Dendroecology and dendrochemistry in Trentino: the Grotta di Ernesto project

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SUMMARY - Dendroecology and dendrochemistry in Trentino: the Grotta di Ernesto project. Sampling and analyses for dendroecological and dendrochemistry studies have been carried out in forests of Trentino, south-eastern Italian Alps, to complement the extensive speleothem database and recognize tools for cross-correlation of the two archives. Dendroecological data will be compared with the series of winter temperature and anthropogenic sulphate concentration trend obtained from three stalagmites sampled at the Grotta di Ernesto cave. The main objective of the investigation is to analyse different aspects of anthropogenic impacts recorded by the tree-ring series, such as variability in the load of pollutants and land use changes, and discriminate them from natural phenomena. We also aim at recognizing ecosystem storage of sulphur, which has been recognised in speleothem studies. Sampling was carried out for trees growing within 1000 m radius around the cave. We selected trees which had a minimum of 50 and 150 annual rings, a requirement for both computer assisted dendrochronology and isotope analysis. 85 trees belonging to the species Fagus sylvatica, Larix decidua, Picea abies and Abies alba were sampled through Pressler coring. Planned analyses included traditional dendrochronology, dendroclimatology (measuring carbon and oxygen isotopes and blue light reflectance) and dendrochemistry (extraction of sulphur). The dendroecological data obtained by the study will be compared and correlated with meteorological series from 5 permanent stations dating back to 1812. The tree-ring data will be also compared with isotope values extracted from growth annual laminae developed from the year 1900 to the year 2000 AD in stalagmites from Grotta di Ernesto.

Key words: dendroecology, dendrochemistry, sulphur, Grotta di Ernesto

Parole chiave: dendroecologia, dendrochimica, zolfo, Grotta di Ernesto
1. AIMS OF THE DENDROECOLOGY STUDIES NEAR GROTTA DI ERNESTO SITE

The current palaeoclimate and environmental studies, in particular for the past few centuries, require archives of proxy data with annual to sub-annual resolution. In the Trento Province both tree ring and speleothem proxy records have made substantial new contribution to our understanding of natural climate variability and the effects of anthropogenic forcing. In particular, the Grotta di Ernesto cave is one of the key sites for palaeoclimate and environmental research in the Alps (Frisia et al., 2003, 2005). Speleothems from this cave are temperature-sensitive in their growth rate, and encode in their chemical properties information about atmospheric sulphur load. The forest trees near Grotta di Ernesto, therefore, would allow for multiparameter comparison of tree rings and speleothem proxy data at least over the past 150 years, which is the time interval that is better constrained in the annually laminated speleothems (Frisia et al. 2003). In particular, Frisia et al. (2003) not only found evidence for correlation of speleothem growth rate and temperature, but also identified the 11-year sunspot cycle, which was related to ecosystem response to solar forcing. A dendroclimatological study has the potential to cast better insight on the interannual variations of climate parameters and how modes of variability have changed through time. It is important, here, to remind that while tree rings are an excellent proxy for the temperature in the growing season, speleothems, at Grotta di Ernesto, preferentially record the cold season.

The present study builds its rationale from the premise that tree-ring samples collected from trees in the vicinity of Grotta di Ernesto could be used to monitor tree response to climatic variables and to anthropogenic pollution over the previous 150 years, and provide data complementary to speleothem data. Planned analyses included traditional dendrochronology and, more importantly, ring series for the isotope work envisaged here, as there is an age effect clearly discernable in the isotopic records of tree-rings. A climate signal cannot be found in young trees and therefore the isotopic records for the first 40 years growth of individual trees are discounted from climatic reconstructions. In an ideal world, tree-ring records of at least 200 years are desirable for tracing environmental impacts related to changing climate and to industrial development in northern Italy. Field sampling took place between 11th and 20th July 2005 from the excellent base of the Albergo San Marco in Enego and with assistance of the Borgo Valsugana Forest District of the Forest Service of Provincia Autonoma of Trento (PAT).

An exploratory field investigation in 1997 had identified a number of species that might be suitable for this project: Fagus sylvatica (Beech), Larix decidua (European Larch), Picea abies (Norway Spruce) and Abies alba (Silver Fir). In that pilot study, larch seemed to have a good response to temperature. A search was then undertaken for mature/old trees in the area above and adjacent to Grotta di Ernesto. As can be seen in figure 1, the entrance to the cave is on the upper slope of Valsugana to the west of the village of Martincelli. Many dendroecological studies have shown that the growth response of trees located on slopes can often mask meteorological signals (Urbinati et al. 1997; Oberhuber et al. 1998; Oberhuber & Kofler 2000; Oberhuber 2004) and therefore another important consideration was to find trees rooted on flat or only gently sloping ground. The circle drawn in figure 1 describes a 1 km radius centred on the entrance to the Grotta di Ernesto and clearly illustrates why the search for suitable trees focused to the west and south of the cave.

A further restriction on sampling is the extensive area of tree-less pastures. The word “malga” is a common prefix for mountains meaning cattle-shed and can be found in many localities on the plateau within circa 6 km to the west/north-west of the cave (M. Aveati, M. Vacchetta, M. Val Capertadi Sotto, M. Campo di Sopra, M. Val d’Antenne), indicating areas that have been pasture for some considerable time.

The mixed forests in the area are predominantly of Picea abies, with Abies alba, Larix decidua and Fagus sylvatica. Mean stand density is typically 250 trees per ha and tree basal area is about 25-30 m² per ha (Virgilietti 1998). Many stands over the last 40 years have been managed under a silvicultural system, “taglio di curazione”, which is similar to “naturalistic” silviculture or a selection system (Ferrari 1984).

This semi-natural conifer forest with beech understorey is characteristic of this zone of Trentino at 1000-1500 m a.s.l. in the Valsugana (Ferrai & Mazzucchi 1974). Large old beech trees are present scattered in some parts of the forest, the remains of seed-producing trees that were present in former beech coppices (Loss

2. SAMPLING

Sampling of tree-rings was governed by a number of criteria in order to provide suitable samples for the analyses identified above. Initially, it was important to identify trees species growing in the area immediately surrounding Grotta di Ernesto, which would provide ring series suitable for basic dendrochronology and, more importantly, ring series of sufficient length to facilitate isotopic analyses. At least 50 annual rings are required for computer-assisted dendrochronology, and 150 rings are needed for the isotope work envisaged here, as there is an age effect clearly discernable in the isotopic records of tree-rings. A climate signal cannot be found in young trees and therefore the isotopic records for the first 40 years growth of individual trees are discounted from climatic reconstructions. In an ideal world, tree-ring records of at least 200 years are desirable for tracing environmental impacts related to changing climate and to industrial development in northern Italy. Field sampling took place between 11th and 20th July 2005 from the excellent base of the Albergo San Marco in Enego and with assistance of the Borgo Valsugana Forest District of the Forest Service of Provincia Autonoma of Trento (PAT).

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& Ferrai 1984), or some were possibly just isolated trees in the pasture. These beech growing together with larch are mostly found in private forests. Public forests are dominated by almost solely by *Picea abies* and *Abies alba*. This major distinction in the forest is the result of the intensive silvicultural management that was practiced in the beech coppices and the intensive grazing under larch trees on private lands. There are also the remnants of charcoal pits where charcoal was made from beech wood and the waste wood from conifers.

This forest had been affected quite regularly by disturbance and significant regeneration occurred only after 1920 (Motta et al. 2002). Before the war the land had been exploited as pasture, as was quite common in such regions (Backmeroff 1996; Piussi 2002), especially where the slope was not excessive. A forest management plan from the ’20s (stored in the Borgo Valsugana Forest District Archives) reveals that people exerted a large influence on the forest. Forest management plans for the Grigno area were useful in the interpretation of the data obtained through earlier dendroecological research, although events defined in the tree-rings did not always correspond with data from the management plans (yearly thinning, felling, wind-throw damage) as stand-level details were always missing from the plans. These plans dealt with areas of several hectares (Motta et al. 1999).

Despite these limitations, the information included in the management plans is of crucial importance in studying stand history, and only by using all sources of information it is possible to delineate and to identify the most important natural and human features of the history and disturbance that affected the origin and subsequent growth of the forest stands.

In addition to the culture impacts discussed above, the area was also particularly affected by the First World War. Ruins of trenches are still to be seen and it is not infrequent to find in tree stems with the presence of splinters of bursting shells (G. Messina pers. comm.).

Today these areas, formerly kept open due to intensive summer grazing (Fig. 2), are still being re-colonised by the forest, as it is generally the case in many mountain regions in the Alps (Piussi & Pettenella 2000). As a result, large areas of the plateau are covered by forest younger than 100 years (Fig. 3).

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Due to topographic restrictions and the generally youthful nature of the forest, detailed local knowledge of surviving older trees was essential to the success of the isotope part of the project.

Foresters from the Forest Service of PAT took the sampling team to areas where there were large larch (Fig. 4) and beech trees (Fig. 5). Even the largest larch trees, such as the one shown in figure 4, were generally only around 90 years old. Beech trees, such as the one illustrated in figura 5, were either standing or dead and fallen, all with central rot making them difficult to core and even more difficult to measure. Although there was strong beech regeneration in parts of the area indicated in figura 5a, there was no scope for bridging the dendrochronological gap between the living and dead trees.

Attention turned to Norway spruce and Silver fir. As with the larch, it proved very difficult to find any living individuals over 100 years old. The foresters, however, knew of wood piles composed of trees thought to be old, which had been felled in the winter.
of 2004–2005. Two wood piles were inspected, one less than 2 km from the cave (WP1) and the other 4 km (WP2) (Fig. 6). Trees piled at each had not been transported far after felling and the wood piles also permitted easy viewing of stem cross sections (Fig. 7a). Quick ring counts helped to identify a number of trees of around 150 years and older. Large diameter trees were not always the old ones (Cherubini et al. 1996; Rozas 2003; Jimenez et al. 2003) so being able to see the cross-sections saved much trial and error coring. This sampling advantage was offset by the impossibility of coring some trunks lodged within the centre of the wood pile. Another drawback was that bark was sometimes missing from the visible portion of the trunk and species identification could only be confirmed later by microscope examination of the wood structure. In tangential sections, the rays of spruce are seen to be comparatively small – 10–15 (25) cells high – with included resin canals while the rays of fir are 15–25 (40) cells high without resin canals.

Increment cores, 5 mm and 12 mm diameter cylinders of wood, were removed using hand-operated Pressler-type corers (Figs 8a–d and Tab. 1). A few replicate disks were also removed using a chainsaw (Fig. 8e).
3. LABORATORY ANALYSES

Increment cores were taken to the Dendrochronology Laboratory at Manchester Metropolitan University (UK), where they were mounted on wooden channels and sanded using coarse through to fine grit sandpapers to clearly reveal tree-ring wood structure and in particular the boundaries between rings. Tree ring-width measurements were then made for each sample using a measuring stage, binocular microscope and specialist computer software. Measurement started with the innermost ring (ring closest to the centre of the tree/pith) and followed by a series of consecutive rings towards the bark edge.

4. INITIAL RESULTS

A ring-width record was made for each core and individual records were crossmatched (that is compared with others for similarity). Using t-value correlations it was possible to combine contemporaneous series to form site chronologies. Chronologies were successful-
Data produced from all the afore-mentioned analyses will be compared to meteorological data (monthly and annual means) from meteorological stations listed in Table 2 and data obtained from analyses of the speleothems from Grotta di Ernesto.

Table 2 - Meteorological data available for comparison with tree-ring data.

<table>
<thead>
<tr>
<th>Meteorological Station</th>
<th>Data coverage (years AD)</th>
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<tbody>
<tr>
<td>Milan</td>
<td>1812-2004</td>
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<tr>
<td>Trento</td>
<td>1875-2004</td>
</tr>
<tr>
<td>Bienti</td>
<td>1924-2004</td>
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<tr>
<td>Lavarone</td>
<td>1921-2004</td>
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<tr>
<td>Pieve Tesino</td>
<td>1963-2004</td>
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5. FUTURE OBJECTIVES

There is an exciting future for sulphur analyses in tree-rings of specimens collected near a site for which increasing sulphur concentration trends have been detected for the past 100 years from the speleothem archive. It is envisaged that ring-width chronologies already built will be strengthened and it may also be possible to work up tree-ring chronologies for larch and for fir. The tree-ring team is looking forward to collating the results from the range of analyses and to drawing conclusions about past climate in the hinterland of Grotta di Ernesto and about the links Sulphur forges between natural and human modified systems above and below ground.

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