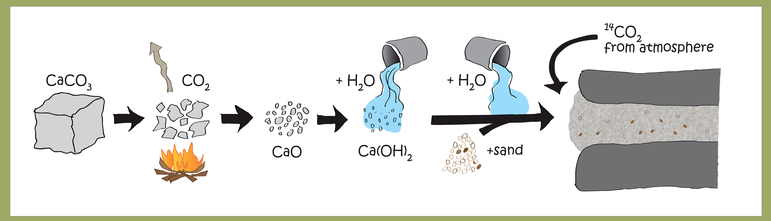
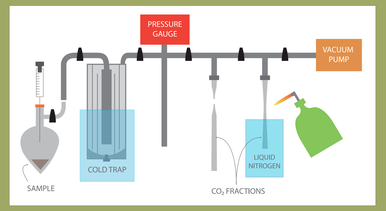
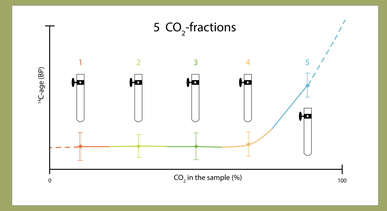
This poster focuses on recent methodological development in dating mortar, exspecially on classical archaeology and the dating of lime lumps embedded in the mortar



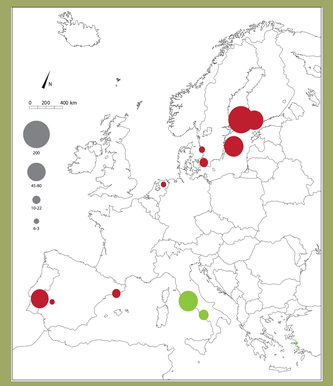
Mortar is not an organic material. Yet the chemical process in the hardening in principle makes it into an ideal matrix for ^{14}C dating. To make mortar, limestone has to be heated up to at least 900 ºC. After the carbon dioxide has been released in the process, calcium oxide (un-slaked lime) is mixed with water and aggregate, usually sand. In the hardening process the slaked lime reacts with atmospheric carbon dioxide, and calcium carbonate is produced. Thus the mortar absorbs the carbon dioxide from the atmosphere and thereafter behaves as if it were organic. Unburned limestone in the mixture can contaminate the result, yielding dates too old.



To avoid the effects of contamination different types of separation are needed. At first a mechanical separation with gentle crushing of the sample. The grains are then sieved into 39/45-75 microns for further analysis. In the following chemical separation 85% of phosphoric acid is poured over the sample, creating a gas of carbon dioxide.



In the process mortar is more easily soluble than limestone, thussthe first fractions should be free from contamination. Therefore, to illustrate the entire dissolution process, the gas-flows interrupted at several stages create a sequence of CO_2 age profiles. The contamination is shown towards the end of the profile.



The International Mortar Dating Project 1994 - Map of mortar dating sites, those in red mark lime mortars, those in green pozzolana mortars.

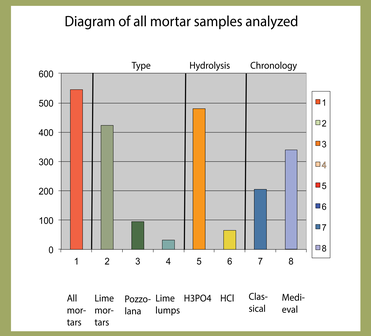


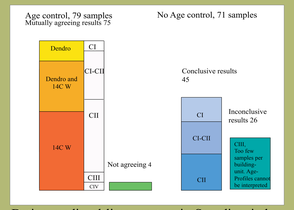
Diagram displaying mortar samples analyzed. By now the databank covers results from more than 550 analyses of some 470 individual samples. Some of the samples were analyzed repeatedly, in different laboratories. The samples include different sorts of mortar, and they cover both Classical and Medieval archaeology.

Recent Advances in Radiocarbon Dating of Ancient Roman Mortar and Concrete

Åsa Ringbom, Åbo Akademi University, Finland
John R. Hale, University of Louisville, Kentucky

Why mortar?

The aim of archaeological excavations is often to establish the chronology of a site. Mortar, lime mortar or pozzolana mortar, is often the only datable material available, in abundance, from all the different building stages. Differently from other datable materials like dendrochronology and ^{14}C of organic materials, and differently from archaeological artifacts such as coins and ceramics, mortar analysis dates the actual time of the construction, or when the mortar hardened. It would therefore be helpful to use mortar dating on a routine basis in archaeological excavations or in a process of conservation.



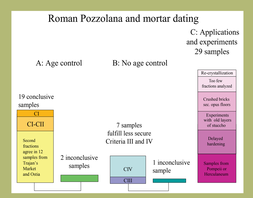
Dating medieval lime mortars in Scandinavia has yielded promising results.More than 96% if all the results agree with age control from other dating methods, as shown from the Åland Islands between Finland and Sweden

Reliability criteria for the interpretation of the age profiles

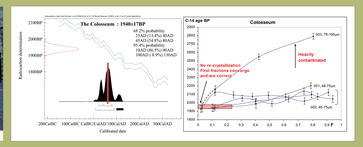
Criterion I: when analyzed in two to five CO_2 fractions and the results from the two first CO_2 fractions agree

Criterion II: when there is mutual agreement between the dates of the first CO_2 fractions in a seriesof three or more samples from one single building.

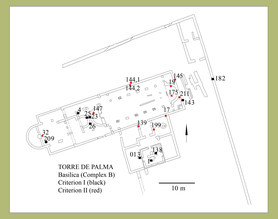
Criterion I and II yield a conclusive date independently of age control.



Dating pozzolana mortars, however, was problematic. Only some 50% of all samples could be considered successful, and the interpretation of the CO_2 age profiles was seen as complicated.

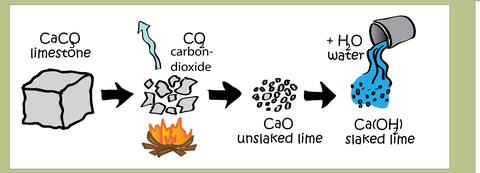


The mortar dating group, Lynne Lancaster, Jan Heinemeier, Åsa Ringbom and Alf Lindroos outside the Colosseum, where successful results meet the demands of Criterion I and Criterion and II, and the calibrated result agrees with written sources.



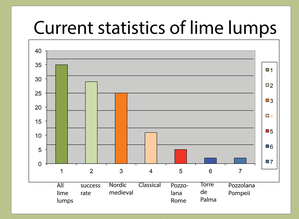
The Roman Villa of Torre de Palma, Portugal, mortar analyzed in 1997-2000, was our first encounter with Classical archaeology. Out of a total of 64 samples analyzed 18 yielded Criterion I results. Independently of other materials and methods these 18 samples could indicate the date of 12 out of 21 structures, thus marking the outlines of the chronology of the site. The earliest structure was the temple in the East Court (70-170AD), and the latest are the apse 3 of the Basilica (580-630AD) and the large font of the Baptistery (570-690AD).

Lime lumps embedded in mortar

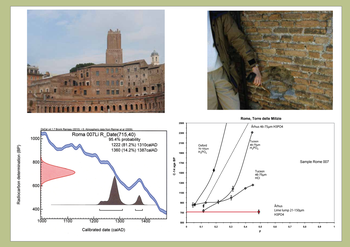


Why lime lumps?

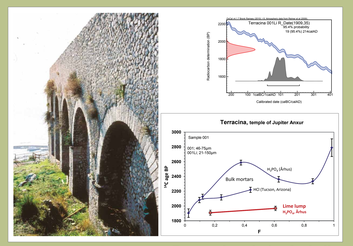
Lime lumps embedded in the mortar are highly interesting in this context. There may still be clods of quicklime in the putty, which become slaked and carbonated possibly already before the aggregate is added. These form aggregate free white lumps in the mortar. In principle therefore well-burnt lime lumps should be free from contamination.



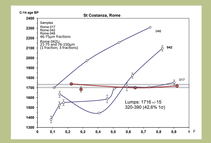
Statistics of results from 32 liumps embedded in the mortar. 25 lime lumps were identified in lime mortars, whereas 7 were embedded in pozzolana mortars. Of these 32 samples, 7 had been exposed to fire. The majority comes from medieval Scandinavia.

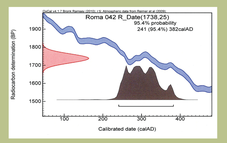


Torre delle Milizie, Rome, The result of Rome 007Li, (Li=lime lump) as compared to analysis of Rome 007 from different AMS laboratories (Aarhus, Denmark, Oxford UK, Tucson Arizona). The lime lump analysis supports our earlier interpretations - that the top of Torre delle Milizie was erected towards the end of the 13th century.



Terracina, Temple of Anxur. Repeated analysis of a bulk sample of pozzolana mortar (Terracina 001)resulted in two different looking age profiles, which seemed to converge at the first CO_2 fractions. A lime lump embedded in the pozzolana confirmed the earlier interpretation.





Santa Costanza, at Via Nomentana, Rome. The age of construction is debated. It was built as a mausoleum either by Constantina, daughter of Constantine the Great, before 350, or by her brother–in–law Julian the Apostate some 10-12 years later. Mortar samples were analyzed in Oxford, Tucson and Aarhus all forming confusing age profiles. The lime lump Rome 042 was analyzed twice, resulting in an almost horizontal age-profile, which is easy to interpret. But because the calibration curve wiggles at this point the result is not helpful enough in pinpointing the chronology. We can never defeat the irregularities of the calibration curve.

Conclusions:

a) Medieval lime mortars in Scaandinavia and Classical mortars based on marble (Torre de Palma) have yielded promising results.

b) Hydraulic Pozzolana mortars have been less successful.

c) Pozzolana mortars from Pompeii and Herculaneum cannot be dated, regardless of whether bulk mortars or lime lumps embedded in the mortars are used.

d) Lime lumps embedded in the mortar have shown a great deal of success, both in lime - and pozzolana mortars. Lime lumps generally contain very little contamination from unburnt limestone, thus fewer CO_2 fractions are needed, thus cheaper.

e) Above all, for pozzolana mortars analyzing lime lumps may be the obvious solution.

A Mortar Dating Workshop in Åland, 2006: Fiona Brock, John R. Hale, Jan Heinemeier, Åsa Ringbom, Alf Lindroos and Pia Sonck-Koota.