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EXAMPLE OF HOLOCENE ALPINE TORRENT RESPONSE TO ENVIRONMENTAL CHANGE: CONTRIBUTION TO ASSESSMENT OF FORCING FACTORS

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ABSTRACT

Although the major features of Holocene torrent evolution in the Southern Alps have been described during the last twenty years, it is now admitted that both the intrinsic characters of each watershed and the terms of their anthropisation strongly influence the geomorphological response to environmental change. Located in the middle Ubaye valley, the Abéous is to our knowledge the only torrent in the French Alps which has provided sufficient data for it to be possible to reconstruct its history throughout all the Holocene. The authors put forth the recurrence of debris flow facies in the stratigraphy of this torrent's alluvial fan, including during the Atlantic, and note an increase of its torrential characteristics as from the Bronze Age. They also focus on the conditions prevailing at the time of sedimentation of the thick silt levels which are part of the «main Holocene fill». In the light of this long evolution, this article proposes an analysis of the contemporary spontaneous reforestation and active channel narrowing trend.

Key-words: Southern Alps, Ubaye valley, Holocene torrentiality, Alluvial fan, Stratigraphy, Contemporary torrentiality, Little Ice Age, Environmental change, Spontaneous reforestation, Active channel narrowing.

RÉSUMÉ

UN EXEMPLE DE RÉPONSE D'UN TORRENT ALPIN AUX CHANGEMENTS ENVIRONNEMENTAUX À L'HOLOCÈNE : CONTRIBUTION À L'ANALYSE DES FACTEURS DE FORÇAGE

Si les grandes lignes de l'évolution de la torrentialité Holocène des Alpes du Sud sont désormais connues, on sait que les caractéristiques intrinsèques de chaque bassin versant et les modalités de leur anthropisation influent sur la réponse géomorphologique fournie aux changements environnementaux. Situé dans la moyenne vallée de l'Ubaye, l'Abéous est à notre connaissance le seul torrent des Alpes françaises à avoir livré suffisamment d'informations pour que l'on puisse en reconstituer l'histoire tout au long de l'Holocène. Les auteurs mettent en évidence le caractère récurrent des faciès torrentiels dans la stratigraphie du cône de déjection de ce torrent, y compris à l'Atlantique et constatent une accentuation du caractère torrentiel depuis l'Age du Bronze. Ils s'interrogent par ailleurs sur les conditions de formations des épais niveaux limoneux qui composent pour partie le «remplissage holocène principal». A la lumière de cette longue évolution, l'article propose une analyse de la dynamique contemporaine de reboisement spontané et de rétraction de la bande active du torrent.

Mots-clés : Alpes du sud, Vallée de l'Ubaye, torrentialité Holocène, cône de déjection, stratigraphie, torrentialité contemporaine, Petit Age Glaciaire, changements environnementaux, reboisement spontané, rétraction de la bande active.

1 - INTRODUCTION

Alluvial fan stratigraphies testify to a complex hydro-geomorphological evolution of torrents in the Southern Alps during the Holocene. Torrent response to environmental change is illustrated by the variety of facies provided by these mountain streams. Multidisciplinary research led over the last twenty years by Alpine Quaternarists has defined the major features of evolution during the Holocene. Invariable patterns have been established by M. Jorda (1985), who underscored the ubiquity of a succession of sedimentation phases separated by incision periods. Moreover, he established a distinction between early Holocene torrentiality, characterized by a depositional phase which lasted several thousands of years he called «main Holocene fill» («remblaiement holocène principal»), with exclusive climatic controls, and a Subboreal/Subatlantic torrentiality with combined climatic and anthropic causes (Jorda, 1985; Jorda and Provansal, 1996; Ballandras, 1998). Without denying

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these regional mechanisms, recent studies show that on a more precise scale, correlations exist between hydro-geomorphological responses provided by each torrent, and the intrinsic characteristics of their watersheds (Rosique, 1993; Liébault *et al.*, 2002) to which must be added anthropic impacts of various intensity (Flez and Lahousse, 2003).

Located in the middle Ubaye valley (fig. 1), the Abéous torrent has already been a part of several regional scale stratigraphical studies (Jorda, 1985; Ballandras and Nevière, 1991; Ballandras, 1997). These have provided some stratigraphical data and radiocarbon dates which were used to complete a regional evolution pattern, without being sufficient to give an exhaustive view of this torrent's Holocene evolution. After the construction of two check-dams at the apex of the alluvial fan at the beginning of the 1990s, a several meter channel incision revealed some deep sedimentation levels that were not accessible at the time of the earlier studies. These levels provided us with 3 radiocarbon dates (one of which is the oldest at this time for a torrential facies in the Ubaye valley: 8720 ± 40 BP; GX-27037 AMS), but most of all made it possible to work on a complete stratigraphical series of the inset terraces corresponding to the different Holocene sedimentation periods.

Thus, the Abéous is to our knowledge the only torrent in the French Alps to have provided sufficient data for it to be possible to reconstruct the main features of its Holocene evolution. This kind of approach has already been attempted by N. Surian (1998) on a piedmont gravel-bed river of the Venetian Alps, but remained to be done for an intra-mountainous torrent of the Southern Alps. We noticed some differences between the facies of late Holocene *i.e.* when morphogenesis was submitted to combined natural and anthropic controls and early Holocene *i.e.* the period during which, in spite of some isolated evidence of anthropisation in the Durance basin pollen diagrams, climate control is considered exclusive (Jorda, 1985). Indeed, the stratigraphies of the «main Holocene fill» include some recurrent sand and silt levels with alluvial patterns. On the other hand, the late Holocene deposits (*post* 4700 BP), corresponding to a period when anthropic forest clearings in the Ubaye valley are ascertained by palynologists (de Beaulieu, 1977; Wegmüller, 1977), are nearly exclusively composed of debris flow deposits. The evolution of the sedimentary dynamic in the Abéous during the Holocene seems to lead to an increase of torrential characteristics during the Subboreal and Subatlantic. The correlation between these changes recorded in the sequences and the increase of anthropic pressure in torrent watersheds of the Ubaye valley since the Bronze Age seems to point to a complex hydro-geomorphological response, whose crises are furthermore chronologically linked to well-known climate changes (Jorda, 1985).

By what means did the abuse of forest exploitation, leading to its near complete destruction in Modern Times, long considered as the unique cause of torrentiality (Surell, 1841), aggravate torrential activity in the Little Ice Age context? The 20th century seems to correspond in several areas of the Southern Alps to a period of torrent appeasement and sediment delivery reduction (Liébault and Piégay, 2002; Lahousse and others, 2002; Flez and Lahousse, 2003). Land use change in the Abéous watershed enabled a spontaneous reforestation of the slopes leading to a strong reduction of sediment delivery. Nevertheless, in spite of a 65 % active channel narrowing since 1948, the torrent carries on regularly producing violent debris flows (Flez and Lahousse, 2003).

This paper aims to analyze the geomorphological changes of one torrent over a long period. Firstly, in order to discriminate the importance of natural and anthropic watershed controls in the sedimentary responses observed in a context of environmental changes that are ascertained on a regional scale. Secondly, the Abéous appears to be a significant example of a mountain torrent whose geomorphologic functioning combines features observed on piedmont torrents *i.e.* active channel and solid transport adjustment to basin changes, afforestation in particular, with the capacity, permanent throughout the Holocene, of producing several tens of thousand cubic meters solid discharge in one flood, as observed on steep, mountain debris flow torrents (Lahousse and others, 2002). Therefore, the authors suggest that although signs of con-

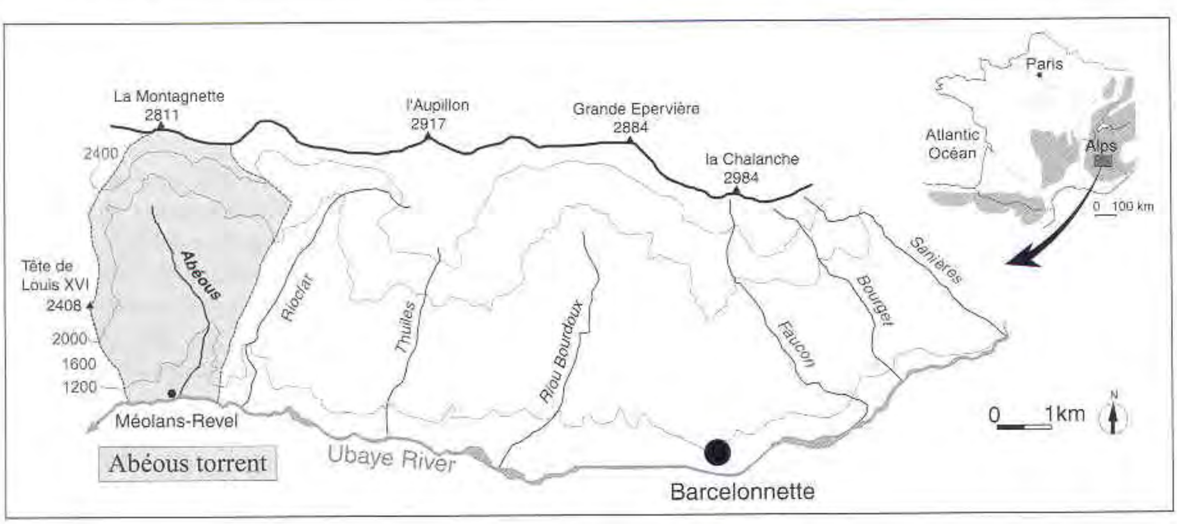


Fig. 1: The middle Ubaye valley and the Abéous watershed.
Fig. 1 : La moyenne vallée de l'Ubaye et le bassin versant de l'Abéous.

temporary appeasement similar to those measured in the Southern French Prealps (Liébault, 2003) are ascertained, consequences in terms of solid transport and furthermore, of natural hazard, are altogether different.

2 - THE STUDY SITE

With a 1440 ha watershed, the Abéous torrent is with the Riou Bourdoux (2200 ha), among the major torrential tributaries of the Ubaye river. It is located on the south facing slope of the valley, about 15 km downstream of Barcelonnette (fig. 1). Climate is characterized by Mediterranean influence with two rainfall maximums in spring and autumn. The lower part of the catchment area is cut out in Callovian-Oxfordian black marls, but abundant glacial deposits limit the marl outcrops which are eroded into badlands and very common in the rest of the Ubaye valley. Above a contact line that varies from 1400 to 1500 m in altitude, the allochtonous series of flysch and grey limestone of the Autapie nappe are cut in abrupt slopes. The surface of the alluvial fan is relatively small compared to the size of the catchment area. It is quite a complex system of fill-cut terraces comprising three main levels. The Abéous flows following a north-south trend, from 2811 m at the Montagnette to 1030 m at the confluence with the Ubaye River. The total gradient in altitude is around 1800 m for a 5.5 km course, giving an average slope angle of 32 %. The slope gradient reaches 66 % in the upper part of the watershed, 20 % in the channel and lowers to 10 % on the alluvial fan. Active channel width has varied considerably during the study period, measures on year 2000 aerial photographs give a mean channel width of about 20 m. Bedload grain-size ranges from silt to boulders after debris flow floods like the one observed in July 2003.

3 - METHODS

3.1 - CHRONOSTRATIGRAPHIC ANALYSIS

A section in the upper part of the alluvial fan, exhumed by channel incision, was cleared and deepened by a bulldozer before being drawn in detail and sampled. Some granulometric analyses were done, and some polarizing microscope observations were made on samples of the silt levels. Two samples of charcoal, one of wood and a fossil tree trunk provided four radiocarbon dates (samples dated by Geochron Laboratories, USA).

3.2 - TOPOGRAPHY

The topographical data collected with a Leica® TC 307S tacheometric station give a precise geometrical vision of the various terraces that compose the alluvial fan. A series of 3 cross-profiles and 2 long-profiles measured in May 2001 is complementary to the stratigraphical approach and makes it possible to draw a sketch map of the terraces (fig. 2).

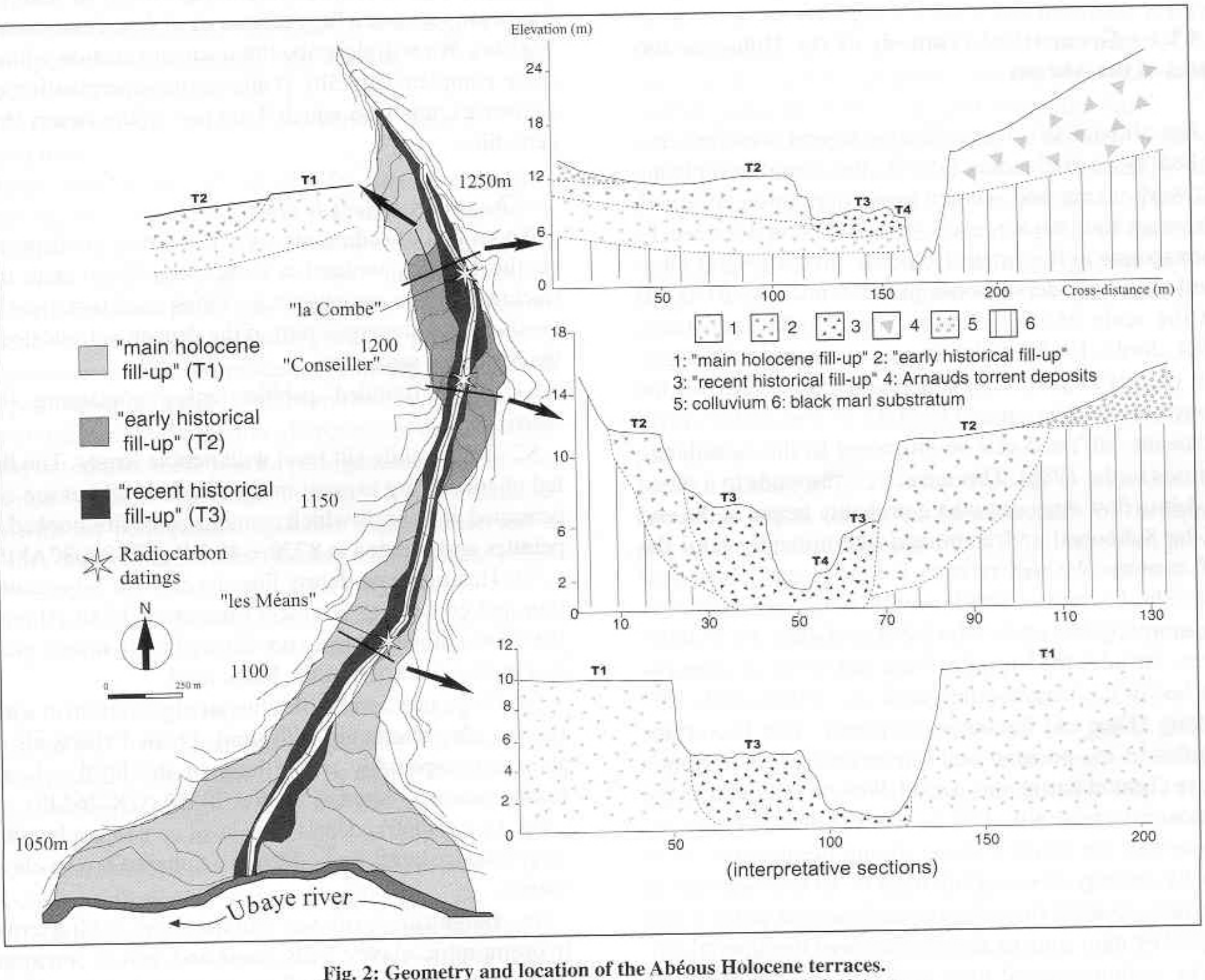


Fig. 2: Geometry and location of the Abéous Holocene terraces.
Fig. 2 : Géométrie et localisation des terrasses holocènes de l'Abéous.

3.3 - DIACHRONIC ANALYSIS OF AERIAL PHOTOGRAPHS

Contemporary evolution of the torrent's active channel (low-flow channels and unvegetated gravel bars) was measured on aerial photos from 1948 to 2000 (scales range from 1: 17000 to 1: 25000). After having geometrically straightened the photographs, the margin of error between profiles measured on recent photos and field measures is satisfactory, *i.e.* between 2 and 5 m. We measured active channel width every 100 meters; on the entire reach, by using 20 cross-sections, we calculated a narrowing index by considering index 100 to be the mean active channel width in 1948 and the results were expressed in a box-plot diagram (fig. 6b). We also produced a diachronic series of large scale sketch-maps of a representative area (fig. 6a). Narrowing stages can be analysed and we can measure the consequences of spasmodic bedload evacuation during debris flows both on the channel morphology and on the riparian vegetation.

Spontaneous reforestation of the slopes was measured by comparing maps made by the Forest State service at the end of the 19^{th} century with aerial photographs of 1948 and 2000.

4 - RESULTS

4.1 - THE TORRENTIALITY OF THE ABÉOUS FROM THE BOREAL (8800 BP) TO THE END OF THE 20^{TH} CENTURY

4.1.1 - Geometrical synthesis of the Holocene terraces of the Abéous

The alluvial fan of the Abéous torrent was first described by S. Ballandras (1997). We intend completing his work taking into account new information collected. There are four terrace levels (fig. 2). The first terrace T1 corresponds to the "main Holocene fill", a several thousand year long depositional phase defined by M. Jorda on the scale of the Southern Alps (Jorda and others, 1984; Jorda, 1985), which begins at the end of Lateglacial (recent Dryas), although this is not asserted in the Ubaye valley. The second level T2 is inset in the "main Holocene fill", and can be attributed to the Subatlantic period (Jorda, 1985). This terrace corresponds to a series of debris flow episodes which probably began at the end of the Subboreal and continued intermittently until the 10^{th} century. We will refer to it as the «early historical fill». The T3 terrace, which is inset in T2, corresponds to the morphogenic crisis which began during the Middle-Ages, includes the Little Ice Age, and which consequences last in the Ubaye valley until the middle of the 20^{th} century (Flez and Lahousse, in press). The T3 surface testifies to the position and importance of the torrent's active channel during this period. We will refer to it as the «recent historical fill». The T4 terrace corresponds to the position of the active channel during the last quarter of the 20^{th} century; it is slightly inset in T3 and has been in a terrace position since the channel incision of the 1990^s caused by dam construction upstream of the alluvial fan. Three sections located from upstream to downstream of the alluvial fan make it possible to proceed with a chronostratigraphic analysis of these terraces, and to reconstitute the complete Holocene stratigraphy of the Abéous by combining the new information with the existing works.

4.1.2 - The Combe section

This section, located on the right bank of the torrent, is delimited upstream by a black marl bedrock outcrop and downstream by the confluence of the Abéous and one of its left bank tributaries: the Arnauds torrent, at 1190 m in altitude (fig. 2).

At this place, several terrace levels can be identified in the topography (fig. 2). On the right bank, the T1 terrace known as «de la ferme des Graves», which corresponds to the «main Holocene fill» is now 10 m above the torrent's bed and connected to the slope by a colluvium glacis. The T3 terrace, attributed to the «recent Holocene fill» is inset in T1 without the «early historical fill» being represented in this area. T3 dominates the channel by about 6 m. Aerial photography shows that the torrent still occupied a considerable part of T3's surface in the 1960's (Flez and Lahousse, in press). The T4 terrace, dominated by 1.5 m by T3 testifies to the position of the active channel between the middle of the 1970's and the channel incision which took place in the 1990's. On the left bank, the vast terrace which dominates the channel by 12 m corresponds to the «main Holocene fill» of the Arnauds torrent and has been previously described by M. Jorda (1987). On the section, which is about 50 m long, two 5 m wide sections where measured in detail and sampled (fig. 3a). We will describe the upstream section which is more complete (fig. 3b). It shows the superposition of 9 sequences, amongst which 7 are part of the «main Holocene fill».

- The «main Holocene fill»:

About 6 m of sediments are visible, they are deposited on the bedrock without it being possible to state their thickness as the autochthonous black marl is not visible. Furthermore, the upper part of the deposit is truncated by the historical sediments.

S1: Well rounded pebble lenses containing little matrix.

S2: Beige sandy silt level with pebble lenses. The floated charcoals are present in the whole level but are concentrated at its basis which contains some fire-cooked red pebbles and is dated at 8720 ± 40 BP (GX-27037AMS).

S3: Heterometric debris flow level, with no organisation and containing boulders measuring 15 to 20 cm at the most, embedded in a very clayey brown matrix provided by the alteration of the black marl.

S4: Beige silty level with a fluvial organisation in which settling clay alternates with sand. Floated charcoals are abundant, especially at the base of the level, where a fossil trunk was dated at 7630 ± 70 BP (GX-26249)

S5: Heterometric debris flow level containing boulders up to a metre large, embedded in an altered brown clayey matrix.

S6 : Beige silty level, very similar to S4, with alternate hydromorphic clayey beds, sand and gravel containing shells but no matrix, as well as two floated charcoal beds,

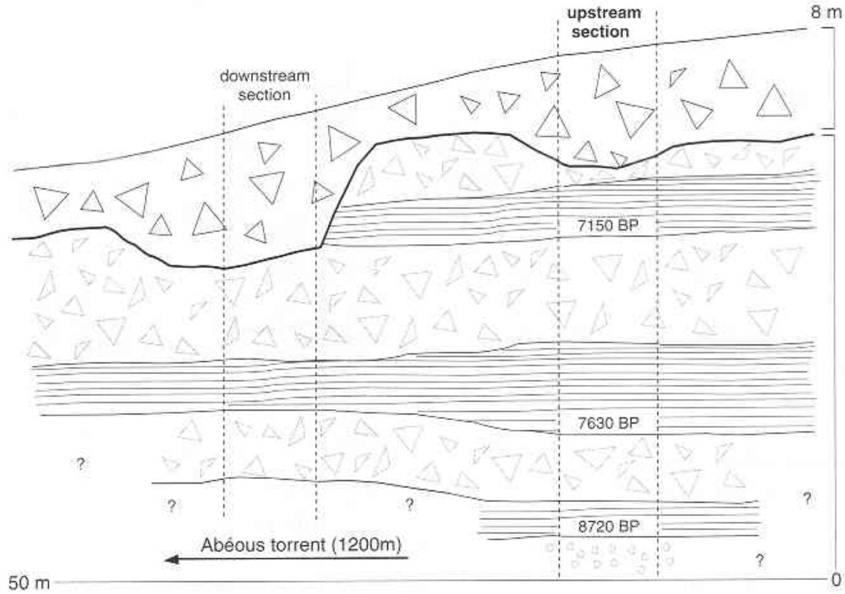


Fig. 3a: The Combe section: general view.
Fig. 3a : La coupe de la Combe : vue d'ensemble.

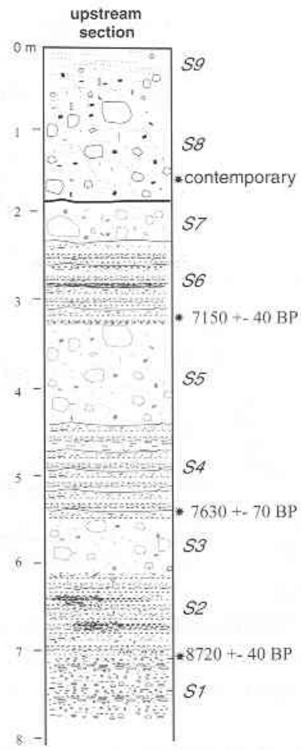


Fig. 3b: The Combe section: detail.
Fig. 3b : La coupe de la Combe : détail.

one of which, located at the base of the level is dated at 7150 ± 40 BP (GX-27036-AMS). This date confirms the work of S. Ballandras who studied this section about 50 m upstream and dated this silty level at 7149 ± 69 BP (ARC 1257) (Ballandras, 1997).

S7: Heterometric debris flow deposit with a brown altered matrix.

Observation of the S2, S4 and S6 silty levels with a polarizing microscope indicates that they correspond to settling silt deposed in a fluvial environment. Interstitial gaps in the sand levels have not been filled, indicating that there has been no evolution after the sedimentation. Absence of visible micro-bedding and the predominance of hydromorphic facies indicate a reducing environment and poor water drainage. Moreover, the absence of leaching, of different horizons and of brown soil development, seems to indicate there was no pedogenesis. This conclusion must be used with caution because it is in contradiction with the pedogenesis episodes usually observed in the silty levels of the «main Holocene fill» (Jorda, 1993). Furthermore, the upper part of the silty levels, liable to contain evidence of pedogenesis, was probably gullied during the debris-flow episodes which followed.

The "recent historical fill":

It is about 2 m thick, and is gullied onto the "main Holocene fill" from which it can be easily differentiated by its black matrix, provided by non altered black marls.

S8: Heterometric debris flow deposit with boulders up to 50 cm, embedded in a black matrix. Wood sample provided a "contemporary" date (GX-27035).

S9: Roughly stratified level with gravel and sand lenses, in a black matrix corresponding to the end of a debris flow.

4.1.3 - The Conseiller section

This 5 m high section is located in the middle part of the alluvial fan, on the left bank of the torrent at 1165 m altitude (fig. 2). It corresponds to a terrace made of the «early historical fill» alluvium, and has been previously described and dated by M. Jorda (1985) (fig. 4a).

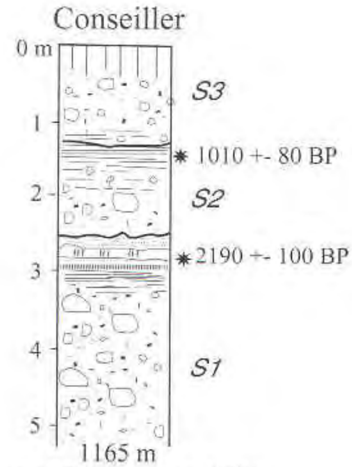
It is composed of three sequences of debris flow deposits with non altered black marl matrix, separated by discordant gullying. The two lower sequences are topped by thin hydromorphic silt levels containing floated charcoals dated respectively from the end of Iron Age thus 2190 ± 100 BP (GIF 5535) and from the 10^{th} century thus 1010 ± 80 BP (GIF 5536).

4.1.4 - The Méans section

This 8 m high section is located in the downstream part of the alluvial fan, on the left bank of the torrent, at 1082 m altitude (fig. 2). It corresponds to a vast terrace known as «de la ferme des Méans» made of the upper part of the «main Holocene fill» (T1). It has been previously described several times (Ballandras and Nevière, 1991; Ballandras, 1997), we will therefore only provide a succinct description. It is composed of three sequences separated by discordances (fig. 4b):

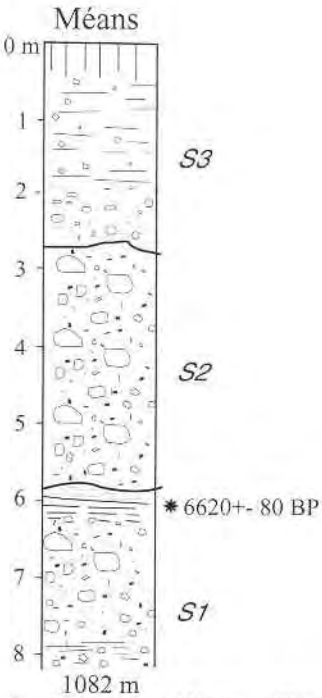
S1 : Sequence containing at its base a heterometric debris flow level with an abundant silt and gravel matrix, topped by some well sorted sand lenses and silt containing charcoal dated from 6620 ± 80 BP (Ly 4651) (Ballandras et Nevière, 1991). It is possible either that this level is the equivalent of the one dated from 7150 BP in the Combe section, or that they are separated by a debris flow episode which is truncated in the Combe section.

S2: Thick heterometric debris flow level with little sand and silt matrix.



(modified from Jorda, 1985)

Fig. 4a: The Conseiller section.
Fig. 4a : La coupe de Conseiller.



(modified from Ballandras and Nevière, 1991)

Fig. 4b: The Méans section.
Fig. 4b : La coupe des Méans.

S3: Thin fluvial facies with well-rounded pebbles in a silt and sand matrix, topped by a grey silt level with a little gravel attributed to colluvium.

4.2 - CONTEMPORARY AFFORESTATION WITHIN THE ABÉOUS CATCHMENT

4.2.1 - Spontaneous slope reforestation

At the end of the 19th century, the Abéous watershed was almost completely deforested, not to the point of the Riou Bourdoux (Delsigne and others, 2001), but more than the Ubaye valley average (Piégay and Salvador, 1997). Excluded from the Ubaye reforestation perimeter for local political reasons (Flez and Lahousse, 2003), the watershed has benefited from spontaneous reforestation during the 20th century (fig. 5). Whereas in 1890 the forest surface did not exceed 35 ha (2.5 % of watershed), it reached 150 ha (10 % of watershed) in 1948 and some 350 ha (25 % of watershed) in 2000, not including the reforestation undertaken by the state services since 1994. Over a little more than a century, the forest surface in the Abéous watershed has been spontaneously multiplied tenfold, benefiting from land use change and «recent warming» climate context (Jorda, 1985), and has equalled the mean forest cover of the Ubaye valley where a major reforestation policy has been conducted since the 1860's.

4.2.2 - Active channel narrowing

At the same time as the land use changes observed on the slopes, we record a considerable active channel narrowing (fig. 6a). Testified as from 1948 by aerial photograph diachronic analysis, channel narrowing probably began before, but at a very slow pace. Comparison between the 1812 cadastre, a 1894 oblique photograph and the 1948 aerial photograph shows a similar active channel width. During the second half of the 20th century, narrowing is fast but irregular. A first period of fast narrowing is recorded between 1948 and 1971 (fig. 6b), it seems typically linked to basin afforestation as observed by other authors in south-eastern France (Liébault and Piégay, 2002; Liébault, 2003). The fast rate of narrowing:

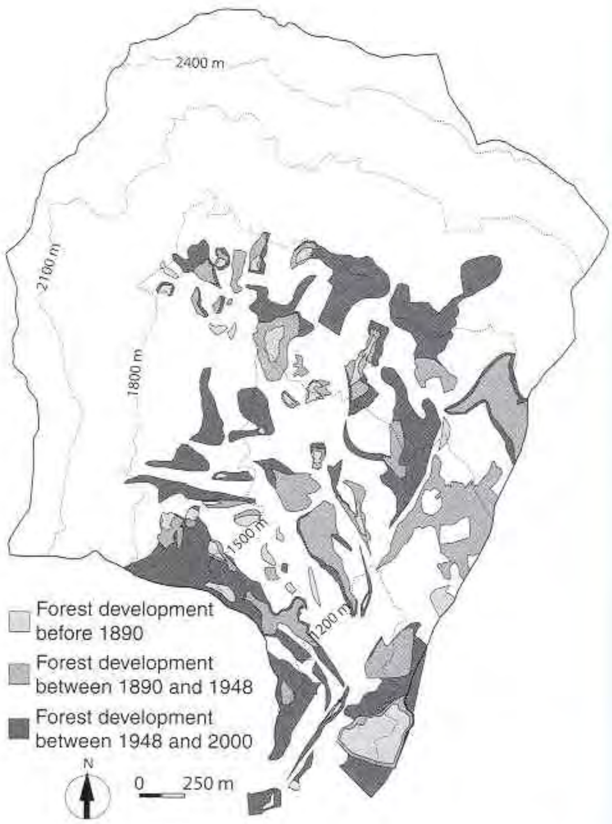


Fig. 5: Development of forest areas in the Abéous watershed between 1890 and 2000.
Fig. 5 : Développement de la forêt dans le bassin versant de l'Abéous entre 1890 et 2000.

44 % in 23 years, thus an average of 2 % per year could be explained by the overstepping of an efficiency threshold in the proportion of forest surface in the watershed. This trend comes to a halt between 1971 and 1990, active

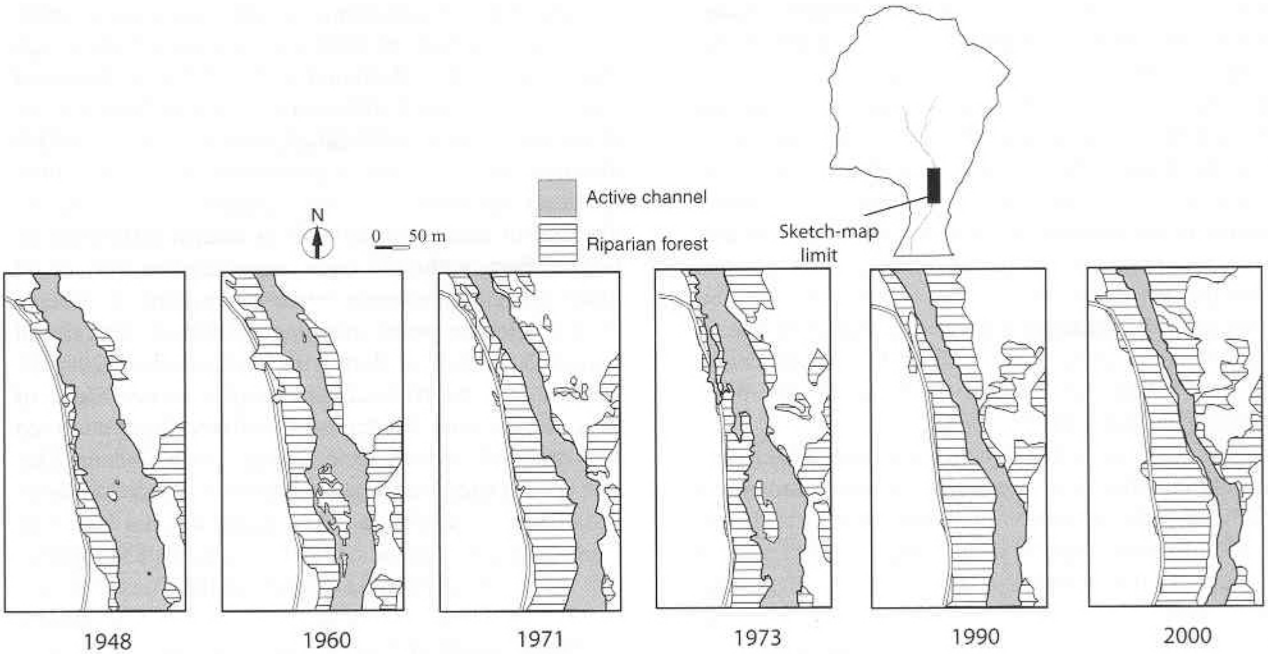
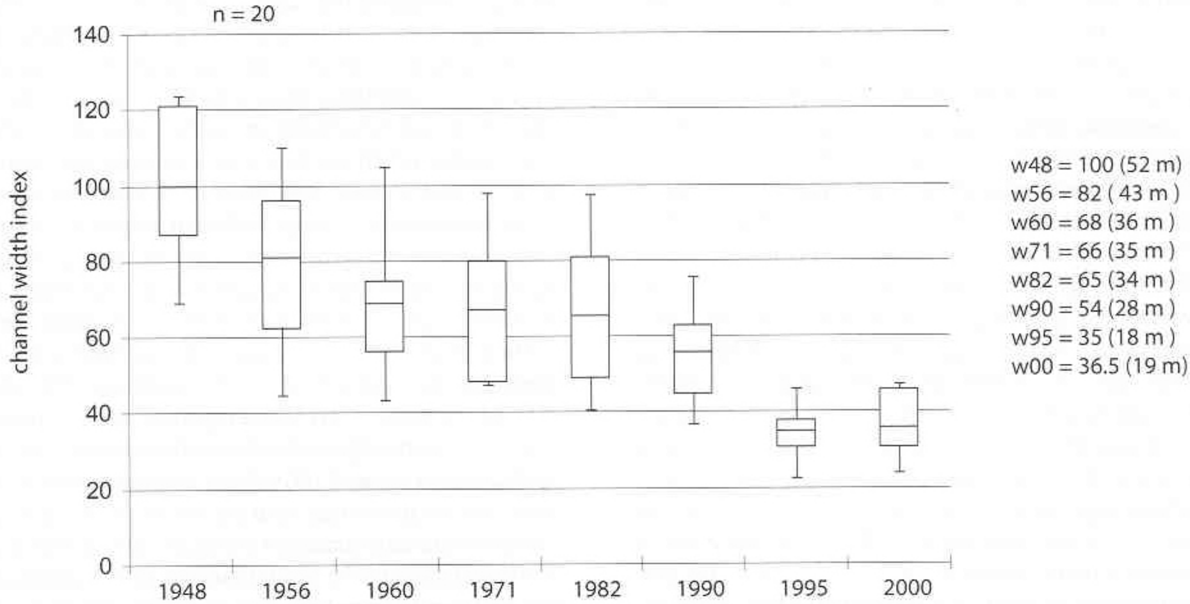


Fig. 6a: Diachronic sketch map of the Abéous active channel.
Fig. 6a : Croquis diachronique de la bande active de l'Abéous.



Boxes represent inner and outer quartiles; vertical lines represent inner and outer tenths; *n*, number of width measurements; *w*, mean active channel values for each date, expressed by an index : 100 = w48 (52 m)

Fig. 6b: Abéous active channel narrowing between 1948 and 2000.
Fig. 6b : La rétraction de la bande active de l'Abéous entre 1948 et 2000.

channel width is only perturbed in 1973 by a very violent debris flow that caused a temporary channel enlargement (fig. 6a), but although the riparian forest was destroyed in some areas (fig. 6a), the consequences rapidly disappeared and narrowing accelerated again after 1990 until reaching 65 % in 2000 (fig. 6b). This second episode of narrowing can be attributed to dam construction in the upper part of the channel causing bed entrenchment. We must note that this phenomenon was not accompanied by an appeasement of torrentiality since 9 debris flows took place between 1973 and 2003, but it seems that the bedload discharge mostly took place during these episodes and not during fluvial transport phases.

5 - SYNTHESIS AND DISCUSSION

The postglacial torrentiality of the Abéous can be globally integrated in the chronological frame established from a large number of torrents of the southern Prealps. After a more or less violent detritic phase during the Preboreal and the Boreal, comes a progressive appeasement of morphogenic activity leading to the deposition of silt facies often accompanied by pedogenesis during the «Holocene bioclimatic optimum» (Jorda, 1980, 1985; Rosique, 1993; Ballandras and Nevière, 1991; Ballandras, 1997). Basin afforestation due to improved climatic conditions seems to be the major factor of change.

In the Abéous however, the morphodynamic pause seems to have been less marked than in medium mountain areas. Indeed, whereas in Prealpine alluvial fans, several meter thick silt deposits are observed, indicating a biostasis period as from the Boreal (Jorda and others, 1984), the Abéous alluvium show recurrent debris flow facies at least until the mid-Atlantic. This fact, which is unique in our knowledge, induces us to reject in this case the interpretation, according to which, the silt facies succeeding the debris flow facies which compose the beginning of the «main Holocene fill» would be due to the development of the watersheds in the autochthonous black marl substratum after the wurmian till had been destroyed (Jorda and others, 1984).

We can question the bioclimatic conditions which prevailed during the slow depositing of these sandy-silt levels with a fluvial facies, of which we can probably only see the remains spared by gullying, and interspersed with relatively thin debris flow levels, probably deposited in the course of a small number of floods. As from the Boreal, the improvement of climatic conditions enabled an important forest development, which was followed by pedogenesis at the Atlantic (Jorda, 1993). In the Ubaye valley, as in other parts of the inner Alps, the more xeric conditions than on the Prealpine margins and the abundance of Callovian-Oxfordian marl outcrops favoured the development of *Pinus sylvestris* (Jorda, 1993; Kharbouch, 2000). The upper forest limit is not asserted but the topographic conditions make it impossible for a dense forest cover to settle on the upper slopes of the Abéous basin. In the watershed, the ground water in forest soils regulates runoff by having a hydrologic buffer effect (Campy and Macaire, 1989; Jorda and Provansal, 1996), whereas the superficial formations are stabilized by the vegetation. The colonisation of the alluvial fan by *Pinus sylvestris* could have a major impact on the sedimentary dynamic, already pointed out by M. Jorda (and others, 1984). The runoffs, which were probably more perennial than they are now (Jorda and Provansal, 1996), were combed by the vegetation on the alluvial fan, thereby depositing a fine sedimentation in shallow channels. The difficulty of water drainage is indicated by the paludal and hydromorphic character of the silt alluvium, and also by the presence of fossil tree trunks that were progressively stifled by the silt alluvium, as they can be observed in the Prealps (Jorda and others, 1984).

After a phase of vertical incision documented in most alluvial fans in the south-east of France (Jorda, 1985) at the beginning of Sub Atlantic, the second major Holocene depositional phase is consecutive, according to Jorda, to the "first climatic-anthropic break" at the boundary between the Atlantic and the Sub-Boreal. Miramont (1998) shows that this period was characterized by short climate oscillations and fast changes in morphogenic behaviour. The Conseiller section in the Abéous, which was one of the examples used to precise the chronology of the "early historical fill" indicates good correlation between climate oscillations, newly aggravated human impact on pollen diagrams and sediment transport (Jorda, 1985). The two debris flow sequences topped by two dated thin silt levels (2190 ± 100 BP and 1010 ± 80 BP) are interpreted as a response to well documented regional climate changes: an erosive phase during the Iron Age that comes to an end around 2150 BP due to improved climate during the Roman period; then another erosive phase during the early Middle Ages (1450 BP – 1250 BP) that ends with climate improvement during the "little medieval optimum" (Le Roy Ladurie, 1983). Due to the lack of data, it is difficult to discriminate climatic factors from anthropic ones, especially as periods of more aggressive climate often correspond to phases of demographic peaks inducing reinforced agricultural impact. Nevertheless, during the Roman period (200 BC – 500 AD), the Abéous stratigraphy shows signs of appeasement with silt deposits similar to those observed during the Atlantic optimum, only much thinner. This fact is correlated with archaeological evidence of human installation in the Ubaye valley, on the alluvial fan of the Faucon torrent (Ballandras, 1997). Jorda (1985) suggests that the small size of the silt levels in the Conseiller section indicates that the inhibitory effect of climate improvement on sediment transport was diminished because of the impact of agriculture on basin vegetation.

This idea is enforced, in our sense, by the absence of silt levels posterior to the 10th century, although rainfall increase preceding the Little Ice Age did not begin before the beginning of the 14th century (Le Roy Ladurie, 1983 *in* Descroix and Gautier, 2002). We therefore suggest that vegetation in the basin and on the alluvial fan is the main control on solid discharge in the Abéous torrent. During the Atlantic optimum, forest development corresponded to improved climate conditions and therefore caused a semi-extinction of coarse sediment transport. Since the "first climatic-anthropic break", the increasing impact of human activities on basin vegetation minimises the morphodynamic response of the torrent to climate improvement.

On a shorter time scale, a general appeasement of torrents has been observed in the Southern Alps during the 20th century. This contemporary appeasement, in a «recent warming» and reforestation (artificial and/or spontaneous) context, provides some elements of thought about the relations that existing between the hydro-geomorphologic functioning of a torrent and the forest cover of its watershed. The main consequences established at this date are a general active channel narrowing (Liébault and Piégay, 2002; Flez and Lahousse, in press), which is accompanied by solid discharge diminution and boulder pavement in the prealpine margins (Liébault and others, 2000). In the Abéous, spontaneous reforestation linked to land use change during the second half of 20th century has caused an important active channel adjustment which is not correlated with any major climate change (Flez and Lahousse, in press), as observed by Liébault (2003) in the Drôme mountains. In spite of these changes, the Abéous torrent remains a spasmodic functioning torrent that evacuates its sedimentary load during violent debris flows which are usually several years a part (9 in the last 20 years) and does not seem to be on the verge of becoming extinct.

There are two explanations to this fact. Firstly, forest in the Abéous only covers 25 % of basin surface and if its development continues, active channel narrowing is likely to follow, especially as the forest administration has planted more than a million tree plants in the upper slopes since 1994. Secondly, we think that contrariwise to piedmont torrents, steep slope mountain watersheds with upper cliffs carved in limestone flysch like that of the Abéous, can not be densely wooded, even during biostasis periods, and therefore remain highly sensitive to morphogenic activity. They were liable to emit debris flows provided the meteorological conditions were favourable, even during the Atlantic, without it being possible for us at this time to determine whether these were minor climate oscillations or simply local storms. There are several contemporary examples of alpine torrents reputed «inactive», with no active channel and a well wooded watershed, which produced large debris flows after one storm (Antoine, 1988; Lahousse and Salvador, 1998, Lahousse and Romelé, 2000).

6 - CONCLUSION

It is now recognized that Holocene torrential activity has not been constant. In the piedmont areas, notably in the French Southern Prealps, torrents went through a morphogenic pause lasting several thousand years resulting in a thick silt sedimentation facies. Available data is less abundant concerning Alpine mountain torrents; nevertheless the examples of the Durance basin (Rosique, 1993) and of the Ubaye basin (Jorda, 1985; Ballandras et Nevière, 1991; Ballandras, 1997, 1998), the Abéous being the one which has provided the most complete information, indicate a capacity to produce debris flows even at the heart of the «Holocene bioclimatic optimum». Improved knowledge makes it possible to refine the comparison between Holocene evolution of piedmont torrents and that of mountain torrents. As a result it seems that all these small size tributaries of South-eastern France can be well integrated in the stratigraphical frame set up by Alpine quaternarists. In the same way, the contemporary evolution of these torrents shows many similarities: a generalized contemporary morphogenic change which is characterized by a decrease in bedload delivery and transport, and whose major consequence is a strong active channel narrowing. And yet, if some Prealpine torrents seem to show signs of extinction with boulder pavement sometimes accompanied by a disappearing of the active channel (Liébault and others, 2000), the debris flow of an estimated volume of at least 30 000 m^3 according to the forest administration, which occurred in July 2003 in the Abéous, demonstrates that mountain torrents remain capable of mobilising large solid volumes during violent storms.

During most of the Holocene, the Abéous torrent has been characterized by a sedimentary dynamic often dominated by mass transport. Even during the Atlantic, the periods of morphogenic calm did not exceed a few centuries, and apart from the incision periods which we know little about, the alluvial fan of this torrent has never been really sheltered from debris flows, especially since man's impact on vegetation has been established in the Barcelonnette basin. In the present context of spontaneous (and artificial since 1990) reforestation, of active channel narrowing and channel incision, is it not to be feared for the decades to come that the new mountain users, forever in search of building space, reproduce the same mistakes as in other parts of the Alps (Lahousse and Salvador, 1998; Flez and Lahousse, 2002 ; Lahousse and others, 2002), by urbanizing alluvial fans which will probably remain dangerous as illustrated by two majors debris flows in the Abéous and Faucon torrents (Ubaye valley) during summer 2003 ?

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