Combining the Use of Fourier Transform Infrared Spectroscopy (FTIR) and Thin-section Analysis to Study Underwater Materials, Dor North Bay, Israel

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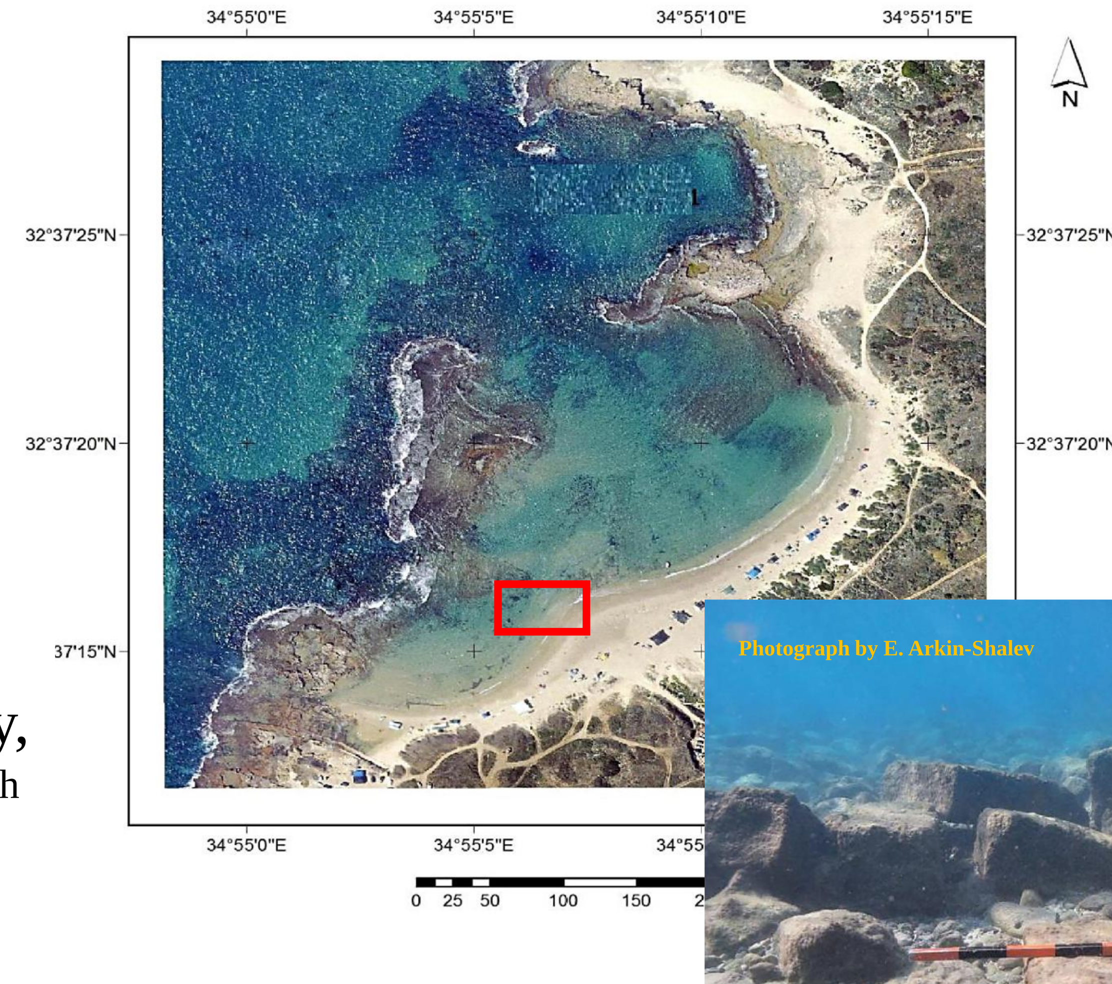
Background: Techniques applied to material studies in archaeology are often deployed to reveal information embedded in artifacts; beginning from their manufacture through their use, up to their discard and post-depositional changes. Here we present two case studies in which such techniques have been applied to underwater archaeological artifacts to facilitate understanding of diagenetic changes in waterlogged pottery and to assign origins for ballast stones.

Study Area, Materials and Methods: The research was conducted following an underwater survey in the North Bay of Tel Dor, Israel. A submerged pile of ashlar stones, ballast stones, and ceramics was identified, mapped and sampled. Based on ceramic typology, the pile formed during maritime activities in the Late Roman and Byzantine periods (1st to 7th century AD). 31 ceramic sherds and 37 ballast stones were sampled and studied using FTIR spectroscopy and thin section petrography. While these methods are often used in-tandem in terrestrial archaeology, here we present their first complementary application in the study of underwater archaeological materials in the Eastern Mediterranean Sea.

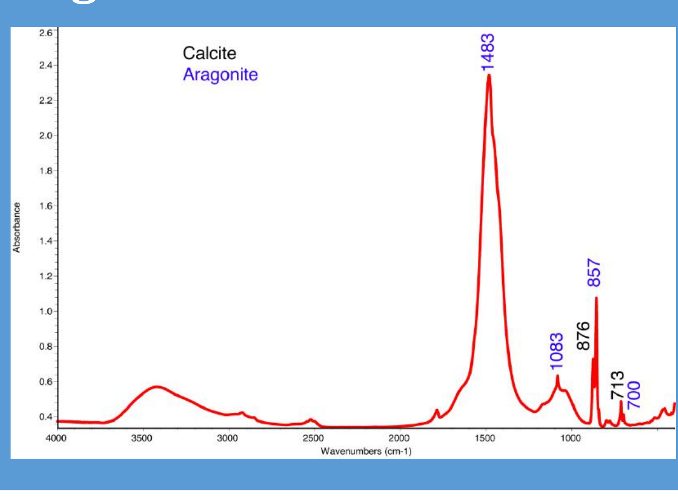


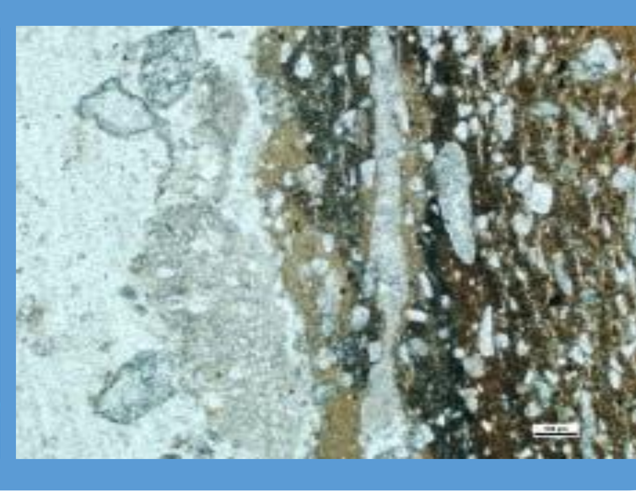
Results: Certain minerals were either easier to identify, or only identifiable, using FTIR, whereas other minerals where only identifiable using thin-section petrography. See the examples below:

Carbonate minerals: Calcite ($CaCO_3$), Aragonite ($CaCO_3$) and Dolomite ($CaMg[CO_3]_2$)

Biogenic crust on pottery:
- Petrography indicates general carbonate
- FTIR shows aragonite with traces of calcite

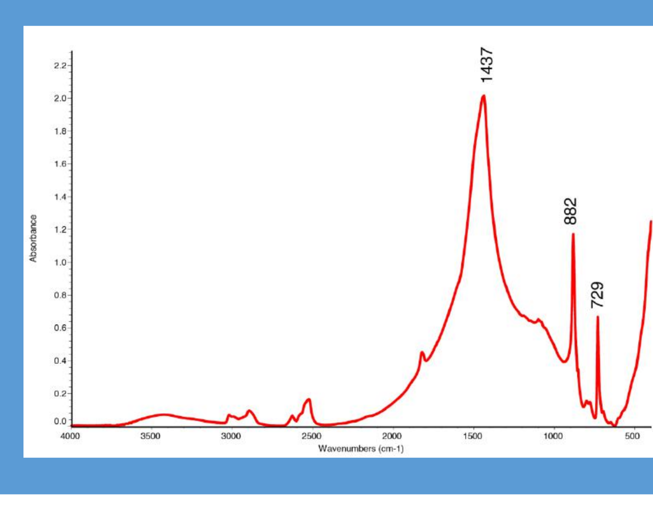
May be also used to distinguish thermal alteration of marine shells; thus pottery firing temperature





Ballast stone:
- Petrography indicates calcite with dolomite trace
- FTIR shows dominance of dolomite

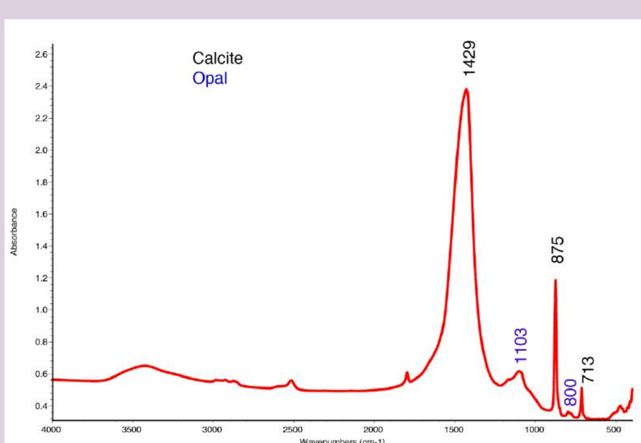
A dolomitic marble ballast stone was identified in this way

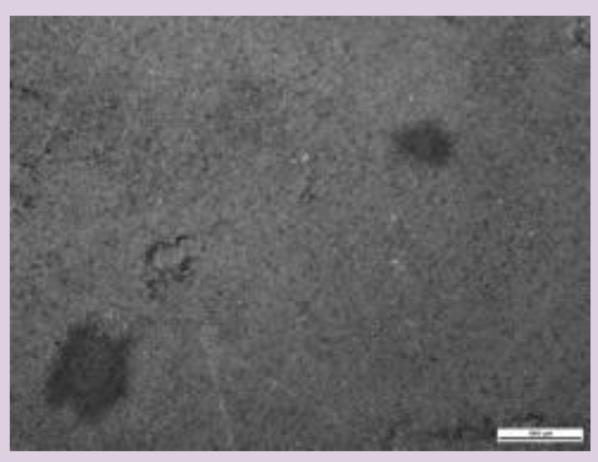


Opal (amorphous silica, $SiO_2 \cdot nH_2O$)

Ballast stone:
- Petrography indicates calcite
- FTIR shows trace of opal and clay

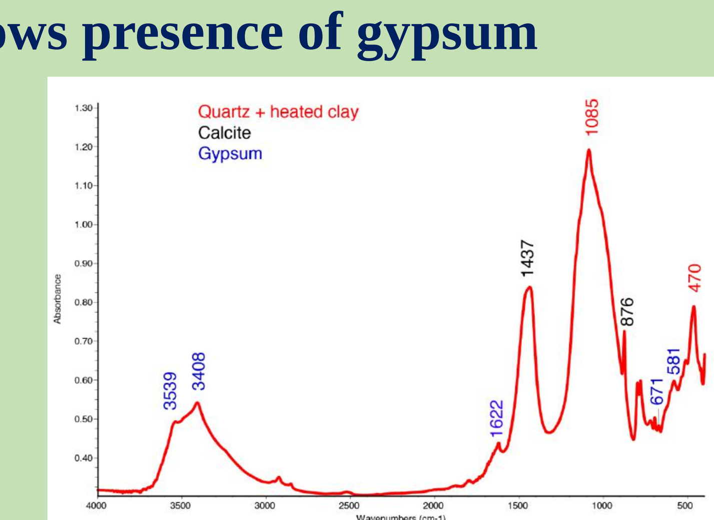
Association of calcite, opal and clay is typical of Eocene chalk outcrops in the Eastern Mediterranean

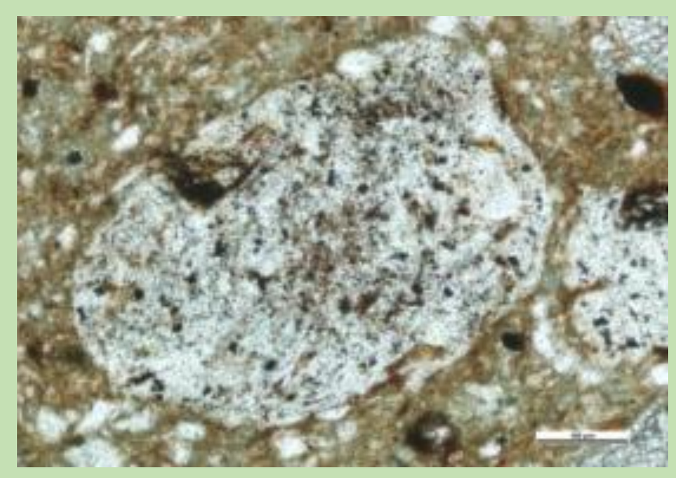




Gypsum ($CaSO_4 \cdot 2H_2O$)

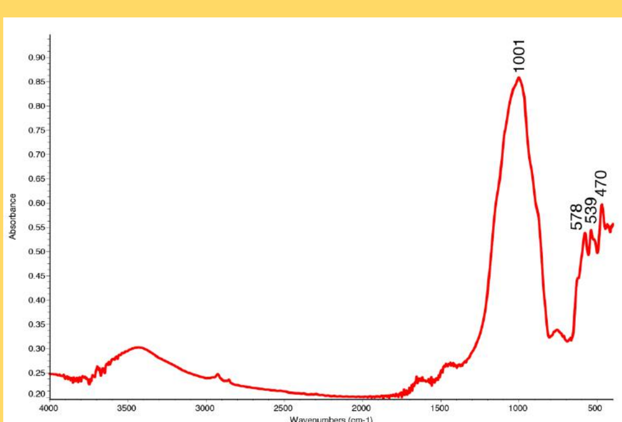
Grain within ceramic sherd:
- Petrography indecisive whether flint or gypsum
- FTIR shows presence of gypsum





Magmatic and metamorphic rocks

Ballast stones:
- FTIR spectra are broad (low crystallinity) and complex (mineral mixtures)
- Petrography is irreplaceable here

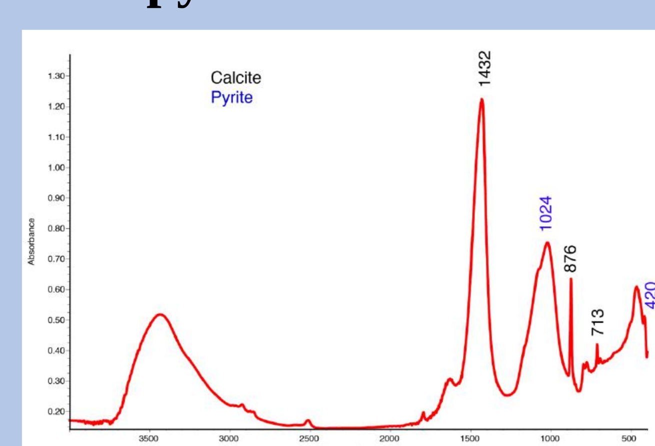


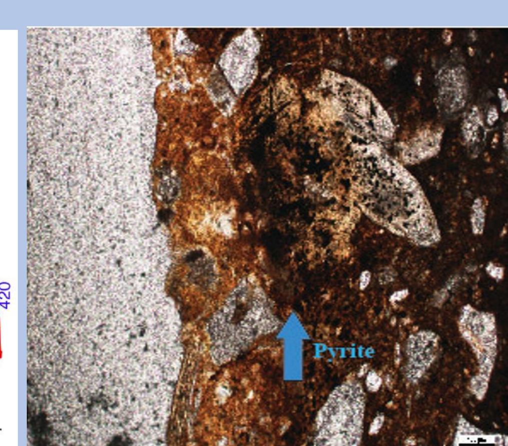
Basalt

Authigenic pyrite (FeS_2)

Marine waterlogged ceramic sherds:
- Petrography masked by unidentified black mass
- FTIR hints to presence of pyrite

Main absorbance band of clay shifts to 1024cm^{-1} hampers reconstruction of pottery firing temperature





Conclusions:

- The complementary nature of the two methods resulted in high-power mineralogical identification in both ceramics and ballast stones.
- The advantages of FTIR over the commonly used XRD technique for mineral identification is a faster turn-around time between sample preparation and results (ca. 5 minutes), a cheaper instrument and the ability to detect amorphous minerals (e.g., opal).
- We identified two main diagenetic processes affecting waterlogged ceramics, precipitation of pyrite and oxidation of pyrite.
- 20 ballast stones are eolianite beachrock and other sedimentary rocks which probably originated locally and as far as the Lebanese southern coast. The other 17 are magmatic and metamorphic rocks which may be sourced to the following general regions: Syria (Palmyrides, Bassit-Baer Massif), Cyprus (Troodos Ophiolite, Kyrenia Ridge, Mamonia Complex), Turkey (Menderes Massif, Marmara Island), Aegean Islands (Thasos, Paros, Egeo, Delos, Skyphos), Crete (Ntikali), Italy (Carrara), Greece (Abdera), and Egypt (Nile River Valley, Aswan).

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