Pedoanthracology and dendroecology: two complementary approaches applied to old forest history

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***Summary**: This paper deals with the combined use of pedoanthracology and dendroecology for the study of forest dynamics. Two forests were studied and compared: the mixed larch/arolla pine subalpine forest of Praroussin (Queyras, French Southern Alps) and the mixed beech/oak mediterranean forest of The Sainte Baume (Var, France). First results reveal the role played by arolla pine (Praroussin) and oak (Sainte Baume) in the past. These species will also play an important role in the future.*

***Key words**: pedoanthracology, Sainte Baume forest, subalpine forests, forest dynamics, dendroecology*

INTRODUCTION

There is increased interest in natural or semi natural forests in Europe due to their high biodiversity. Dendroecology and pedoanthracology were applied to decipher Holocene forest history and dynamics. Two forests were studied and compared: the mixed larch/arolla pine subalpine forest of Praroussin (Queyras, French Southern Alps) and the mixed beech/oak mediterranean forest of The Sainte Baume (Var, France). The aims of this study are: (i) to understand the dynamics that led to the installation these forests, (ii) to assess their current dynamics, and (iii) to enable the future modification of composition and structure of these forests. Results presented here are still preliminary and very incomplete.

STUDY AREA AND METHODS

Beech forest of the Sainte-Baume (43°20'00" N – 5°46'38" E) consists of beech (*Fagus sylvatica*), yew (*Taxus baccata*), holly (*Ilex aquifolium*), mapple (*Acer opalus, Acer campestris*), lime (*Tilia platyphyllos*), and oak (*Quercus pubescens*) (Molinier *et al*., 1959). The Praroussin forest is located on the western slope of the Guil valley at *ca.* 1950 m (44°45'44' N – 6°59'54" E). In this forest many of the larches (*Larix decidua*) and arolla pines (*Pinus cembra*) are several hundred years old. Understorey consists of bilberries (*Vaccinium uliginosum, V. myrtillus*), juniper (*Juniperus sibirica*), and alpenrose (*Rhododendron ferrugineum*).

Pedoanthracology. Five evenly distributed pits 60 to 80 cm deep were dug across the two plots of Praroussin while two pits 40 to 50 cm deep were dug within the three plots of the Ste Baume. Samples were taken at 10 cm intervals from all of the soil profiles. Charcoal was extracted employing protocols as described by Carcaillet and Thinon (1996). Only charcoal fragments larger than 1.25 mm were sorted, weighed and identified.

Dendroecology. In each plot, all trees, saplings, snags, logs, stumps and branches were listed (species, circumference 50 cm high) and spatialized. In order to study the regeneration, each sapling is referenced according to its species, its base circumference and its height. The measurements useful to evaluate the dead wood volumes on the ground were performed on logs, branches and stumps. So as to study the age structure of the plots, we have cored all trees at a height of 50 cm, to maximize the rings' number by core. Because of counting errors related to missing rings, the age structure was built in 10 years age-classes (Payette *et al*., 1990). In order to estimate tree ring/climate relationship, 15 trees were selectionned in each plot. From each tree two increment cores were taken with Pressler's borer.

RESULTS AND DISCUSSION

Praroussin

Pedoanthracology. Arolla pine was present in this area from *ca*. 7600 cal BP (Table 1) to 1500 cal BP. Our results suggest the establishment of larch from *ca*. 6000 cal BP, whereas other studies have indicated an earlier arrival, dating back to 8000 cal BP in the southernmost Alps (Ortu *et al*., 2005). The presence of fir at *ca*. 5900 cal BP, at 1980 m asl on a western-facing slope, confirms that its ecological requirements were less restricted than commonly believed (Ozenda, 1985). There is no doubt that fir had a mid-Holocene distribution that was wider than we had once assumed (Carcaillet and Muller, 2005). The charcoal spectra suggest that the larch forest was mixed comprising larch, arolla pines and isolated firs. The occurrence of willow and small leaf trees indicates that this mixed forest was open enough to allow the expansion of a shrubby understorey.

Pit	Material	Depth (cm)	Species	Age BP	Age cal. BP (2 σ)
PRA I 1	charcoal	50-60	*Pinus cembra*	1655 ± 30	1510-1627
PRA I 2	charcoal	40-50	*Larix decidua*	2595 ± 30	2705-2771
PRA I 1	charcoal	20-30	*Pinus cembra*	2930 ± 30	2973-3167
PRA I 3	charcoal	40-50	*Larix decidua*	5265 ± 35	5934-6123
PRA I 2	charcoal	20-30	*Pinus cembra*	6750 ± 40	7566-7673
PRA II 2	charcoal	20-30	*Larix decidua*	905 ± 30	742-911
PRA II 4	charcoal	10-20	*Pinus cembra*	915 ± 30	764-919
PRA II 2	charcoal	0-10	*Larix decidua*	965 ± 30	795-888
PRA II 4	charcoal	10-20	*Pinus cembra*	985 ± 30	895-959
PRA II	charcoal	OS	*Pinus cembra*	1590 ± 30	1408-1539
PRA II 4	charcoal	30-40	*Larix decidua*	1595 ± 30	1409-1542
PRA II 2	charcoal	20-30	*Abies alba*	5065 ± 35	5734-5908

TABLE 1: Praroussin. List of radiocarbon dates (OS = off site, uprooted tree) (Touflan et al., *2010).*

Dendroecology. On plot 1, the ages vary between 23 and 607 years. All classes are represented in the distribution up to 200 years. For stone pine, the median age is 55 years and the oldest individual is 158 years old. All classes up to 160 years are represented. On plot 2, the ages vary between 9 and 565 years. All classes up to 190 years are represented. Any stone pine exceeds 159 years old and its age structure is shared among 4 ages-groups (10-40, 50-80, 100-130, 140-160 years)

Ste Baume

Pedoanthracology. Preliminary results of charcoal are presented in presence/absence. The beech occurs in all the pits, except one, that was dug in the oak-dominated part of the forest of Ste Baume. The "absence" of beech thus is to be interpreted with caution because work still in progress.

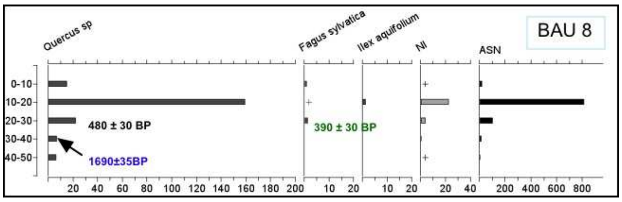

FIGURE 1: Example of pedoanthracological diagram. Bau 8 (Plot 3, beech dominated?).

Charcoals of oak are present in every pit, which would attest the past extension of the oak grove beyond the surface that it occupies today (Fig. 1). Four radiocarbon dates came from *Quercus* deciduous, four from *Fagus sylvatica* and one from *Taxus baccata*. The radiocarbon dates indicate Late Antiquity to Middle Age fire events. The oldest dates come from *Fagus* (778 – 903 AD) and *Quercus* (311 – 422 AD). Other dates range between *ca.* 780 and 1500 AD. In the preliminary results, no fire events have been thus recorded since almost 500 years.

Dendroecology. Trees are *ca*. 182 yrs old. Their installation dates the beginning of the 19th century. This period coincides with the stop in 1815 of the important cuttings made during revolutionary period (Guinier, 1944). Some trees older than 256 years could have played a major role in the natural regeneration of the forest. But beeches could also have been planted. The stand structure is characterized by two dominant classes, very young and old trees.

CONCLUSION

Pedoanthracology and dendroecology bring new light on the forest dynamics. Episodes of fire have taken place for a long time in the studied forests, particularly in the subalpine forest. The study of subalpine forest dynamics (dendroecology) shows that arolla pine will play a major role in the future, as it was already the case in past (pedoanthracology). In the forest of beech, the importance of oak charcoal reveals the past importance of this species and corroborates the results of the dendroecology study. The regeneration of beech is not ensured and is finally going to favor the expansion of oaks.

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