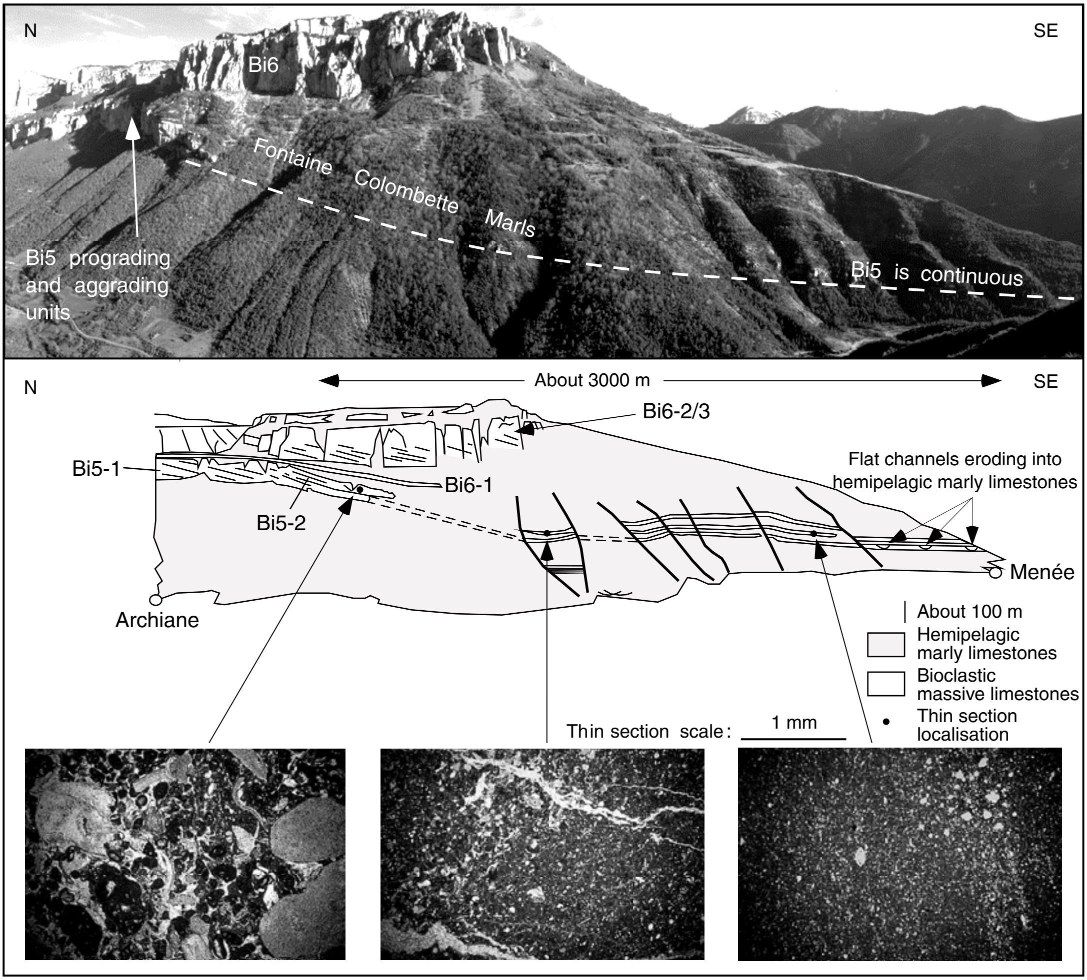

FIG. 5. — The eastern flank of the Archiane Valley (see Fig. 3 for location, area 1): composite photograph, interpretation and thin sections of the Bi5 Member, from proximal to distal part. Notice that the thin section in the middle has been sampled in a place showing the distal effects of storms. Adapted from Quesne (1996).

road allows these chaotic strata to be observed closely (Fig. 9A, B). Location of the outcrop is plotted on Fig. 3 (area 5).

Several types of deformation structures can be identified: 1) marly limestones and massive limestones broken up into tilted blocks (Fig. 9A, B). Within the blocks, the bedding is parallel and undeformed, indicating a translational slide in the sense of Spence & Tucker (1997). The unit is crossed locally by planar post-lithification faults with veneers of calcite; and 2) more distorted strata with imbricated blocks (Fig. 9C) and aircraft-wing shapes (Fig. 9D). These strata are evidence of rotational sliding of slightly indurated but not fully lithified material (Spence & Tucker 1997).

The dip direction of the tilted blocks (Fig. 9B) trends north-eastwards. As they moved along the slope, these blocks slipped and then reached the point of equilibrium in which they are currently observed. The dip directions measured thus indicate the “counter slope” facing north-eastwards

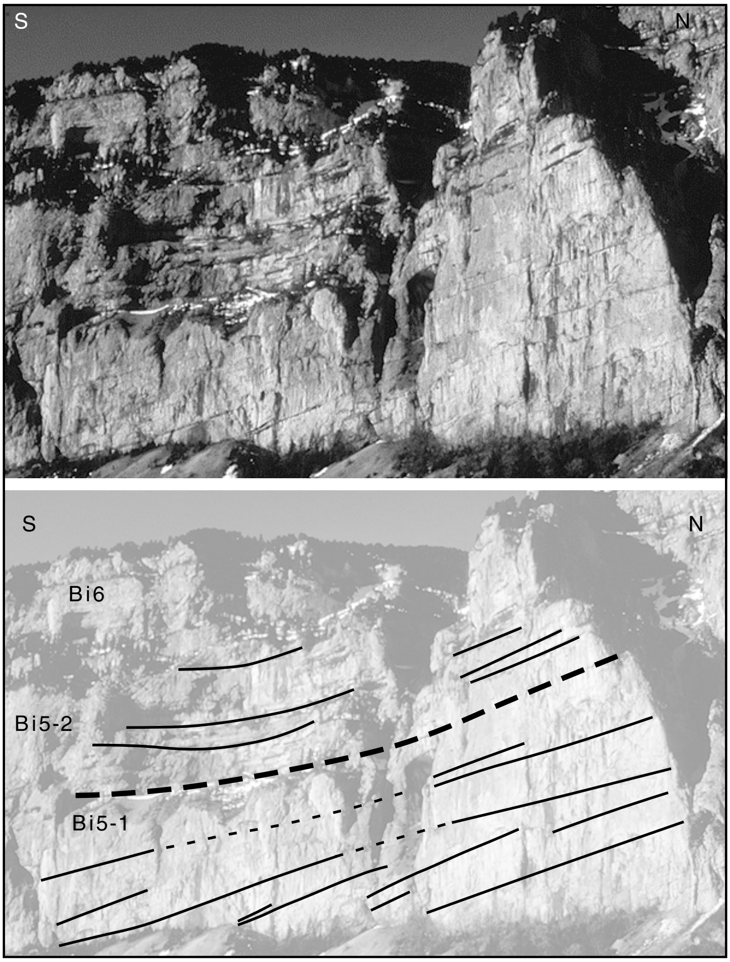

FIG. 6. — The northwestern flank of the Archiane Valley: Aubaise Combe (see Fig. 3 for location, area 2) showing Bi5 units. Bi5-1 progrades southwards whereas Bi5-2 has a more aggradational geometry.

here. The structures shaped like an aircraft wing (Fig. 9D) are characteristic of slumps and show that the palaeoslope in this location ran to the south-west, confirming the direction revealed by measurement of the tilted blocks.

EASTERN SIDE OF THE ARCHIANE VALLEY

Another outcrop just above the hydroelectric plant near the village of Menée on the eastern side of the Archiane Valley (area 6 on Fig. 3 for location) reveals the sudden occurrence of two well-sorted oobioclastic units ranging in thickness from some tens of cm to 2 m. These are arranged in grainstone beds within what are clearly hemipelagic clay-limestone deposits (Fig. 10). These clayey limestones with 10-50 cm thick beds have a wackestone texture (up to 60% of micrite). They contain sponge spicules, small thin bivalves, quartz grains, peloids and foraminifers (Lenticulinidae, Miliolidae) (Quesne 1996). Close examination of the two grainstone beds (Fig. 10) reveals the presence of many ooids and bioclasts: echinoids, bivalves, brachiopods and foraminifers (Miliolidae, Orbitolinidae). The beds have a very sharp lower erosional boundary and exhibit planar cross-bedding with a tangential

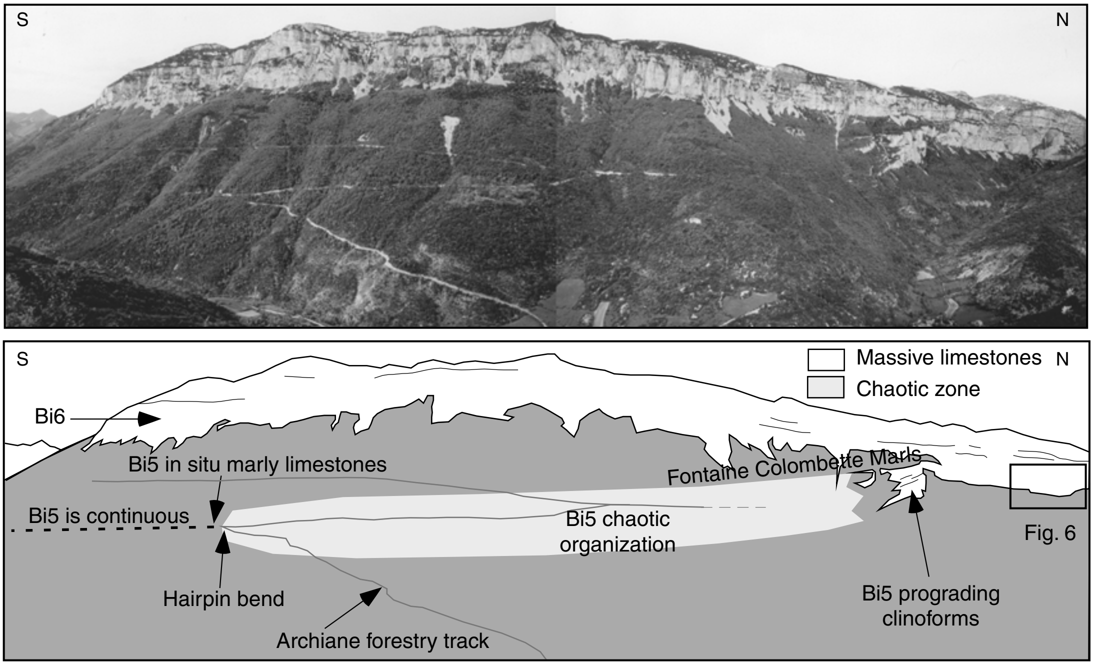

FIG. 7. — Composite photograph of the western flank of the Archiane Valley (see Fig. 3 for location, area 3).

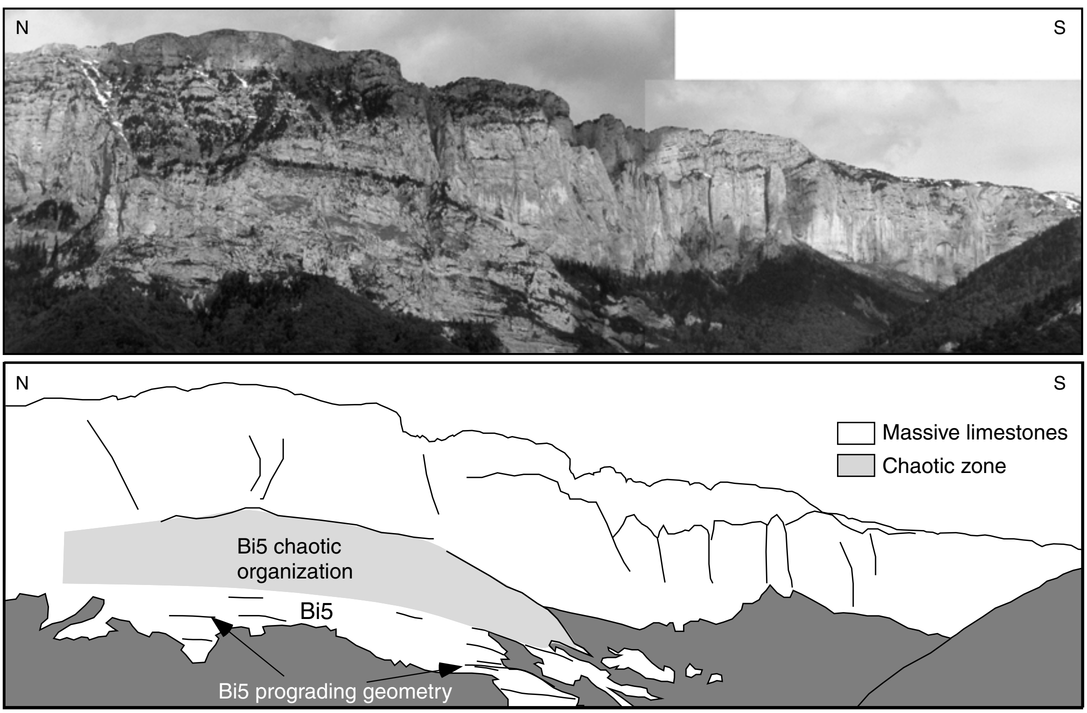

FIG. 8. — Composite photograph and interpretation of the western flank of the Glandasse Plateau (see Fig. 3 for location, area 4).

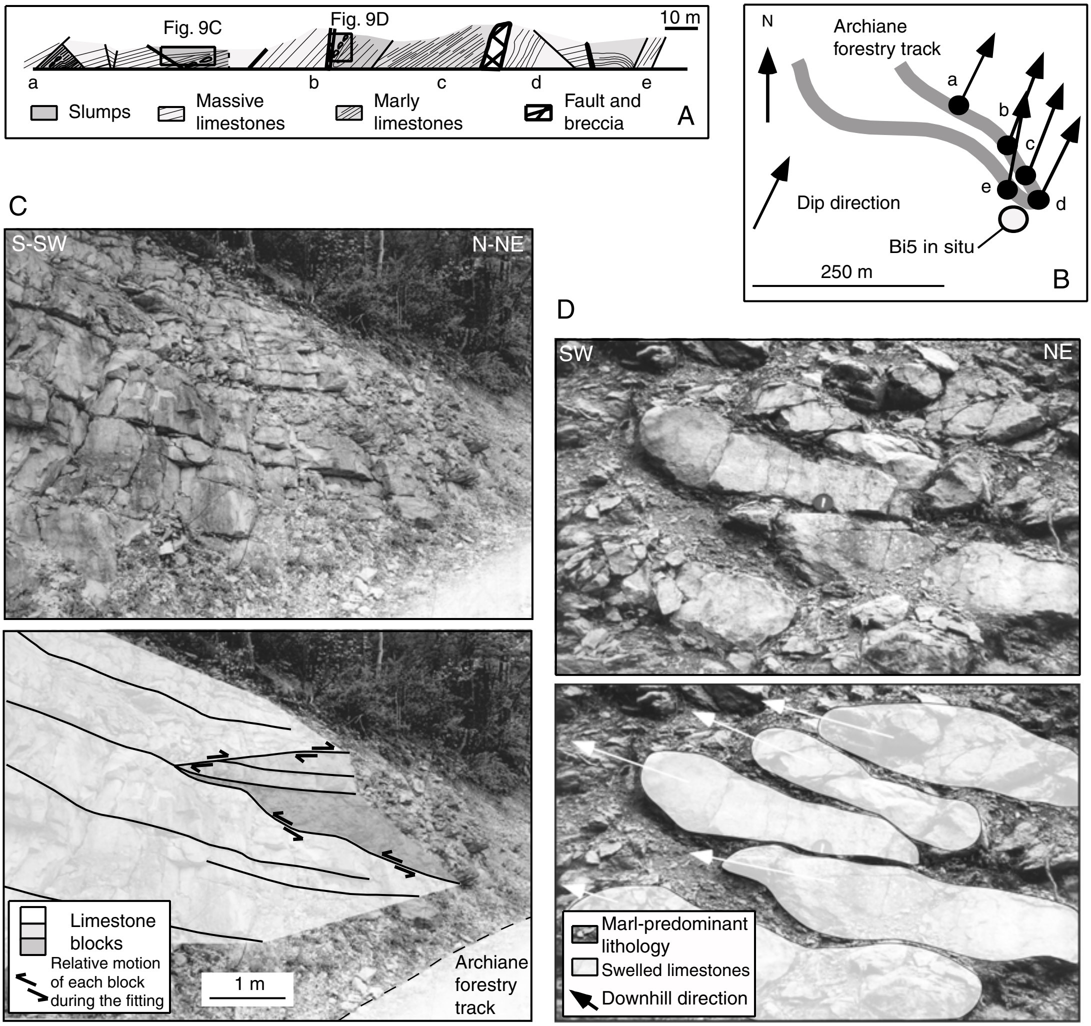

FIG. 9. — Detailed observations of the disturbed zone on the western flank of the Archiane Valley (see Fig. 3 for location, area 5); **A**, disturbed zone structures; **B**, dip directions of the tilted blocks; **C**, imbricated limestone blocks; **D**, aircraft-wing-shaped slump features (cover lens for scale).

basal contact. Cross-beds are oriented in diverging directions (N070 and N330; Fig. 10). Graded bedding is not observed.

DISCUSSION

Observations and measurements of stratal geometry indicate a major disturbance during carbonate deposition of Bi5 in the platform-margin region. It appears that the disturbed zone located on the Glandasse Plateau (geometry, block and slump orientation measurements; Figs 7-9) define an area of post-sedimentary slippage of incompletely lithified material downslope. It seems therefore that there was a scar zone on the Glandasse Plateau originating in the Archiane Valley, which explains the differences in the panoramas between the two sides of the valley. Judging from the various structures observed in

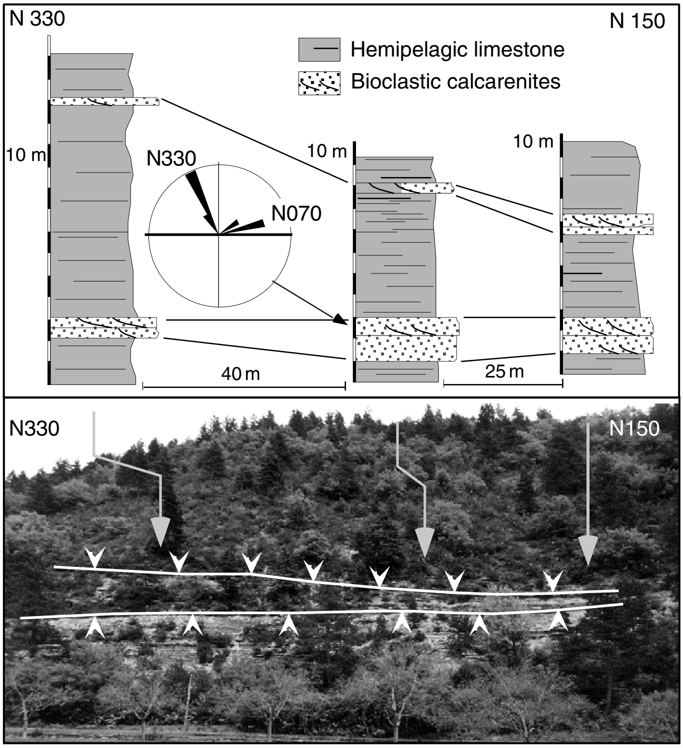

FIG. 10. — Menée logs of the southern part of the eastern flank of the Archiane Valley showing two coarse bioclastic limestone units (white arrows) within the hemipelagic part of the Bi5 Member (see Fig. 3 for location, area 6).

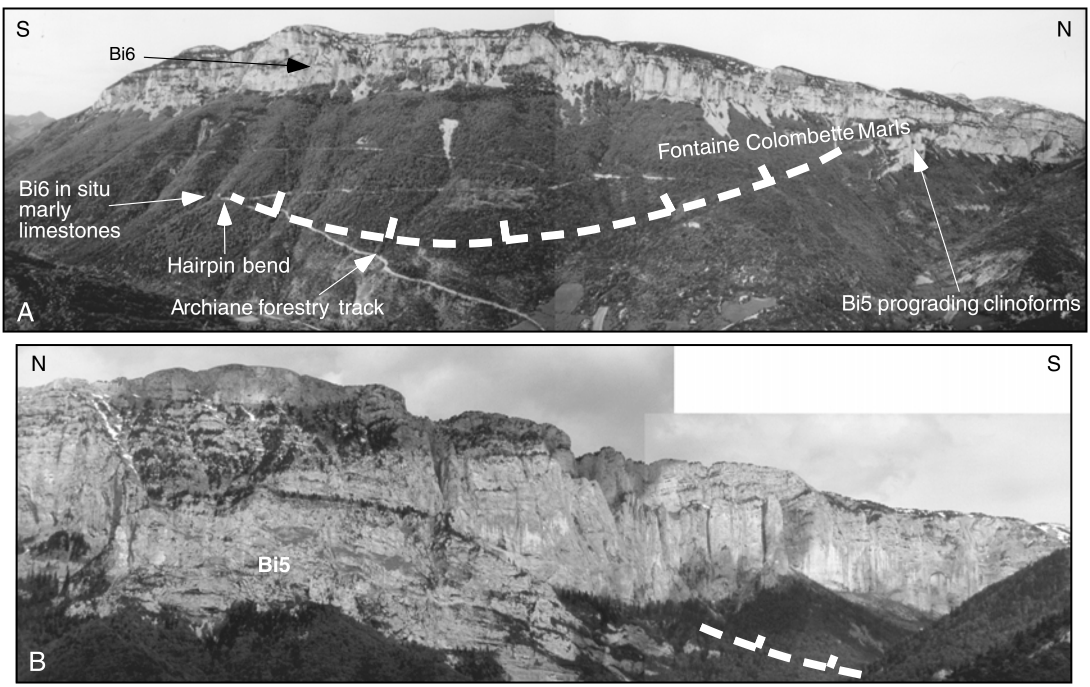

FIG. 11. — Location of the presumed scar zone on each flank of the Glandasse Plateau; **A**, eastern flank of the plateau; **B**, western flank of the plateau.

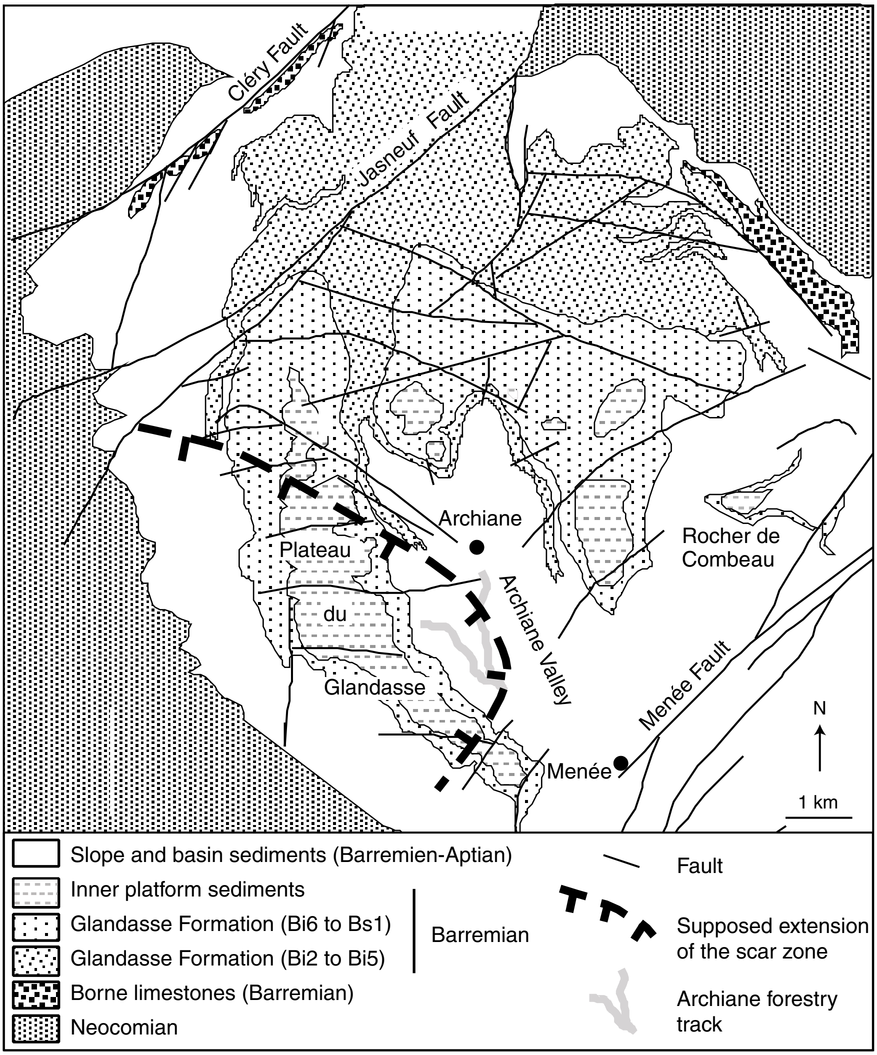

FIG. 12. — Plan view of the presumed extension surface of the disturbed zone over the Glandasse Plateau.

the chaotic zone, the material seems to have slipped in a south-westerly direction (see Fig. 9B, D). Detailed study of the disrupted zone and its surrounding area shows it to be a slide, affecting what can be roughly estimated as 3 km^3 of material from the Glandasse Plateau (Figs 11; 12). The motion of such a mass of sediment downslope must have generated a large submarine wave. The effects of this should be observable in the immediate vicinity of the event, especially as the water depth cannot have exceeded 200 m judging from the storm influences identified in the sedimentary structures of the hemipelagic part of the Bi5 Member.

The presence of the two grainstone beds with shallow-water elements on the western side of the Archiane Valley (Fig. 10) in a distal hemipelagic context is very interesting. There is no unequivocal sedimentologic indication (such as bundles or herring-bone cross stratifications) that these beds could be indicative of sea-level fluctuations. These two levels are located 1500 to 2000 m farther south (towards the palaeobasin) from the sediments exhibiting the distal effects of storms, under the form of laminated beds (Quesne 1996, 1998). Location of these storm beds can be seen on Figure 5 (location of the thin section in the middle). Such sea-level variations would have then led the platform top to major meteoric alterations, resulting in major unconformities. Nevertheless no evidence for major subaerial exposures within Bi5 on the top of the platform has been seen nor reported hitherto. Fouke *et al.* (1995) only state evidence of subaerial exposure on many bedding planes on the top of the platform within the upper part of Bi5, but no major one. In addition, no evidence of an acceleration of downward migration of these platform facies can be observed on the slope. On the contrary, these deposits were settled down during a deepening phase (Hunt & Tucker 1993; Everts 1994; Quesne 1996, 1998). Consequently, it is rather unlikely that these bioclastic levels could have been deposited under a tidal influence.

It seems more appropriated that the cross-beds diverging directions suggest they could be bioclastic deposits settled down under the influence of tractive currents, although somewhat less extensive than the bioclastic lobes described by Ferry (1976, 1978) in the region. Coarse bioclastic sediments were mobilised from the upper slope domain and transported downslope through shallow erosion channels. Such channelling phenomena disrupting calm sedimentation of the slope seem to have occurred rather frequently during the early Barremian (Mayolle 1989; Jacquin *et al.* 1991; Everts 1994; Bièvre 1999).

The palaeocurrent directions measured in these bioclastic strata (Fig. 10) reveal a general north-eastward and northward orientation, towards the Barremian platform. This cannot be the result of gravitational sliding of proximal bioclastic grainstone material. It is postulated that the submarine wave created by the slide of material on what is now the western side of the Archiane Valley propagated centrifugally from the slide zone in all directions and travelled up the surrounding slopes. Though, even if no indications of dating have so far been found to link these two beds with the slide stratigraphically, it could be probable that these beds are the result of sediment sliding down the slope. More precisely, the two bioclastic bodies and the slide may have the same timing, but the internal rearrangement of the grainstone lobes in dunes directed towards the platform can be the result of the action of the submarine wave engendered by the slide. These different observations imply that the sliding phenomenon occurred in two stages, since there are two bioclastic bodies (Fig. 10). It is also likely that the sliding was sudden enough to generate a submarine wave.

A number of factors may have triggered the slide such as sediment overload, tectonic activity, sea-level fluctuations, etc. In this work are exposed two of them, sediment loading and tectonic activity, more or less linked and which are supposed to be the more able for originating the slide.

The first possible cause, sediment loading, could have been initiated by gravity (discharge and/or cascading), as a result of high sediment accumulation that generated sediment instability on the slope (Spence & Tucker 1997). The rate of sedimentation in the region during Barremian times was very high and allowed the accumulation of several 100 m of carbonate sediment (Arnaud 1981: fig. 13).

Another cause of initiation of this unstable zone could be tectonism, compounding high sedimentation rates. The nearby Menée and Jasneuf Faults were very probably active during Barremian times (Joseph *et al.* 1989). Hunt & Tucker (1993) referred to fault movements responsible, in their view, for tilting of the slope during deposition of Bi5-2. Likewise, Quesne & Ferry (1997) proposed the occurrence of local extensional tectonic activity along a NS axis creating a roll-over on the eastern side of the Cirque d'Archiane during this period. Finally, at the Rocher de Combeau (see Fig. 3 for location), within the upper part of Bi5, tectonic activity is also reported under the form of slightly plicated beds overlain by a downlap surface defining a geometrical unconformity (Bièvre 1999). This

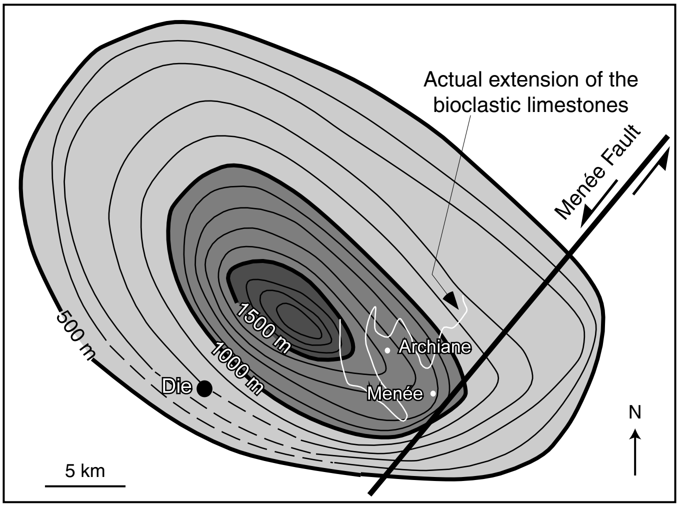

FIG. 13. — Isopach map for the lower Barremian to the base of the upper Barremian (Bi1 to Bs1 in the sense of Arnaud 1981). Notice the NW-SE basin-like structure in which more than 1500 m of sediment accumulated in the lower Barremian. After Arnaud 1981.

tectonic activity allows a stratigraphic correlation between all the events and unconformities depicted above and the slide phenomenon that occured in the Archiane Valley. Working on such high frequency events does not allow biostratigraphy dating methods to be applied. It is then postulated, with regard to the tectonic activity, that the slide and the two bioclastic bodies are stratigraphically equivalent.

Such sliding phenomena have also been reported by Bosellini (2001) and Rusciadelli *et al.* (2003) on the Cretaceous Apulia platform (Central Apennines, Italy). In their view, the leading factor for generating collapses from the platform margin cannot simply be explained by sea-level fluctuations. Tectonic activity is thought to be the predominant cause for the dismantling of this margin, resulting in the accumulation of basinal megabreccia sequences originating from these tectonic-triggered gravitational collapses.

The occurrence of a slide zone in the study area is also consistent with the overall scheme proposed by Arnaud (1979), Ferry & Flandrin (1979) (Fig. 14) and then Arnaud (1981: fig. 13) for this region. The direction of slide (SW) is towards the basin centre.

This sediment instability persisted over time and did not evolve into slope and debris flows as at Boulc and Crest (Ferry 1976, 1978; Ferry & Flandrin 1979). It therefore provides a genetic link between the scours and the large slumps found on the slope and within the Vocontian Basin. This instability may also be connected to a downslope bioclastic deposit reported on the slump of the Crest area (Fig. 14).

CONCLUSIONS

Observations on several scales of the Barremian Bi5 Member in the Archiane Valley and on the Glandasse Plateau of the Vercors suggest a new interpretation of early Barremian sedimentation at the southern platform margin. The observed difference in depositional geometry between the eastern side of the Archiane Valley (Bi5 extends unbroken from the head of the cirque at least as far as the village of Menée) and the eastern and western sides of the Glandasse Plateau (chaotic blocks, stratigraphic gaps) can be explained by the presence of a zone where sediment masses on either side of the Glandasse Plateau were suddenly mobilised.

Recurrent shallow-water bioclastic deposits within Barremian hemipelagic marls, as observed at Menée, large channels (Mayolle 1989; Jacquin

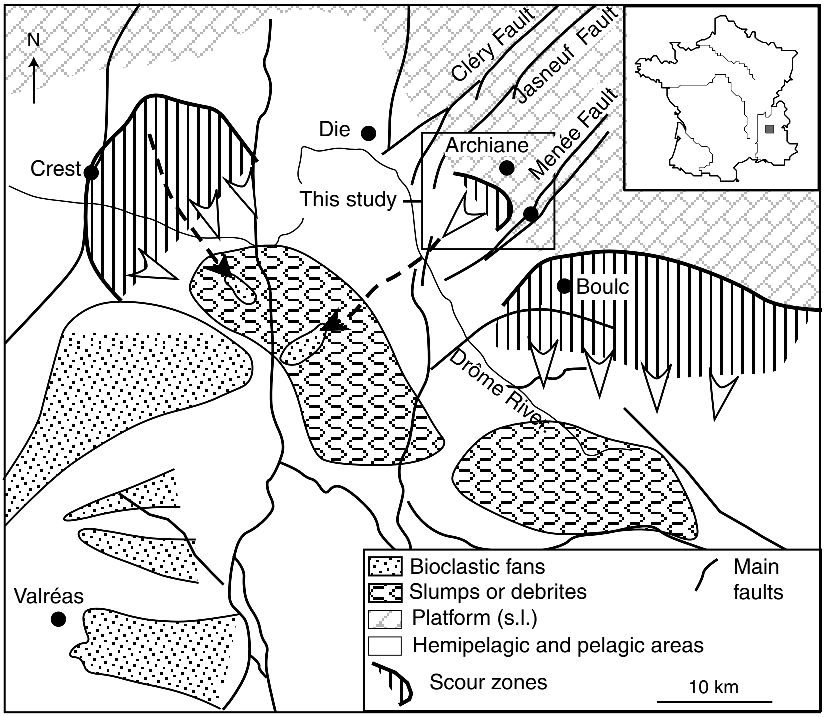

FIG. 14. — Synthetic palaeogeographic map for the location and extension of the recognized scour zones and their effects in the southern Vercors and the Vocontian Basin (modified from Ferry 1976; Ferry & Flandrin 1977; Arnaud 1981). Figure provided by M. Olivier Parize, from the ENS Mines de Paris.

et al. 1991), the occurrence of slide zones (Arnaud 1979; Ferry & Flandrin 1979) and synsedimentary tectonism (Joseph *et al.* 1989; Hunt & Tucker 1993; Quesne & Ferry 1997) all point to the disrupted nature of sedimentation in the study region at the time.

Areas of this type, which are clearly related to fault activity as occurred at Boulc and Crest (Ferry 1976, 1978; Ferry & Flandrin 1979; Arnaud 1981), are morphologically significant in that they form sand traps before basinward transfer, as can be observed on present-day passive margins such as those of Brazil or Angola.

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