Radiocarbon dating of mortar: Case study of the Aqueduct in Skopje

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About the Aqueduct

- One of the landmarks of Skopje, FYR Macedonia
- More than 380 m long; it was a part of a water-supply system with a length of about 10.0 to 10.5 km
- In the northwestern part of Skopje
- Has two access ramparts, 53 pillars, 54 base vaults and 42 smaller vaults on the closed and open discharging openings above the pillars

Justinian I
(AD 527 - 565)

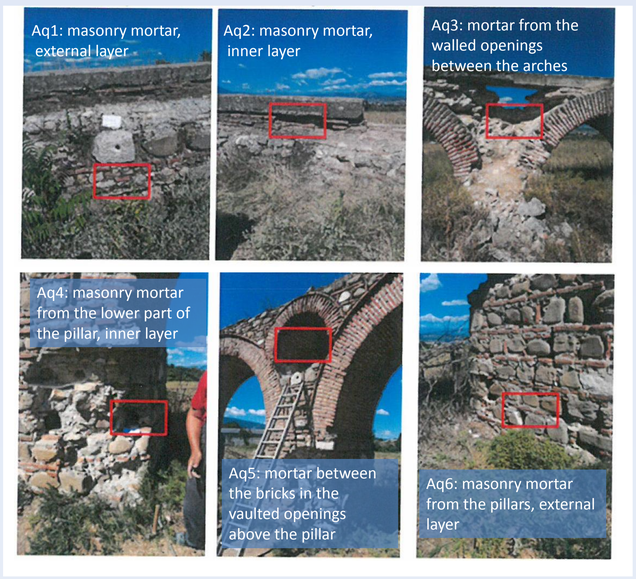
Bayezid II
(AD 1481 - 1512)

Presumed dates

- 6th c. during the urbanization of Skopje by the Byzantine Emperor Justinian I
- 15th c. by Mustafa Pasha (known by the Mosque in Skopje built in AD 1492, Vizier under Bayezid II)
- 16th c. Isa-Beg's water supply system

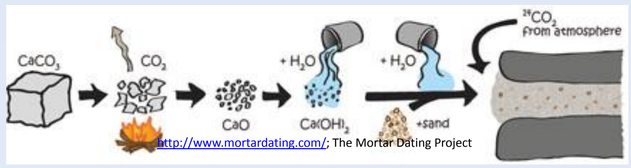
Sampling

- 6 mortar samples from the eastern facade
- By use of hammer and chisel from the ruined parts of the construction
- Weight of each sample was 150 – 200 g



The sampling position on the eastern facade of the Aqueduct

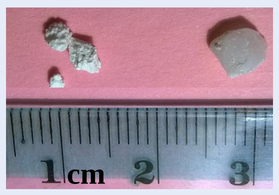
Basis for ^{14}C mortar dating



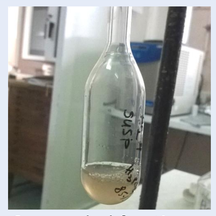
Principle how the atmospheric ^{14}C gets into mortar, enabling mortar dating

^{14}C analyses strategies

- Cryosonic breaking
- Search for inclusions as the most reliable part
- Using ^{13}C as a guide for reliability of the results
- Combination of two methods: (1) selecting the first portion of produced CO_2 when hydrolyzing with acid[1] and (2) selecting the smallest particles[2]



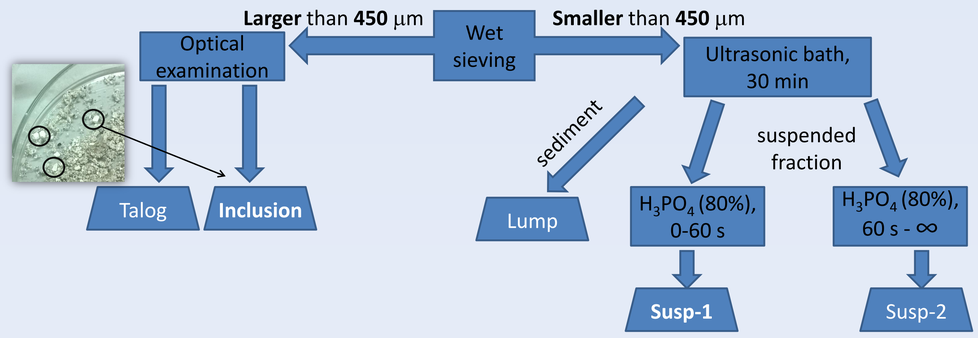
Inclusion and unburned limestone



Suspended fraction in a reaction vessel

Sample preparation

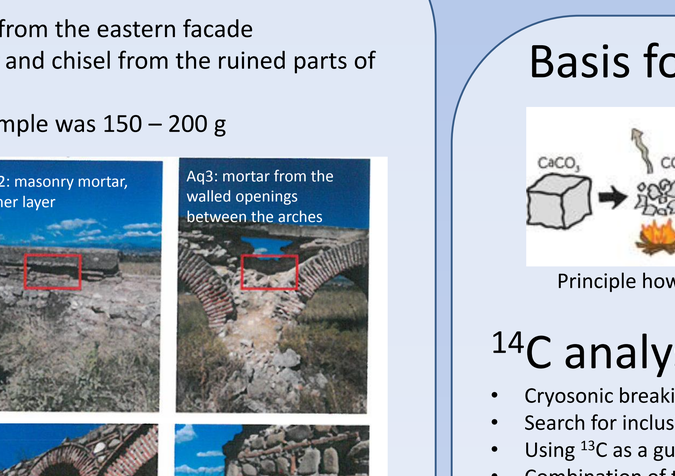
- Surface subsampling 10 – 15 g
- Cryogenic breakdown (N_2(l) <-> 80 °C) and "gentle" hammering
- Fraction separation



Fractions larger than **450** μm

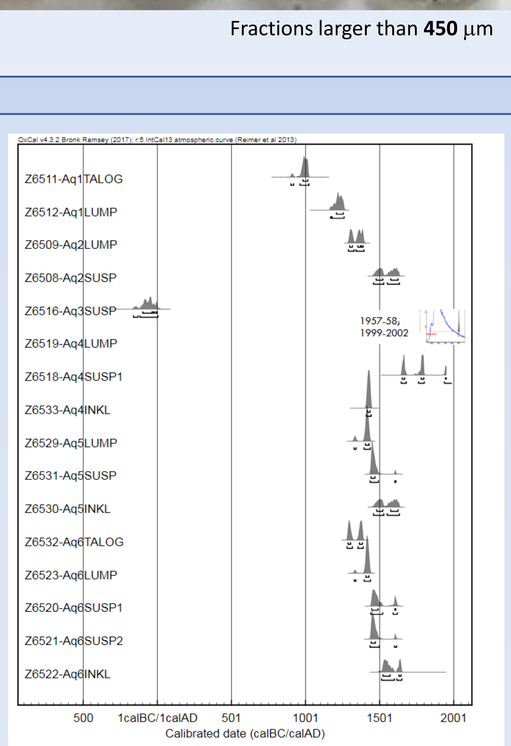
Results and discussion

- Inclusions were found in Aq4, Aq5 and Aq6
- Susp-1 was not produced for Aq1 (error during target production, not enough material left)

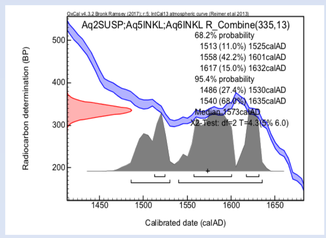


• Aq 4 was dismissed because of negative $\delta^{13}C$ results and modern date for the Lump

$a^{14}C$ results for all the analyzed fractions



Calibrated dates for all the fractions

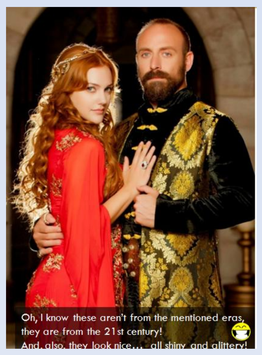


The OxCal Combine function of Aq5 and Aq6 inclusions and Susp-1 Aq2

Conclusions

- $\delta^{13}C$ points to the reliability of the radiocarbon results
- Inclusions are a good material, but **ALWAYS** need to be compared to the other fractions
- CRYOSONIC method (in two cases): $a^{14}C$ of SUSP were lower than $a^{14}C$ of inclusion fractions but within 3 sigma range

The most plausible date of the Aqueduct is 15-16 cent.
The analyses ruled out the Byzantine times.



References

[1] A. Ringbom, A. Lindroos, J. Heinemeier, P. Sonch-Koota, 19 years of mortar dating: Learning from experience, *Radiocarbon* (2014) 619

[2] F. Marzaioli, S. Nonni, I. Passariello, M. Capano, P. Ricci, C. Lubritto, N. De Cesare, G. Eramo, J.A. Quiros Castillo, F. Terrasi, Accelerator mass spectrometry ^{14}C dating of lime mortars: Mineralogical aspects and field study applications at CIRCE, *Nucl. Instr. Meth. Phys B* (2013) 246