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# A METHODOLOGICAL APPROACH TO ELABORATE A MODERN REFERENCE IN ORDER TO EVALUATE THE APPLICATION OF THE LANDSCAPE RECONSTRUCTION ALGORITHM IN THE NORTHERN FRENCH ALPS

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## SUMMARY

In recent years, studies based on modern analogues have been developed with the aim to test and calibrate the methodological advances in palaeoenvironmental sciences. Some of these advances, such as the development of models based on palynological studies to assess the spatial extent of past vegetation, have required validation with modern or historical analogue studies. The Landscape Reconstruction Algorithm (LRA) allows vegetation to be reconstructed at known regional and local scales by considering pollen production and dispersal of each taxa and site-type dependent depositional mechanisms. Although such models are now widely used at European scale, their performance in mountain areas still need to be tested.

The aim of the present study is to reconstruct the spatial and temporal dynamics of vegetation in the northern Alps, by applying the LRA to pollen records covering the last five millennia. In order to optimise the LRA for reconstructing the past, tests on modern archives in known contexts of vegetation cover are essential. Such approach requires a succession of methodological steps, each of which is important for improving the LRA estimates.

• Here, we present our methodological approach to establish an accurate modern reference. We cored 28 lakes and 16 bogs in the northern French Alps area (Fig 1) to obtain **modern pollen assemblages**. Mountain lakes might present very different sedimentation rates. This requires to adapt the thickness of sediment samples in order to obtain a similar time period from one lake to another. To deal with this issue, a fast and non-destructive dating protocol was established.

• Then, in order to compare the LRA results with current vegetation, a vegetation map was created and designed to provide formatted vegetation composition data.

These **two methodological improvements** (chronology and vegetation map), allow us to have **accurate modern pollen assemblages** and an effective comparison between the LRA results and the current vegetation.

## AREA AND STUDY SITES

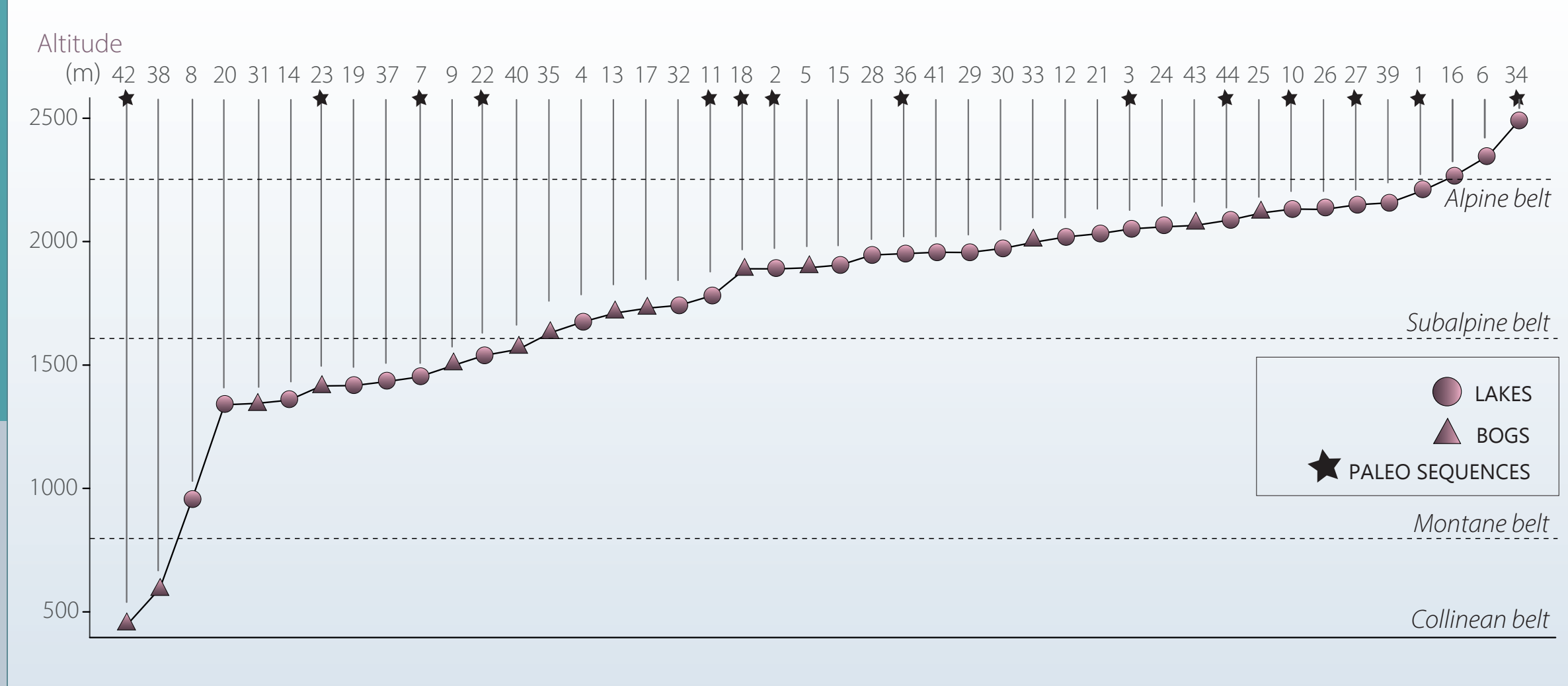
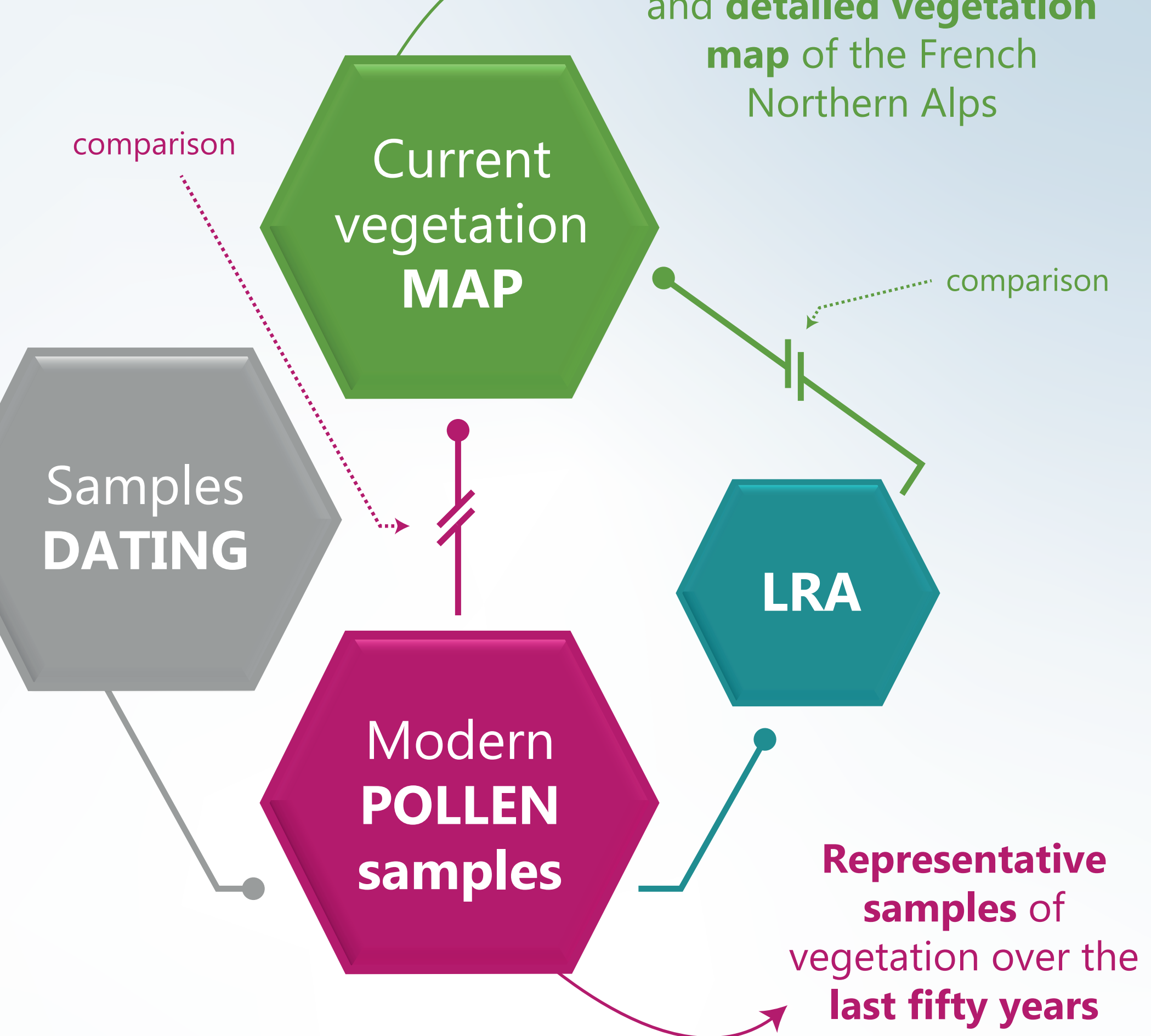


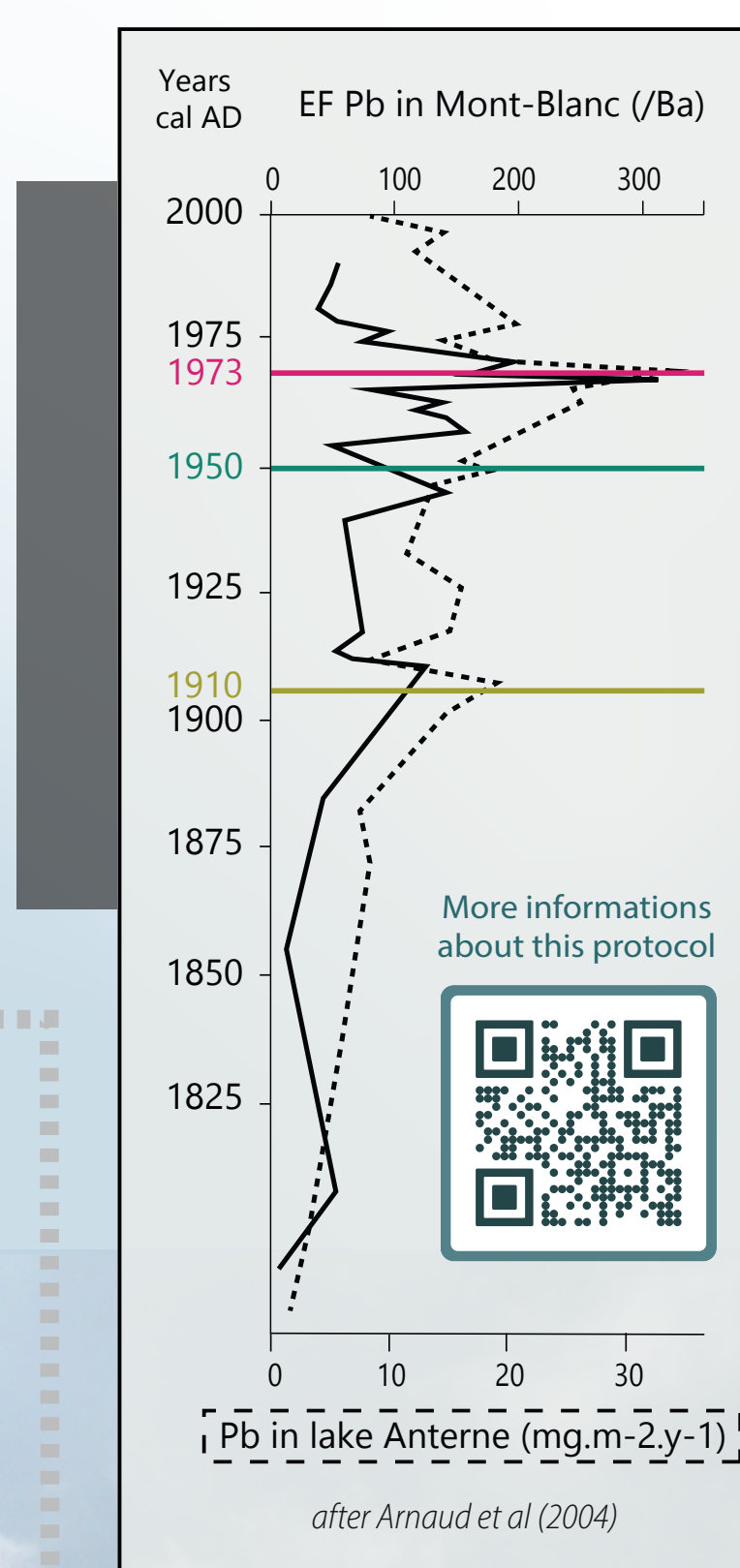
Fig 1. To apply and validate this method, 42 sites were cored in the French Northern Alps (16 peat bogs and 28 lakes) within the framework of the MODALP project. See below (Fig 3) for the number correspondances.

## MODERN REFERENCE

Heterogeneous sedimentation rates --> Need for a fast, cheap and non-destructive dating method



## DATING 2



Because of the very high costs of dating methods and the high variation of sedimentation rates from one core to another in alpine area, we propose here an alternative approach, mostly based on the record of atmospheric lead pollutions during the last 100 years. These lead signals are detected on sediment cores by X-ray fluorescence measurements (Avaatech).

Several studies have shown that there has been significant atmospheric lead pollution since the beginning of the 20th century, with a rise around the 50s and a peak at AD 1973, just before the oil crisis (Arnaud et al., 2004; Bindler 2011; Boutroun et al., 1991; Moor et al., 1996; Shotyk et al., 1996; Rosman et al., 2000.).

This protocol was applied to 31 sites (Fig 5). In most cases, the three markers are well identified (a,b,c). Six sites with an age-depth model generated with <sup>14</sup>C and/or radioelements and sometimes supported by some historical events such as floods were used to validate this protocol. This dating method can be used to obtain quick and 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 needs to be compared with lithology and complemented by the detection of instantaneous deposits associated with specific historical events (floods\*, seisms\*\*, avalanches, local developments...) or with other data information (changes in species composition) to fully understand the recorded lead signal (a,b,d).

Fig 4. Reference curves from Arnaud et al (2014): Mont-Blanc and Lake Anterne curves, located in our study area.

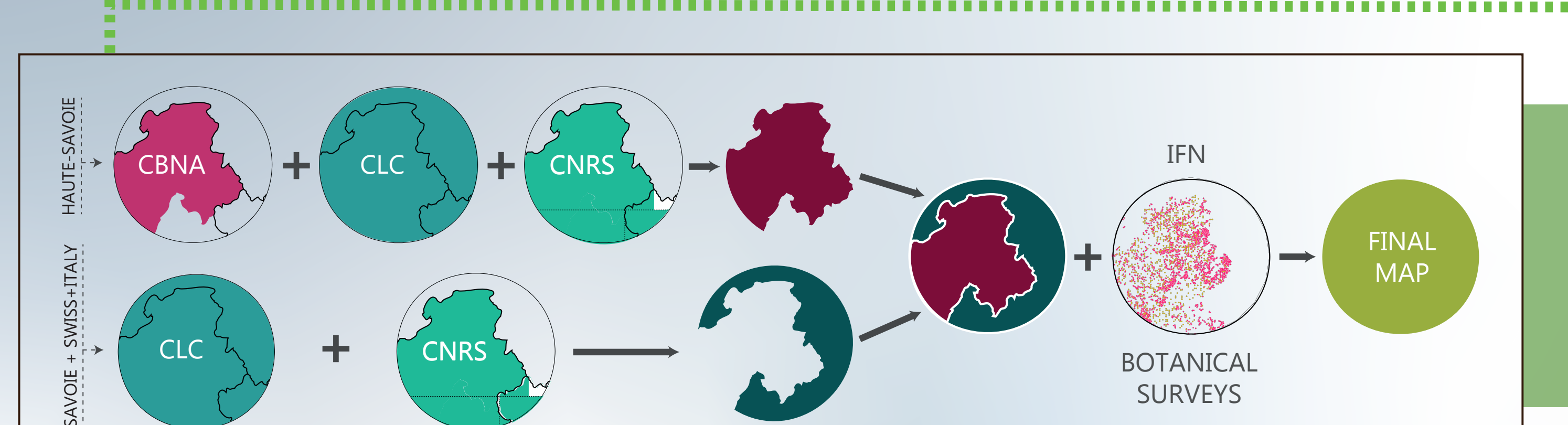


Fig 2. Combination of 3 different maps with different information resolutions (CNRS potential vegetation map, CBNA habitat map, Corine Land Cover) and with inventories from the National Forest Inventory and around 5000 botanical surveys from the CBNA.

### VEGETATION MAP

FOREST	
Deciduous forest	Forest_Alnus glutinosa
Forest_Acer	Forest_Alnus viridis
Forest_Acer/Fagus	
Forest_Acer/Fraxinus	
Forest_Carpinus	
Forest_Castanea	
Forest_Fraxinus	
Forest_Fraxinus/Carpinus	
Forest_Quercus	
Forest_Quercus/Castanea	
Forest_Quercus/Carpinus	
Forest_Quercus/Fraxinus	
Forest_Fagus/Quercus	
Forest_Tilia	
Forest_Deciduous	
Forest_Betula	
Forest_Mix	
Fagus/Abies/Picea forests	
Forest_L1	
Forest_FA	
Forest_FA 6/4	
Forest_FP	
Forest_FP 6/4	
Forest_AF 6/4	
Forest_A1	
Forest_AP 6/4	
Forest_PA	
Forest_P1	
Forest_PF 6/4	
Forest_PA 6/4	
Forest_PAF	
Other coniferous forest	
Forest_Larix	
Forest_Larix/Picea	
Forest_Pinus_montane	
Forest_Pinus_subalpine	
OPEN LAND	
Grassland_montane	
Grassland_subalpine/alpine	
Grassland_with_pine	
Heathland_montane	
Heathland_subalpine/alpine	
Heathland_with_pine	
Meadow_montane	
Meadow_subalpine/alpine	
Wetland_valley	
Wetland_montane	
Wetland_subalpine/alpine	
OTHER VEGETATION	
Riparian vegetation	
Transitional woodland-shrub	
Hedges/forest belts	
CULTIVATION	
Cereals_crops	
Other_crops	
Crops/meadow mow	
Land with principally agriculture	
Fruit trees	
Vineyards	
OTHER LAND COVER	
Bare rock	
Perpetual snow	
Lakes	
Peatbogs	
Fen	
Waterway	
Urban area	
Artificial green areas	

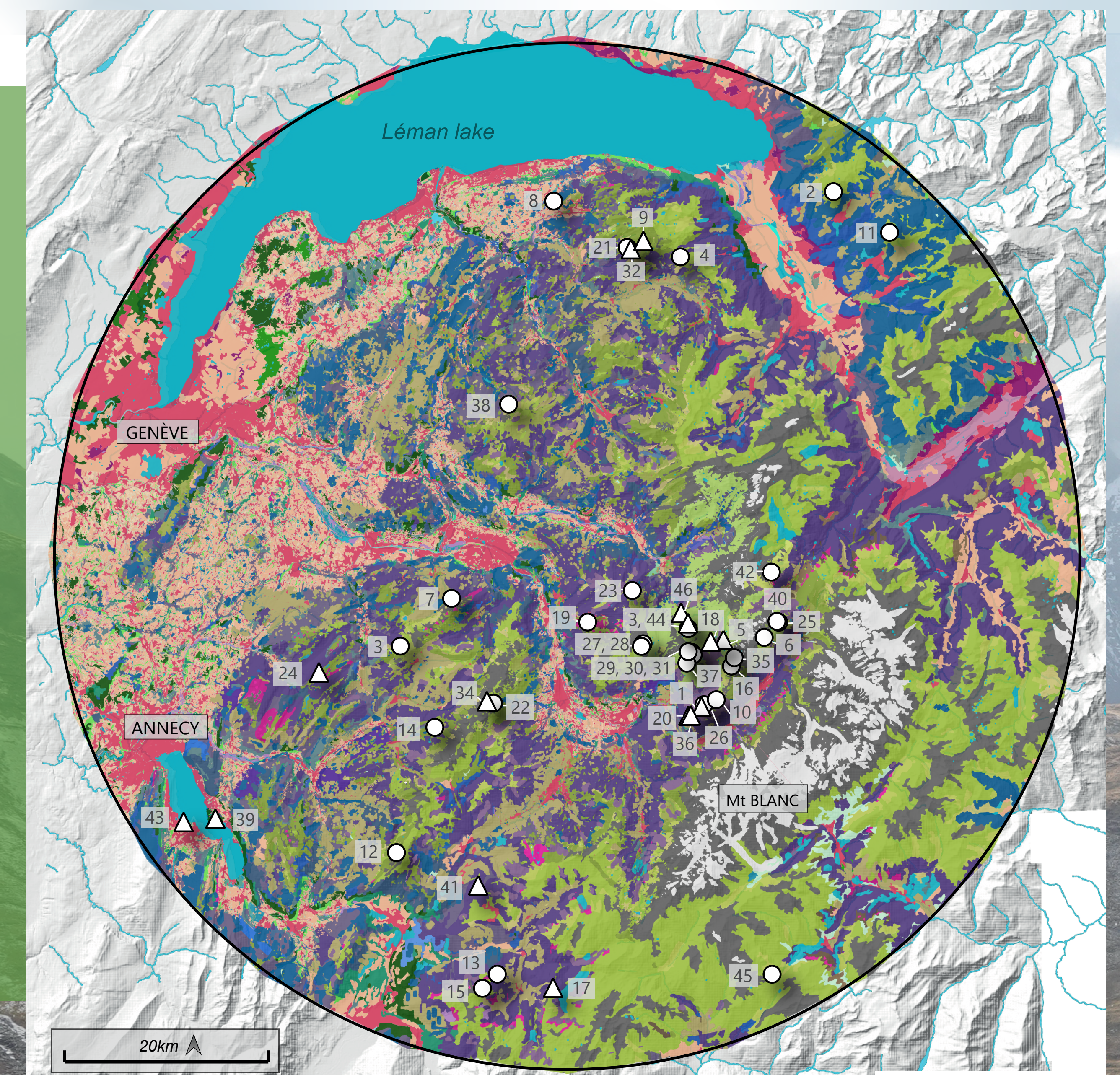


Fig 3. Vegetation Map - MAPALP

After the map creation, botanical compositions were produced for each of the 47 vegetation categories. These compositions indicate the % for 41 taxa by combining information from around 5000 botanical surveys. These % per category were then transformed into a single value for the proportion of each taxon for the entire area.

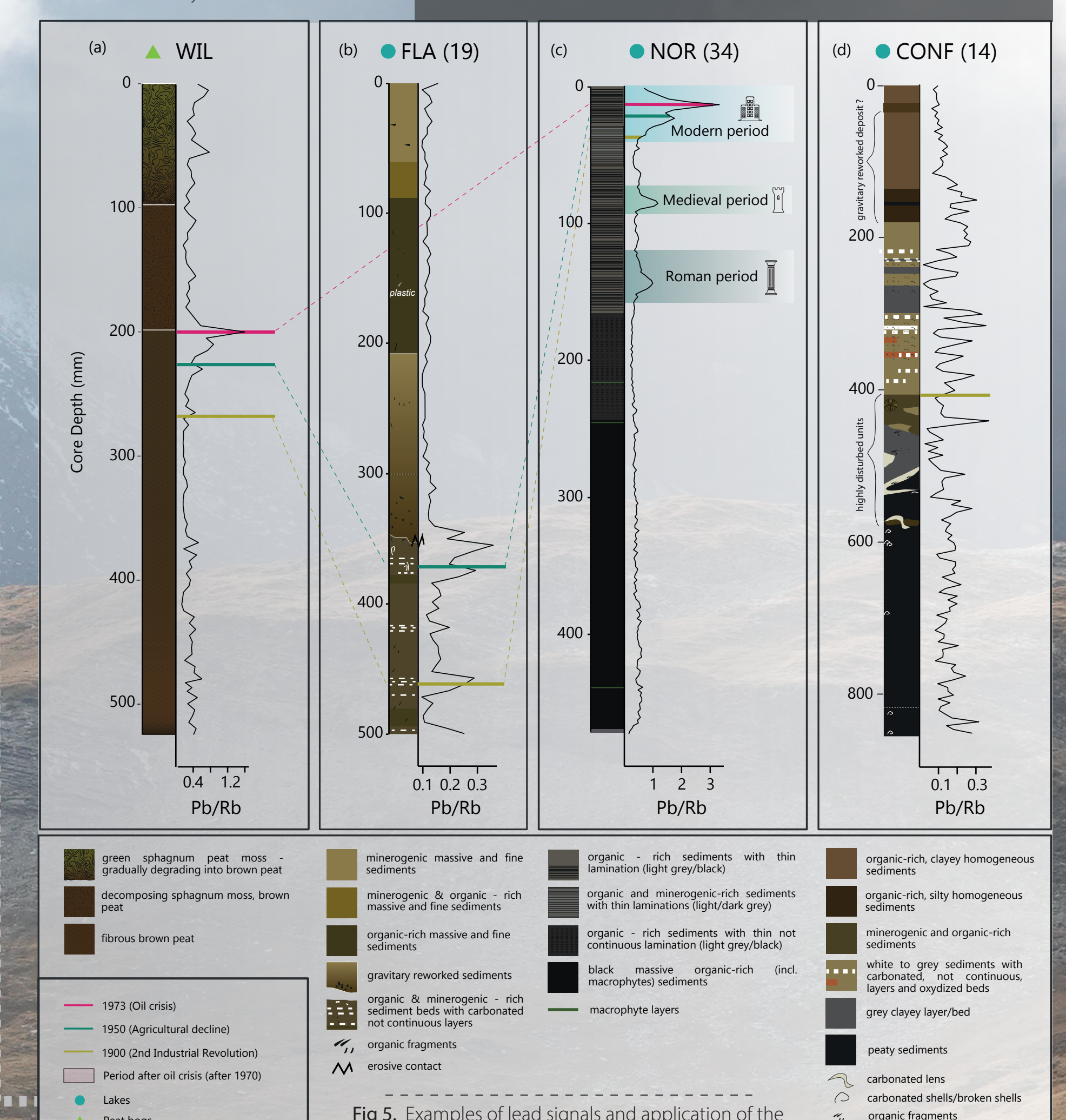


Fig 5. Examples of lead signals and application of the protocol at 4 different sites

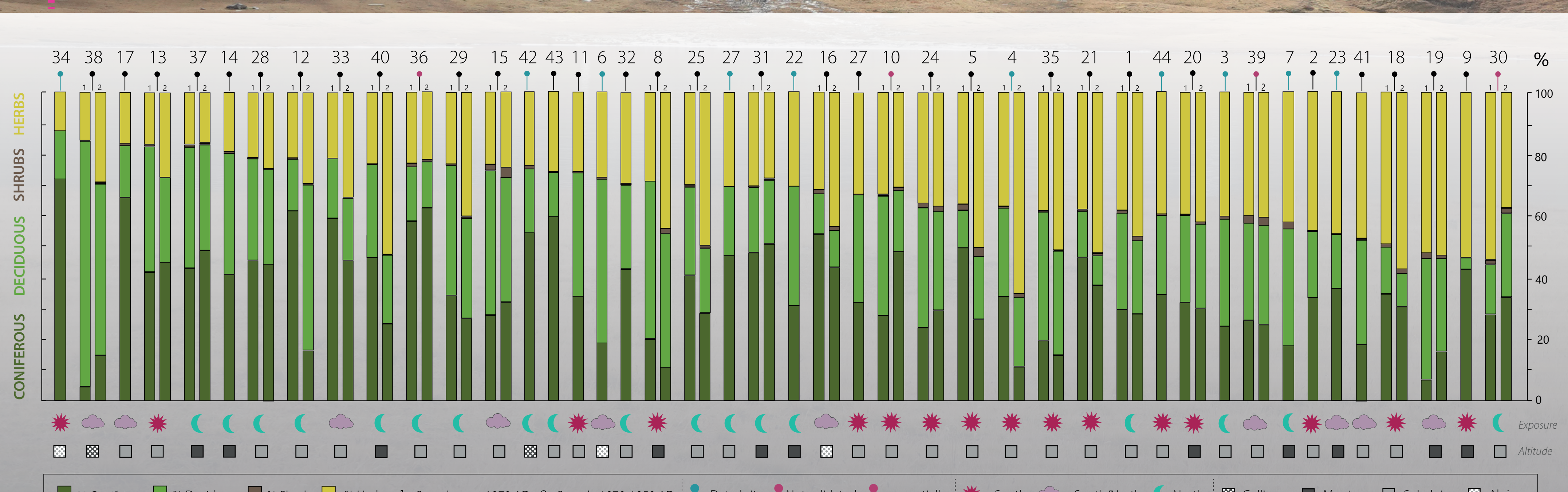


Fig 6. Pollen results for the first two samples of each sites (post 1970, between 1970-1950).

## POLLEN 3

• In our study case, the chronology was also validated using pollen samples. In fact, in the Alps, around the 50s, there was a phase of reforestation led by the decline of agriculture. In all the pollen assemblages of the sector, it is possible to observe this dynamic in the top samples. We therefore took samples before and after this period (after 1970, between 1970 and 1950 and before 1950) to observe this dynamic. The third sample has not been counted yet, but the first two already confirm the established chronology (except for 4 sites).

• These palynological results show a great diversity in the percentages of arboreal and non-arboreal pollen, depending not only on the altitude of the site, but also on exposure, atmospheric conditions, and local human activities.

Methodological improvements in acquiring these reference data will enhance the comparison between actual vegetation and modelled data. However, in addition to these methodological approaches, such as dating or obtaining accurate current vegetation data, it is essential, in order to fully understand the results of the LRA, to know the specific characteristics of each site used, including topography, sedimentology or raw palynological data.

References: Arnaud F., et al (2002) - Terra Nova; Bajard M., et al (2020) - Palaeogeography, Palaeoclimatology, Palaeoecology; Boutroun CF, et al (1991) - Nature; Moor HC, et al (1996) - Environ Sci Technol; Rosman KJR, et al (2000) - Earth and Planetary Science Letters; Shotyk W, et al (1996) - Earth and Planetary Science Letters; Arnaud F., et al (2004) - A Journal of Environmental Monitoring; Bindler R. (1994) - Environmental Geochemistry and Health; Eleaume N., et al (2022) - Regional Environmental Change