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A FAST, NON-DESTRUCTIVE AND LOW-COST DATING APPROACH OF SEDIMENT CORES OVER THE LAST CENTURY

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INTRODUCTION

Radiocarbon analyses and short-lived radionuclides are well-established methods to provide chronologies of sedimentary sequences at the scales of the last 50 ka and the last century, respectively (Hajdas et al., 2021; Bruel and Sabatier, 2020). While the combination of these methods is very effective for dating lake sediments, each of them **is also very expensive**.

In the context of studies based on the analyze of many sites, for instance to develop a reference database on recent sediments to compare with modern or historical data, the application of such dating methods **is difficult to implement because of the very high costs involved.** To overcome this limit, we propose here an alternative ten times less expensive and based on a non-destructive method: the use of lead pollutions peaks detected by X-ray fluorescence measurements (Avaatech) on sediment cores.

Several studies already used this method to get a first idea of the cores chronology or to support age-depth models produced with the other techniques (Bajard et al., 2017; Julien et al., submitted; Giguet-Covex et al., 2014; submitted). However, from our knowledge such approach is not used to assist in the sampling of modern sediments supposed to represent a specific time span, equivalent to that of the current data of interest and thus allowing to create a robust "reference database". Nevertheless, **sedimentation rates from one core to another can vary by several orders of magnitude** (around 1 to 2).

Based on the measurements of lead concentrations, fluxes and isotopes from natural archives (ice, sediments and peats) and well-established dating methods, several studies showed, there has been significant atmospheric lead pollution since the beginning of the 20th century, with a rise around the 50's and a peak at AD 1973, just before the oil crisis (Arnaud et al., 2004; Bindler 2011; Boutron et al., 1991; Moor et al., 1996 ; Shotyk et al., 1996; Rosman et al., 2000..). Historical pollutions are also clearly identified by numerous studies, particularly in the French Alps, Switzerland and Greenland, during the Medieval and Roman periods due to the development of important lead mining activities (Hong et al., 1994; Shotyk et al., 1996; 1998; Giguet-Covex et al., 2011).

AREA AND STUDY SITES

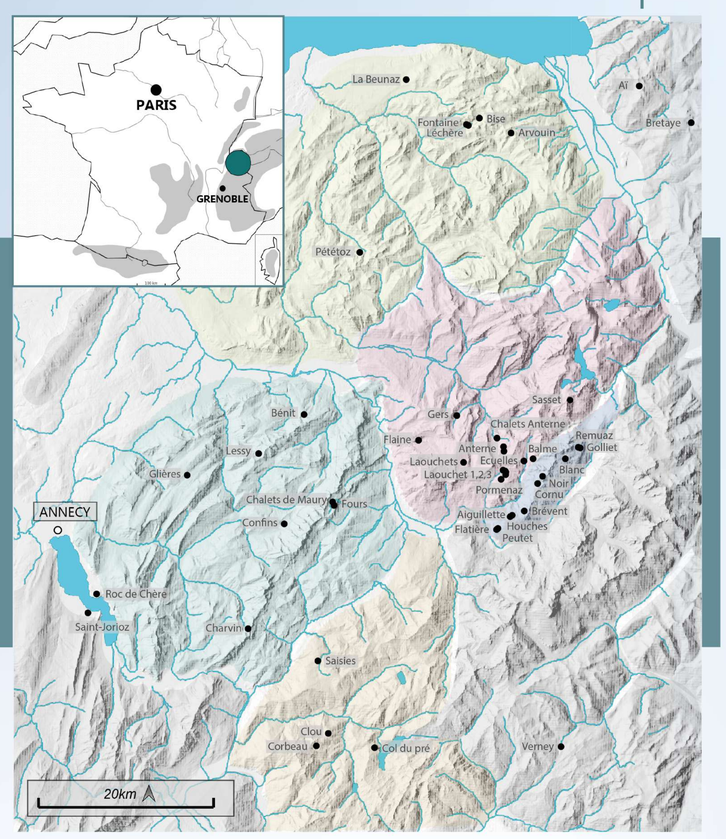


Fig 1. To apply and validate this method, 37 sites were cored in the French Northern Alps (14 peat bogs and 23 lakes) within the framework of the MODALP project.

METHODOLOGY

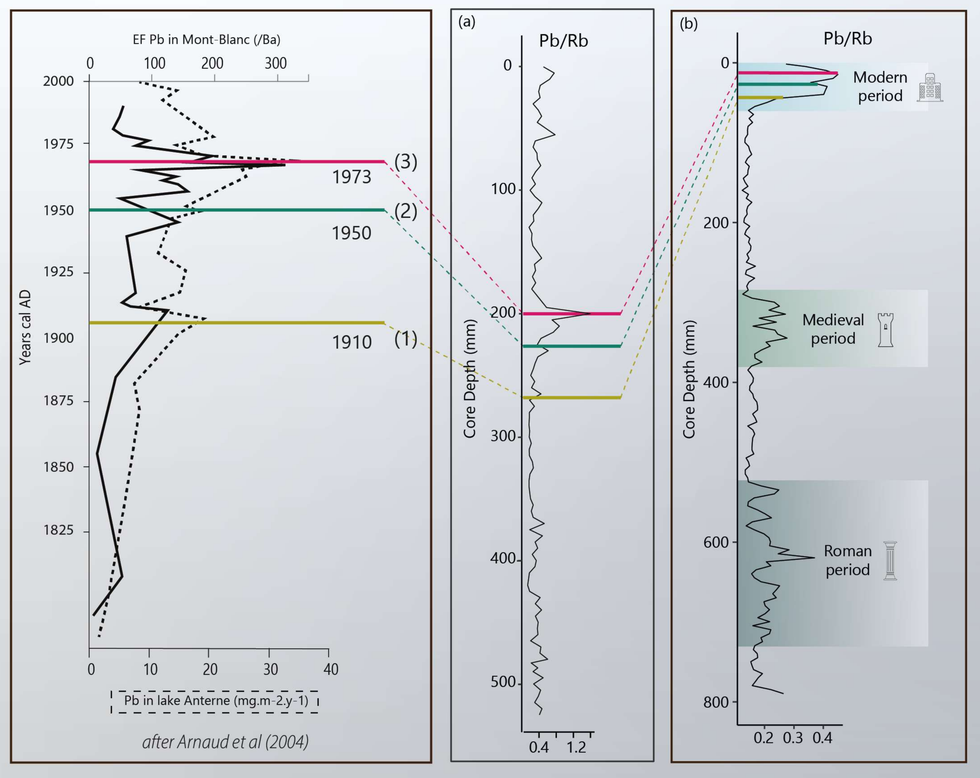
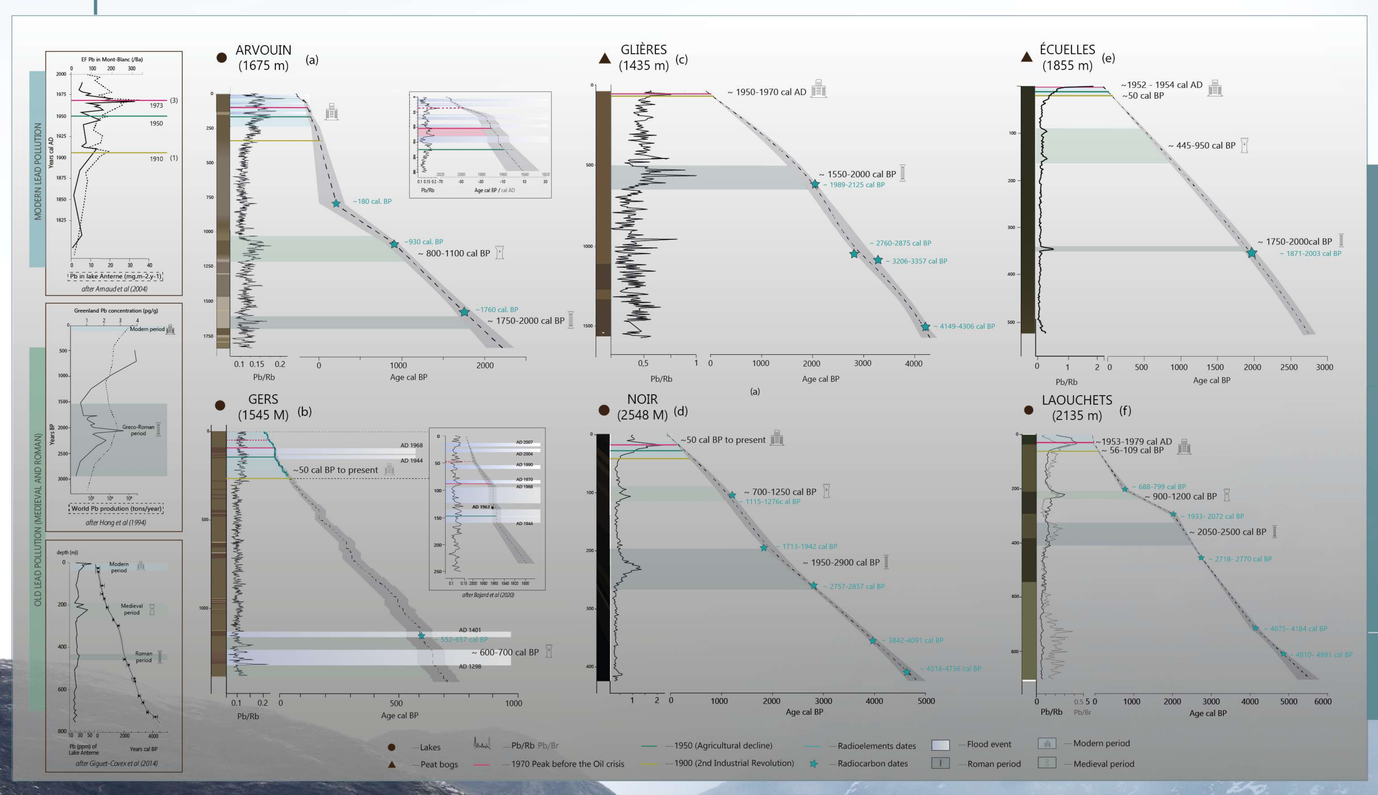


Fig 2. The Pb/Rb curve is compared with the curves of Arnaud et al (2014) from Mont-Blanc and Lake Anterne, located in our study area. In these cases, all three markers are found (a,b). The Medieval and Roman peaks are also observed (b).

- First, the cores must be analysed with by **X-ray fluorescence using an XRF Core Scanner**.
- Then, the aim is to **compare the Pb signal**, or **Pb/Rb** (to get rid of detrital inputs) and **Pb/Br ratio** (to get rid of organic inputs) **with the referential curves selected : Anterne** (Arnaud et al. 2004) and **Mont-Blanc curves** (Rosman et al. 2000) (Fig. 2) to find :
  - -(1) the peak after AD 1900, the beginning of the major increase in atmospheric lead pollution in the 20th century
  - -(2) the beginning of the second rise around AD 1950, just after a phase of decline between 1910 and 1940
  - -(3) the second peak in AD 1973, the most evident to find.

  Several hypotheses can be formulated. In some cases, **it is possible to find peaks from Medieval and Roman periods**. (Fig. 2)
- The final step is to **estimate the sedimentation rate to validate the chronology,** based on knowledge of sediment components and associated processes.

VALIDATION



Six sites with an age-depth model generated with ^{14}C and/or radioelements and sometimes supported by some historical events such as floods were used to validate this protocol. (Fig. 3).
The three markers are well recorded by these six sequences and are consistent with the age-depth models built independently.

Fig 3. This figure shows different age-depth models from several studies : (a,b) Arvouin (Bajard 2017) and Gers (Bajard et al., 2020; Giguet-Covex et al., In review) were made with ^{14}C, radioelements and historical floods ; (c, d, e, f) Glières (Julien et al., submitted), Laouchets (Giguet-Covex et al., submitted), Ecuelles (David 2010) and Noir (Vessies 2022, Master thesis) were made only with ^{14}C .

This protocol was applied to 31 sites (Fig 1, Fig 4). In most cases, the three markers are well identified.

But for seven sites, the results are less robust due to the complexity of interpreting the lead signal (Fig 5).
Indeed, no peaks are visibles for categories (A) and (B), but some trends correlated to the 20th century period can be recorded. These trends should be interpreted with caution. Finally, only one site shows no trend (C).

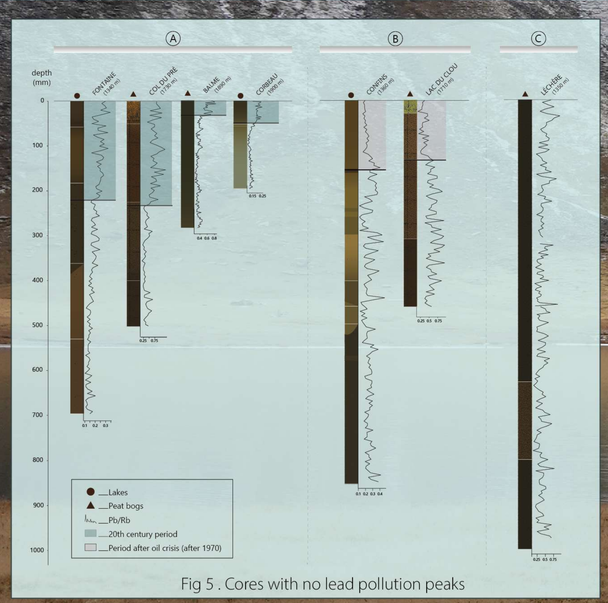


Fig 5 . Cores with no lead pollution peaks

APPLICATION

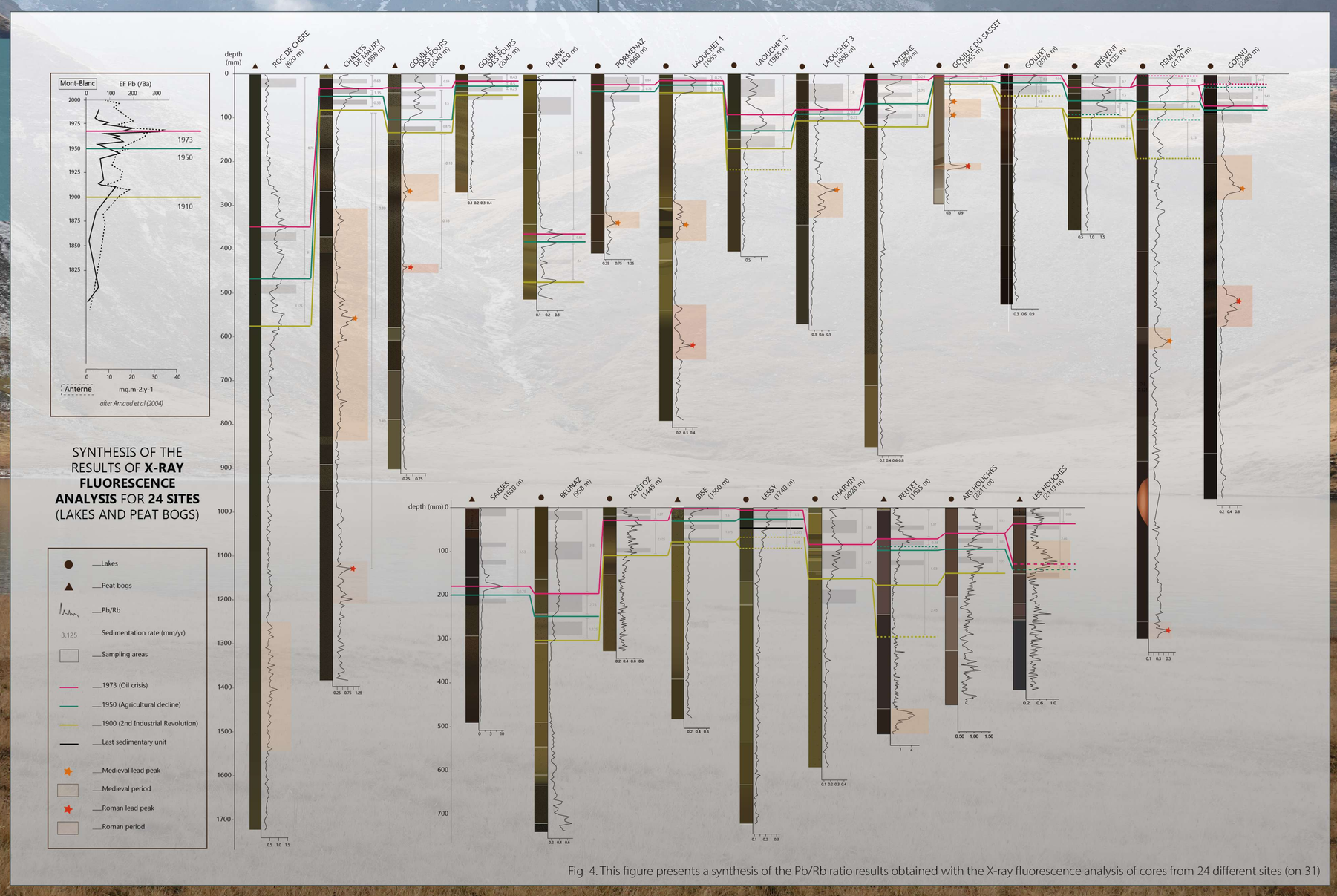


Fig 4. This figure presents a synthesis of the Pb/Rb ratio results obtained with the X-ray fluorescence analysis of cores from 24 different sites (on 31)

CONCLUSION

This method can be used to obtain quickly and at low cost preliminary information on the chronology of cores or to date a large number of sites for recent periods. Although its validation has been tested and verified at several sites, it is always better to combine this approach with independant information (when possible), such as the analyse of a marker whose history is known elsewhere (flood*, seisms**, avalanche, introduced species, change in species composition).

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