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Recent Progress in Application of "Demokritos" TANDEM Accelerator to Earth and Environmental Sciences

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Scientific domain: Mineral surface science, Environmental Mineralogy-Geochemistry, Nanogeoscience

Goal: Elucidation of chemical processes on mineral and rock surfaces, related to dissolution, sorption, and crystal growth phenomena (e.g. interaction with hazardous heavy metals and radionuclides)

Beams: p, d, ^{12}C

Targets: Chemically-modified mineral crystals, rock specimens and metals

Personnel: Senior scientists, 1 PhD student, 1 MSc student, 2 Diploma students

Techniques: NRA, RBS, PIXE complementary supported by *in-situ* AFM, XPS, Laser μ-Raman, solid-state MAS NMR, μ-IR, EPR, XANES/EXAFS, etc.

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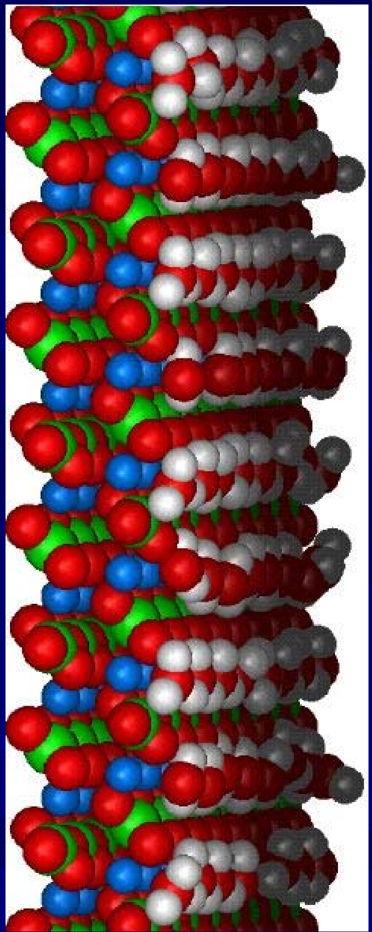

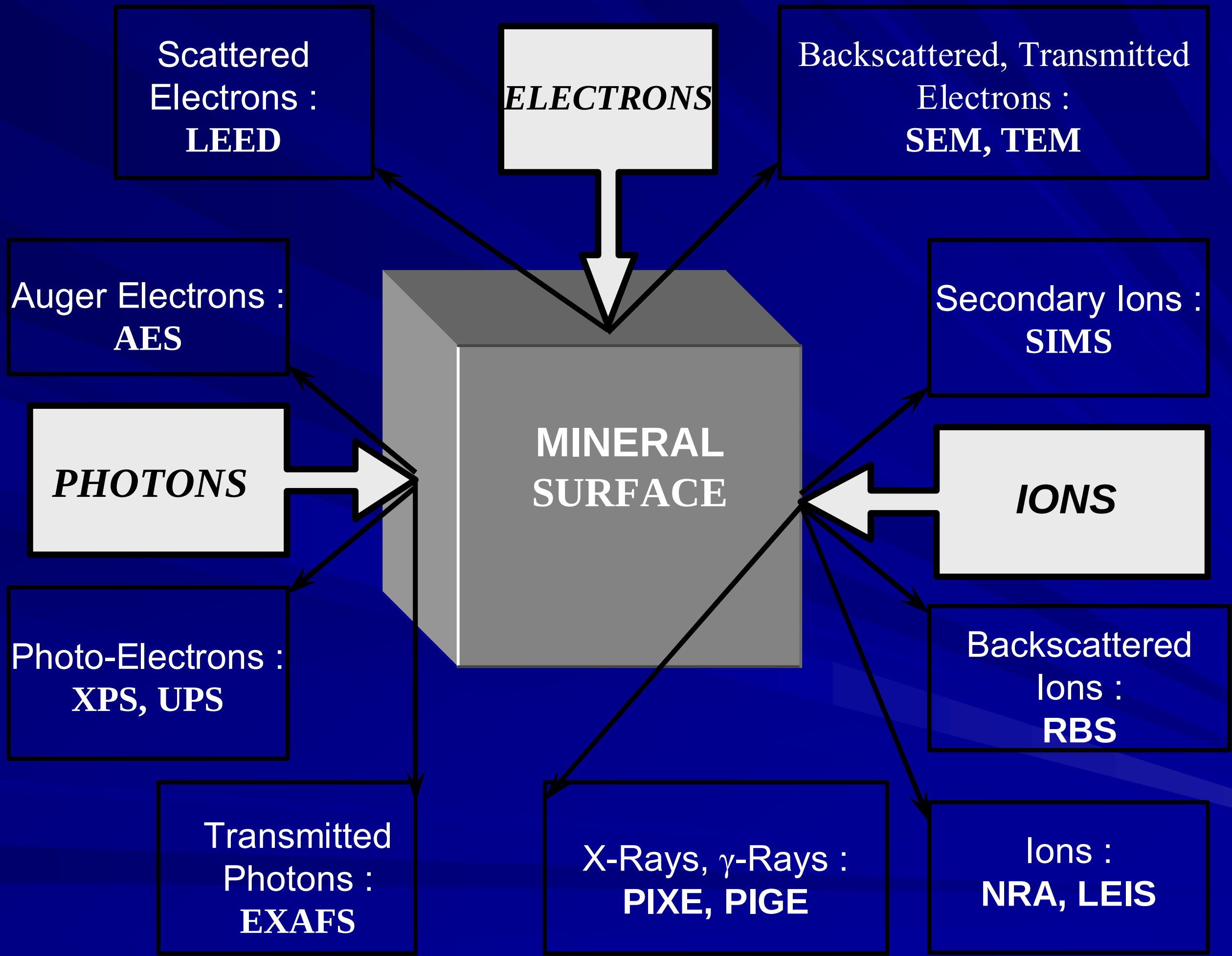

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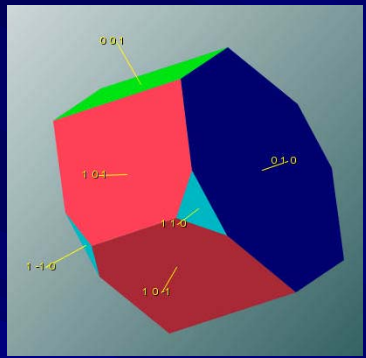
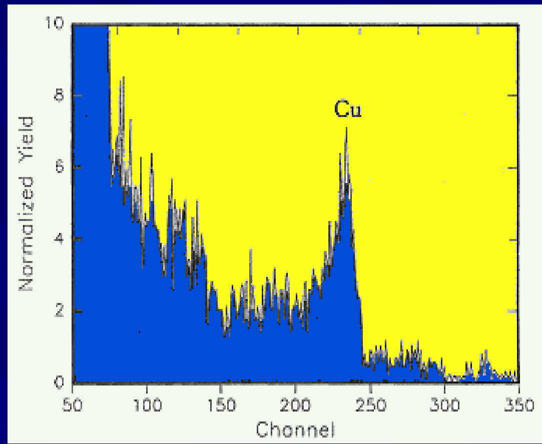
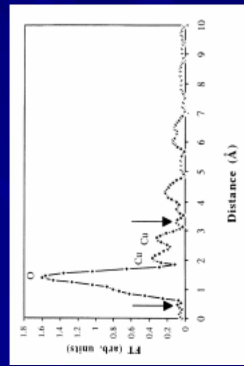
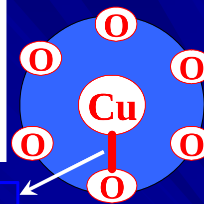
Chemically modified microporous/nanoporous aluminosilicate minerals (zeolites, etc.)

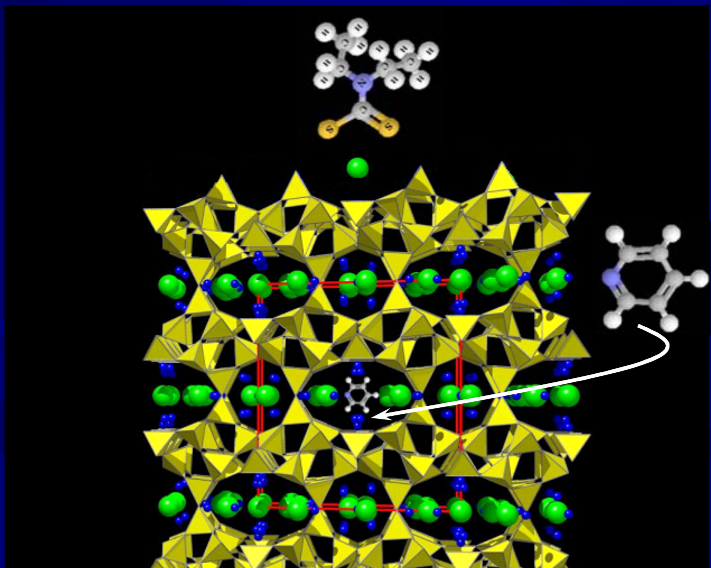


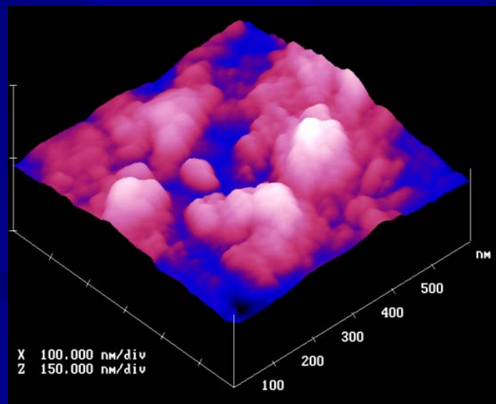


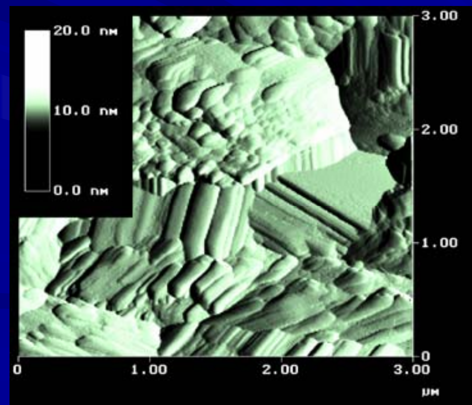




1.88 ± 0.02 Å







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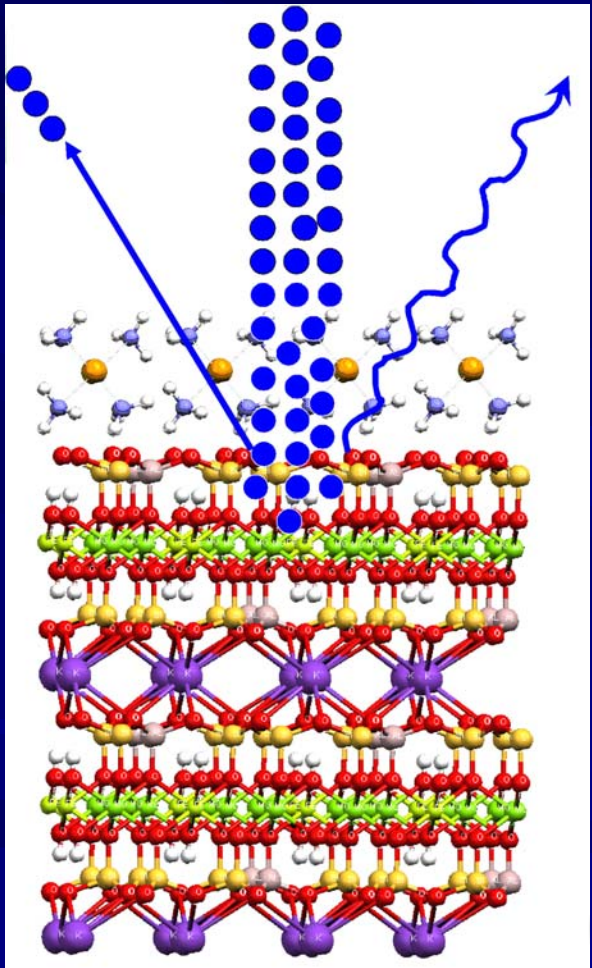
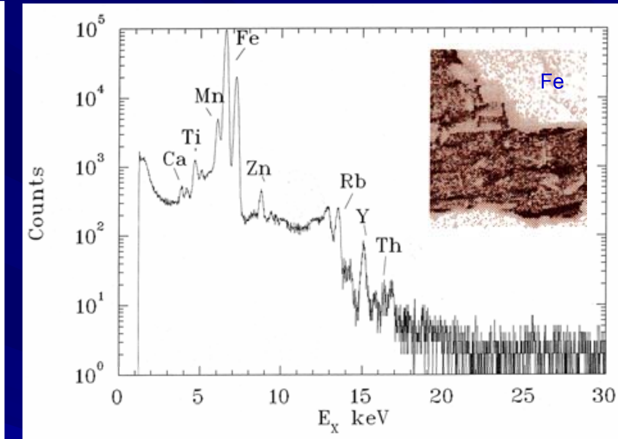
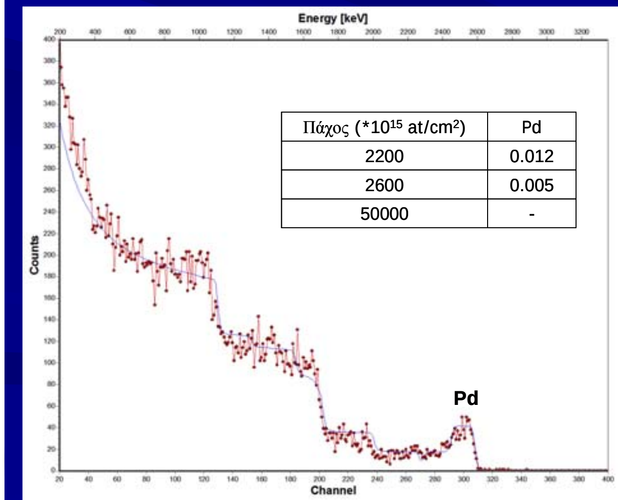
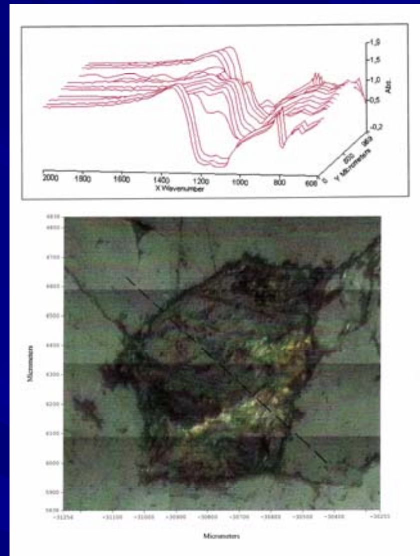
Granitic layered silicate minerals and dissolved heavy metal ions (biotite etc.)

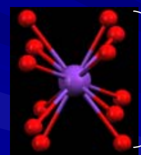


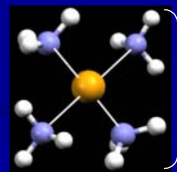




Πάχος ($*10^{15}$ at/cm^2)	Pd
2200	0.012
2600	0.005
50000	-







$Pd(NH_3)_4^{2+}$

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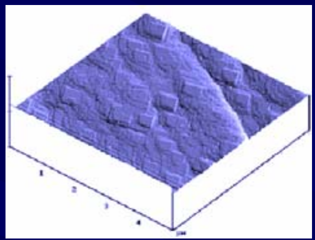
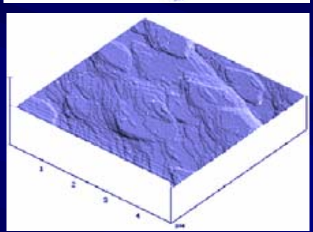
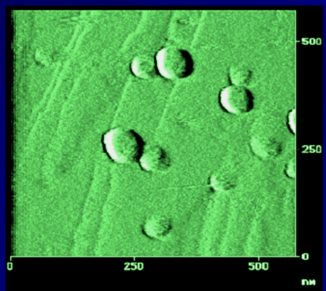
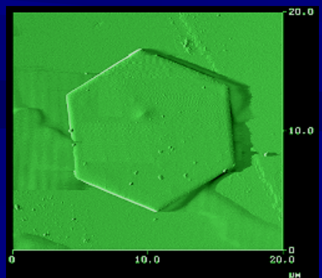
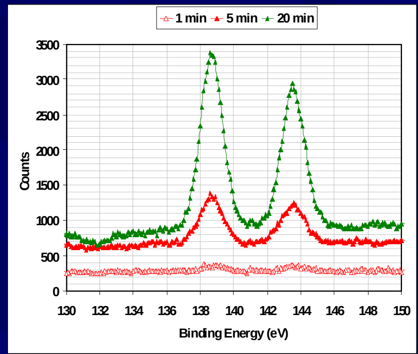
Carbonate mineral surfaces (e.g calcite) and dissolved heavy metal ions (e.g. Pb^{2+})

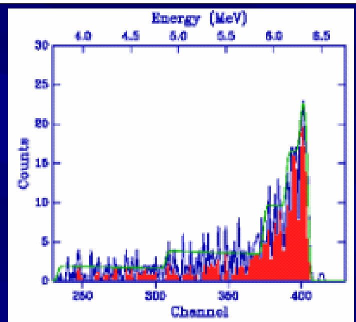


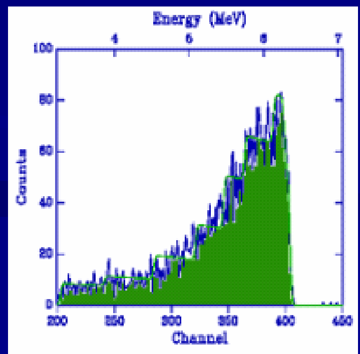


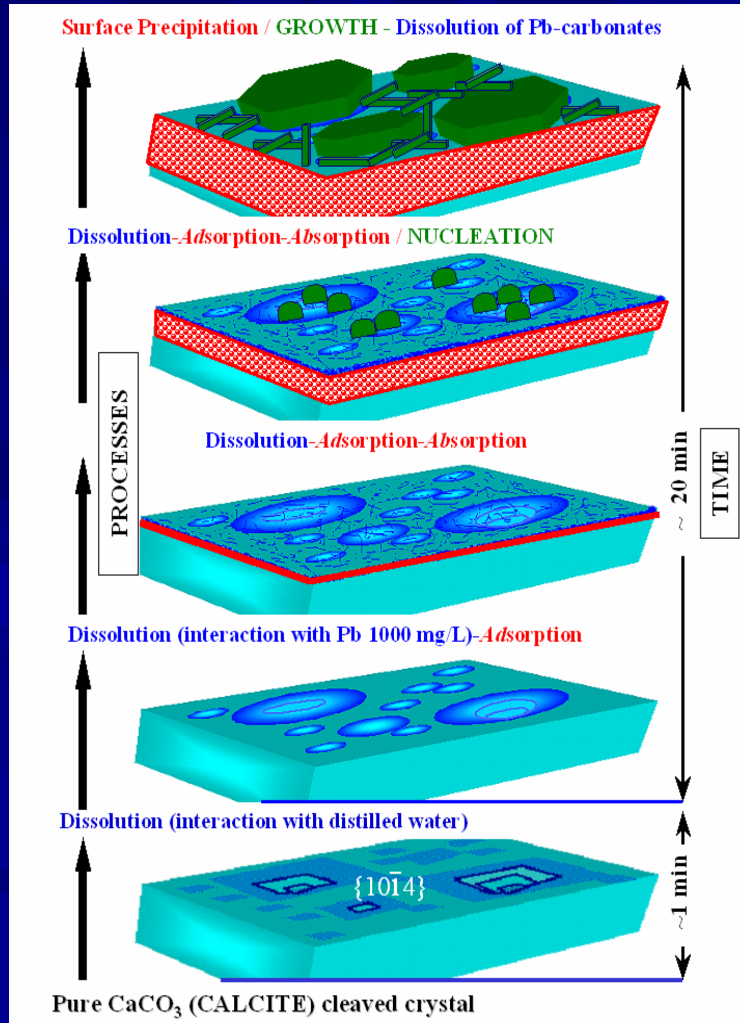






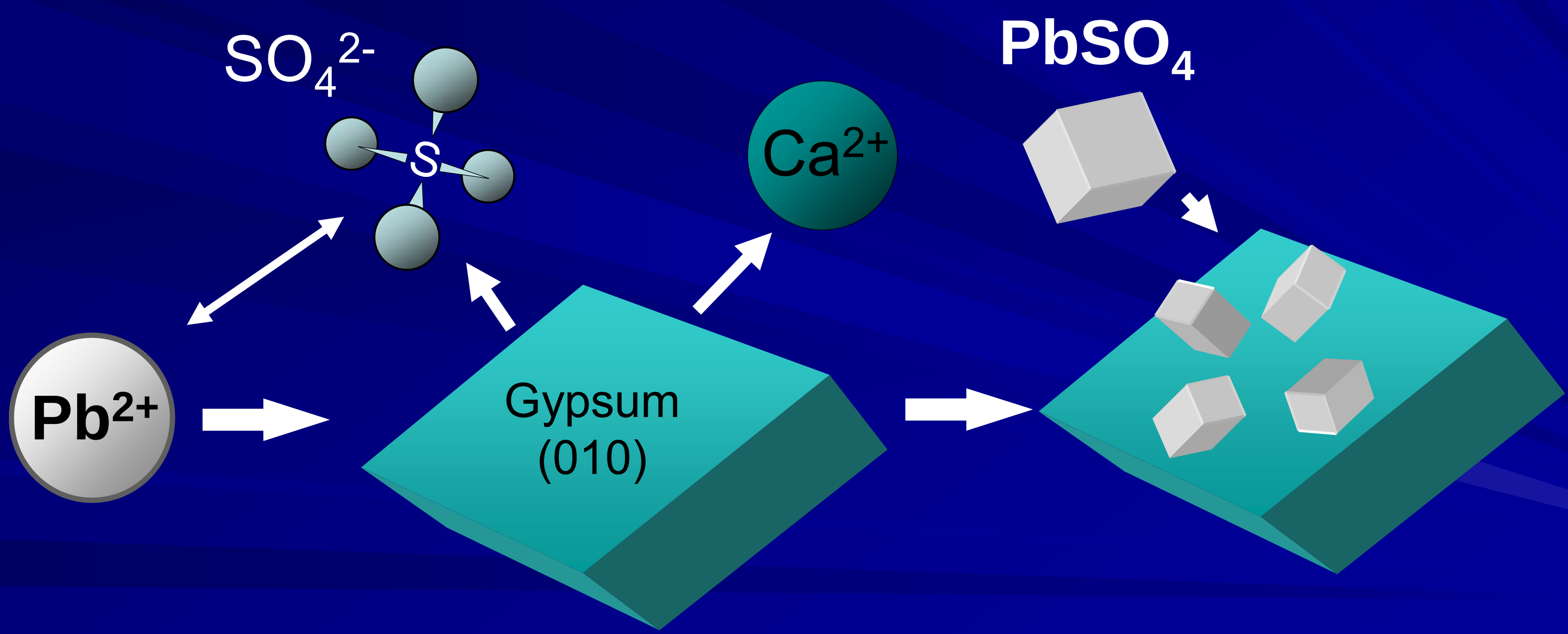






Sulphate mineral surfaces (e.g. gypsum) and dissolved heavy metal ions (e.g. Pb^{2+})

Pb Removal by Gypsum



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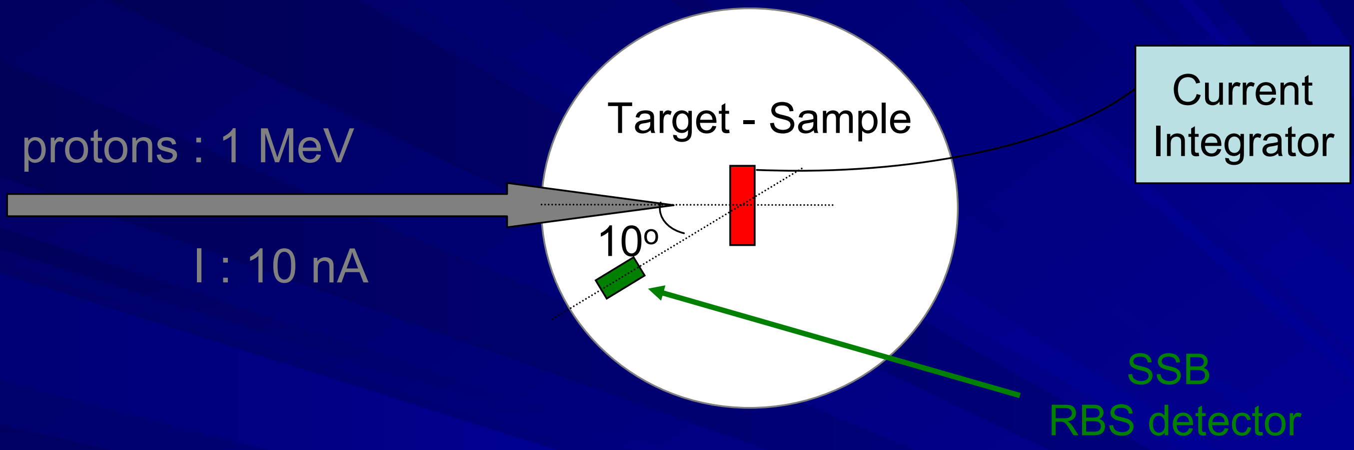

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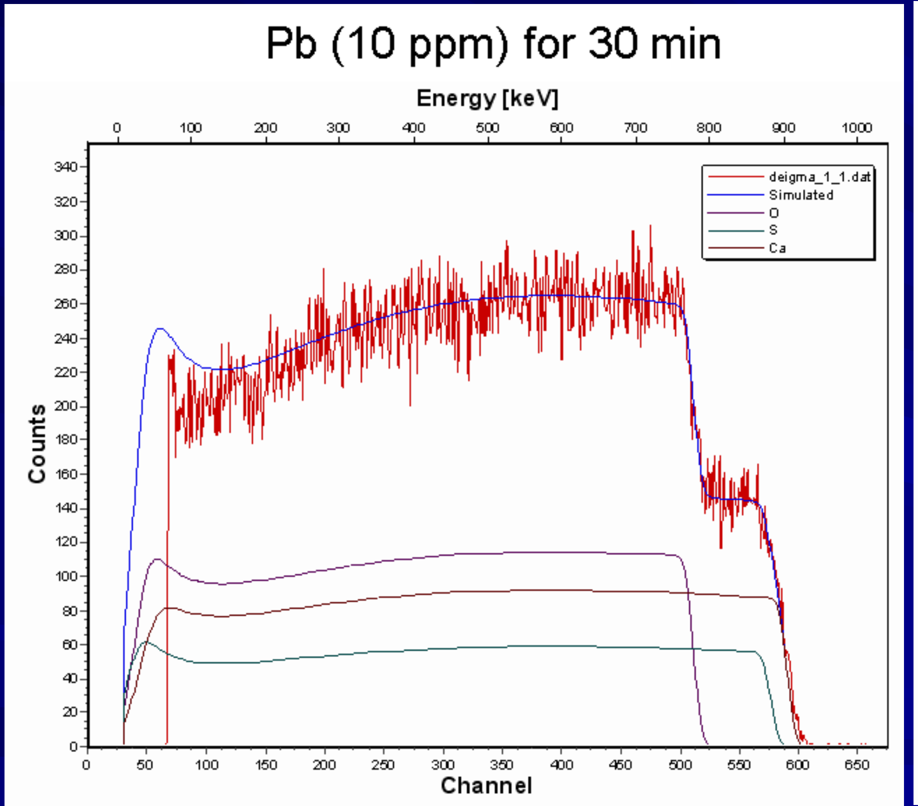

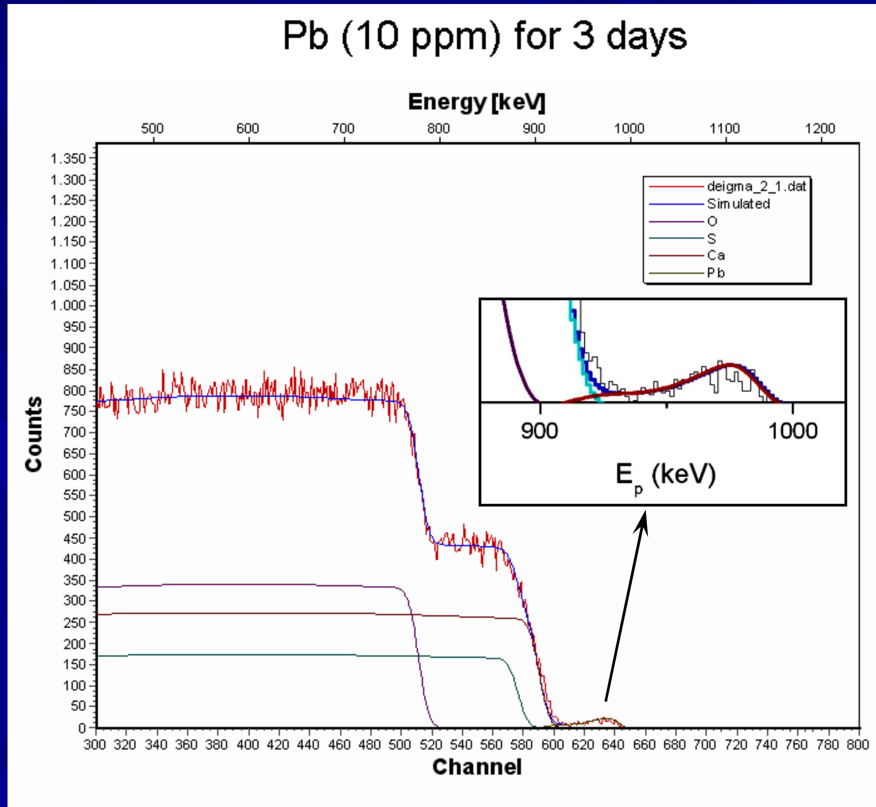

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Carbonate rock surfaces (marbles, limestones) and dissolved heavy metal ions

Thasos island snow-white dolomitic marble ("Thasian Marble")

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Carbonate rock surfaces (marbles, limestones) and dissolved heavy metal ions

Roman, 190 AD

Thasian marble sculptures in European and American collections: isotopic and other analyses

Robert H. Tykot, John J. Herrmann, Jr., Nikolaas J. van der Merwe, Richard Newman, and Kimberly O. Allegretto

Abstract No single analytical technique is usually sufficient to attribute a marble object unambiguously to a particular quarry source in the Mediterranean world, and a number of research groups have emphasized the importance of using a multi-method approach. One exception to this rule is Cape Vathy on the island of Thasos in the northern Aegean, an important marble source in antiquity. Cape Vathy appears to have been the only significant source of dolomitic marble used in the Mediterranean region. Stable isotope analyses of classical sculptures made of dolomitic marble are all consistent with a Thasian origin, indicating that a simple, inexpensive, and essentially non-destructive "dolomite test" can be used to determine whether a marble piece is from Cape Vathy.

Several hundred samples were collected from Greek and Roman statues and reliefs, in museums and private collections in Europe and the United States, that appeared to have been carved in marble from Cape Vathy on Thasos. X-ray diffraction (XRD) was used to test for the presence of dolomite, with the finding that 75% of the "Thasian"-appearing sculptures were in fact dolomitic. Stable isotope analyses of the dolomitic sculptures have reconfirmed their Thasian attribution; these analytical data serve to further refine the isotopic field for Thasian marble and may potentially allow the identification of discrete quarry areas exploited at different times in the past. Isotopic analyses of the calcite marble sculptures add to the more than 100 analyses that we have reported at ASMOSIA III and IV. As the number of sculptures with quarry attributions grows, contributions are made to our understanding of chronological, geographic, and art historical patterns in marble use.

INTRODUCTION

This report is based on the continuing interdisciplinary collaboration, now a decade old, between the Museum of Fine Arts, Boston, Harvard University, and, recently, the University of South Florida. This collaborative effort integrates the research interests of art historians, archaeologists, and laboratory scientists in the sources and exploitation of marble in classical antiquity, and exemplifies the purpose of ASMOSIA.

The marble used for Greek and Roman sculptures and architectural elements was obtained from many different quarries in the Mediterranean region, with the exploitation of individual quarries dependent on their geographical and political location, the color and texture of the marble, and the chronological period in question. A sculpture without archaeological provenance potentially could have been made of marble from any of more than 30 quarries in the Mediterranean region. The identification of the quarry source of a particular marble sculpture may be useful as a test of authenticity when archaeological provenance is uncertain, for the assessment of composite restorations, and as a means of corroborating stylistic analysis. The compilation of quarry provenance information on large numbers of sculptures allows the reconstruction of exploitation patterns and provides important insights into the nature of the Greek and Roman economy.

A single analytical technique, however, is rarely sufficient to attribute a provenance for a marble object unambiguously. The elemental and isotopic compositions of many quarries overlap with one another, as do the physical properties revealed by cathodoluminescence, electron paramagnetic resonance spectroscopy, and other methods.

We have previously emphasized the use of a minimally destructive, integrated approach using stylistic analysis, literary information, and archaeological data in conjunction with grain-size determination, XRD, and stable isotope analysis (Tykot et al., 1999; van der Merwe et al., 1995, 1999). For both XRD and stable isotope analysis, we have typically obtained powdered samples of a few milligrams or less. This approach has enabled us to analyze several hundred marble sculptures from a number of American and European collections, a number that would not have been possible if larger, solid samples were required. We are continuing to

Thasos island snow-white dolomitic marble (“Thasian Marble”)

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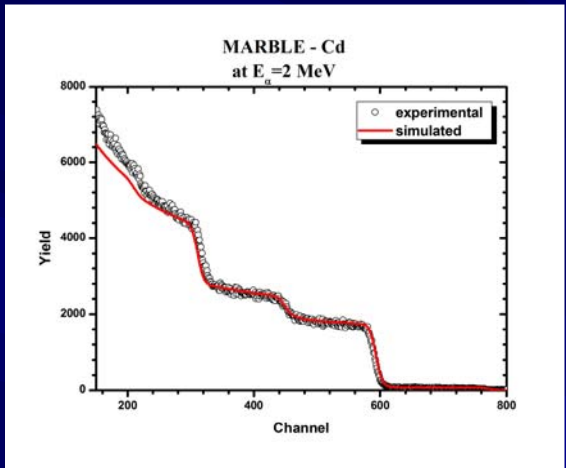
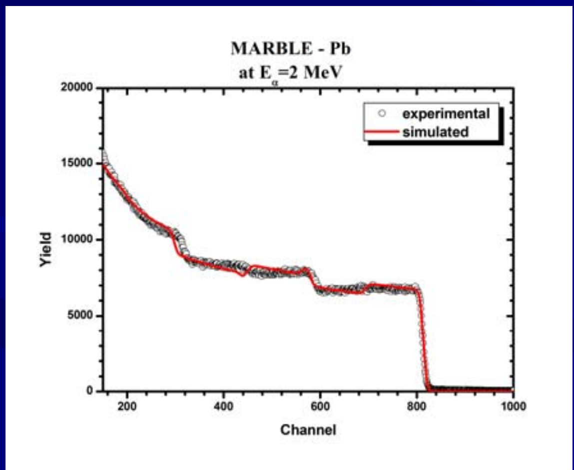
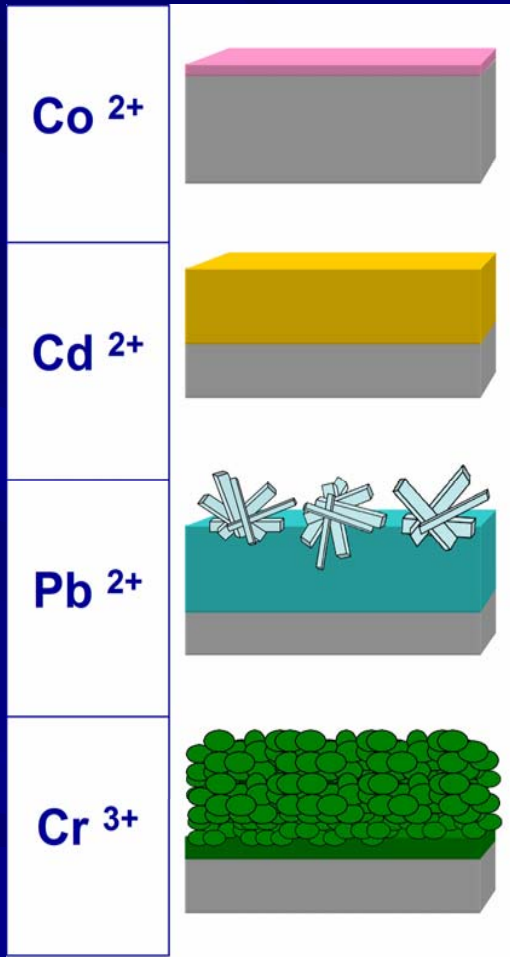
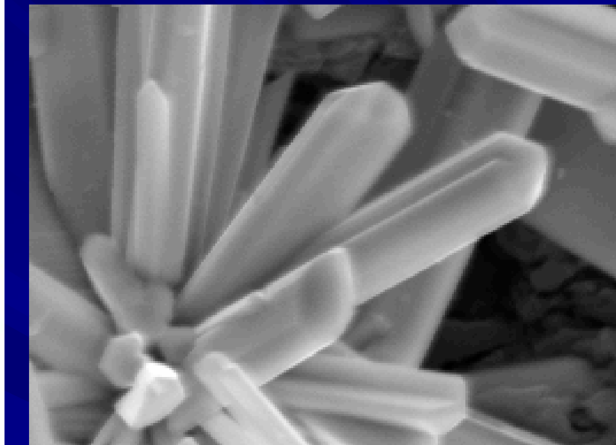
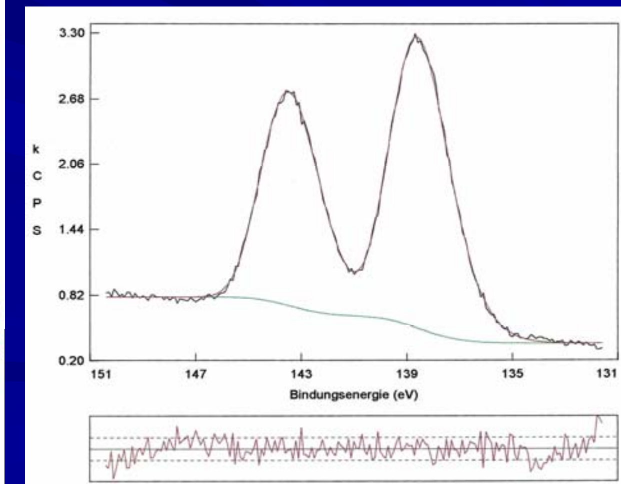
Carbonate rock surfaces (marbles, limestones) and dissolved heavy metal ions











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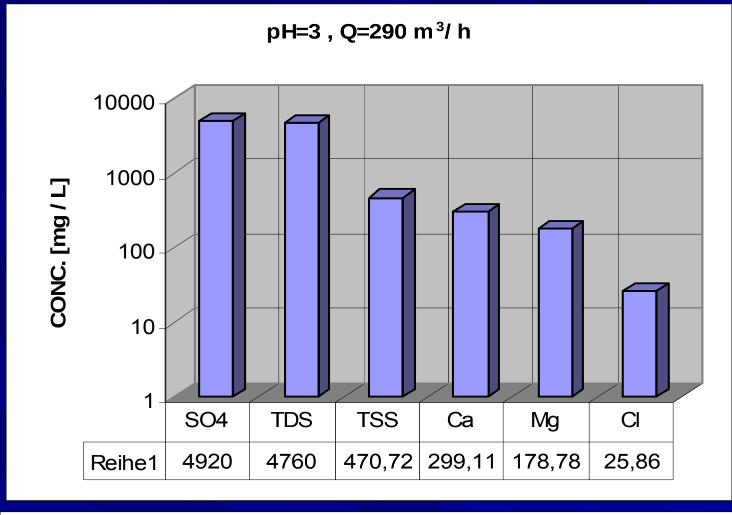
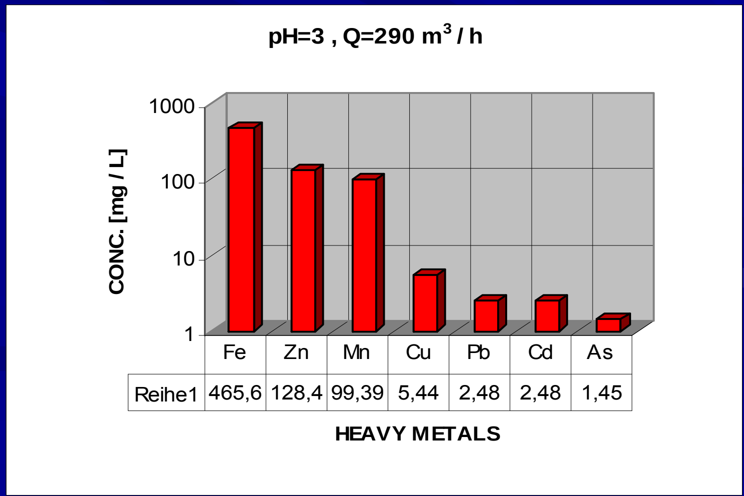
Mineral surfaces and Acid Mine Drainage (AMD)





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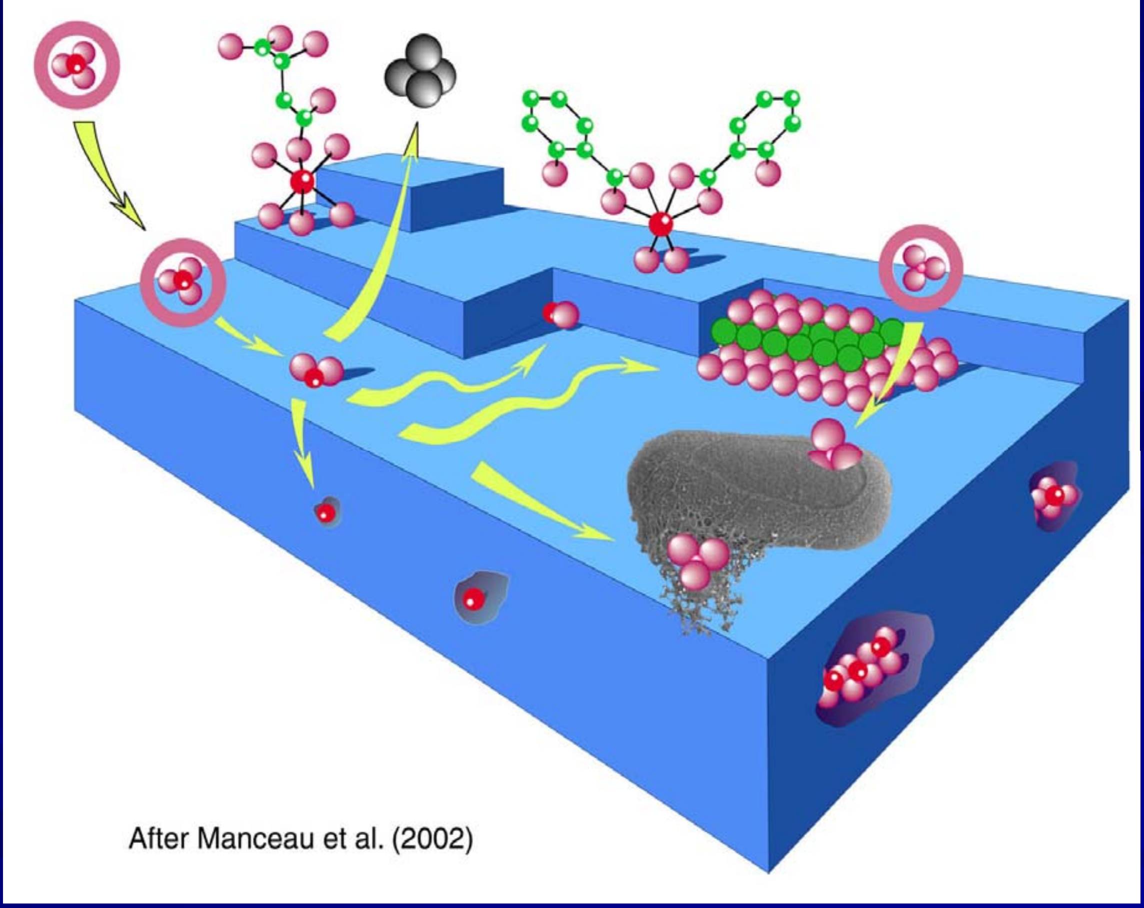

Investigation using a combination of *in-situ* AFM, XPS and Accelerator-based techniques

MINERAL-WATER INTERFACE PROCESSES

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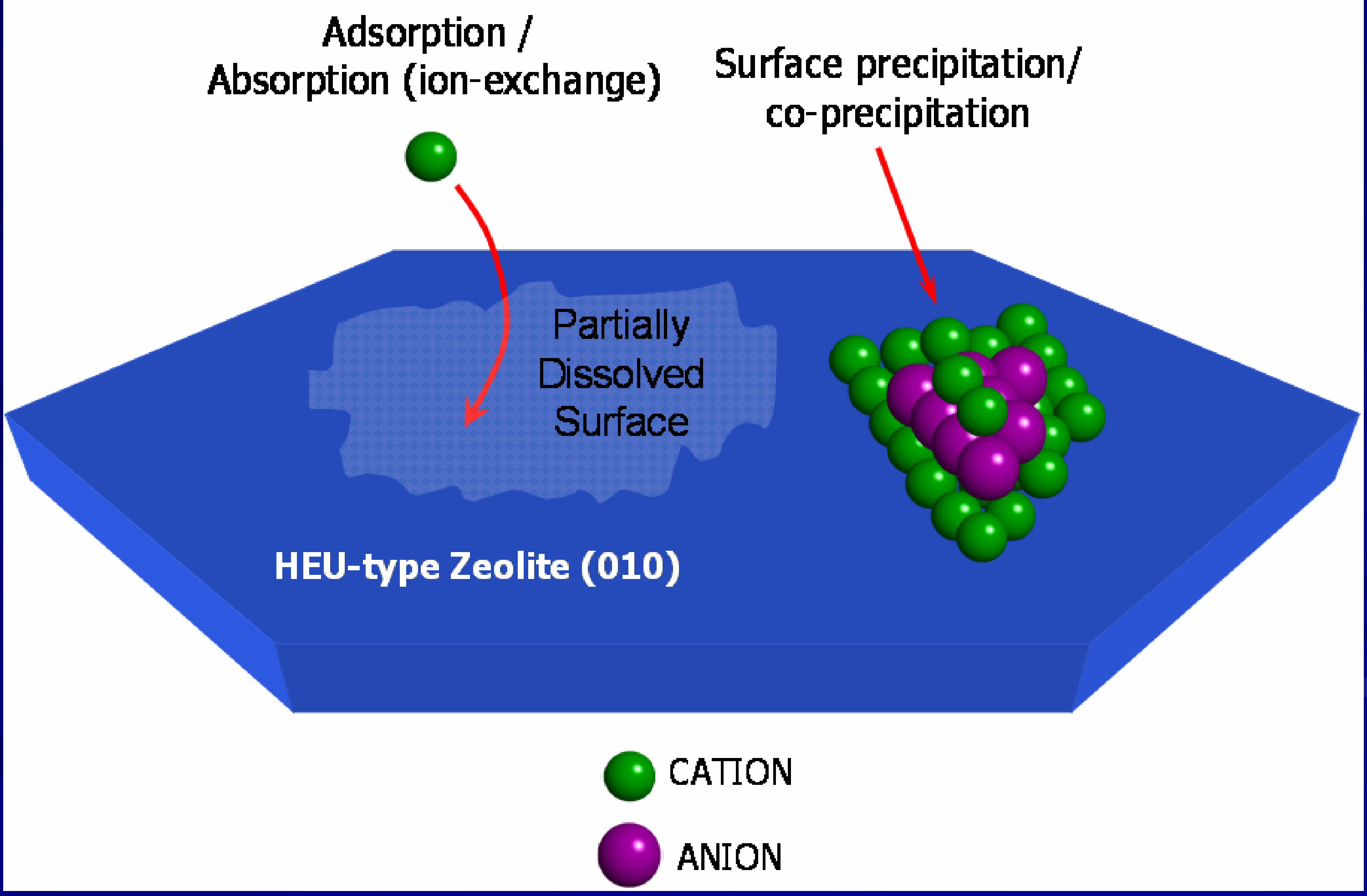

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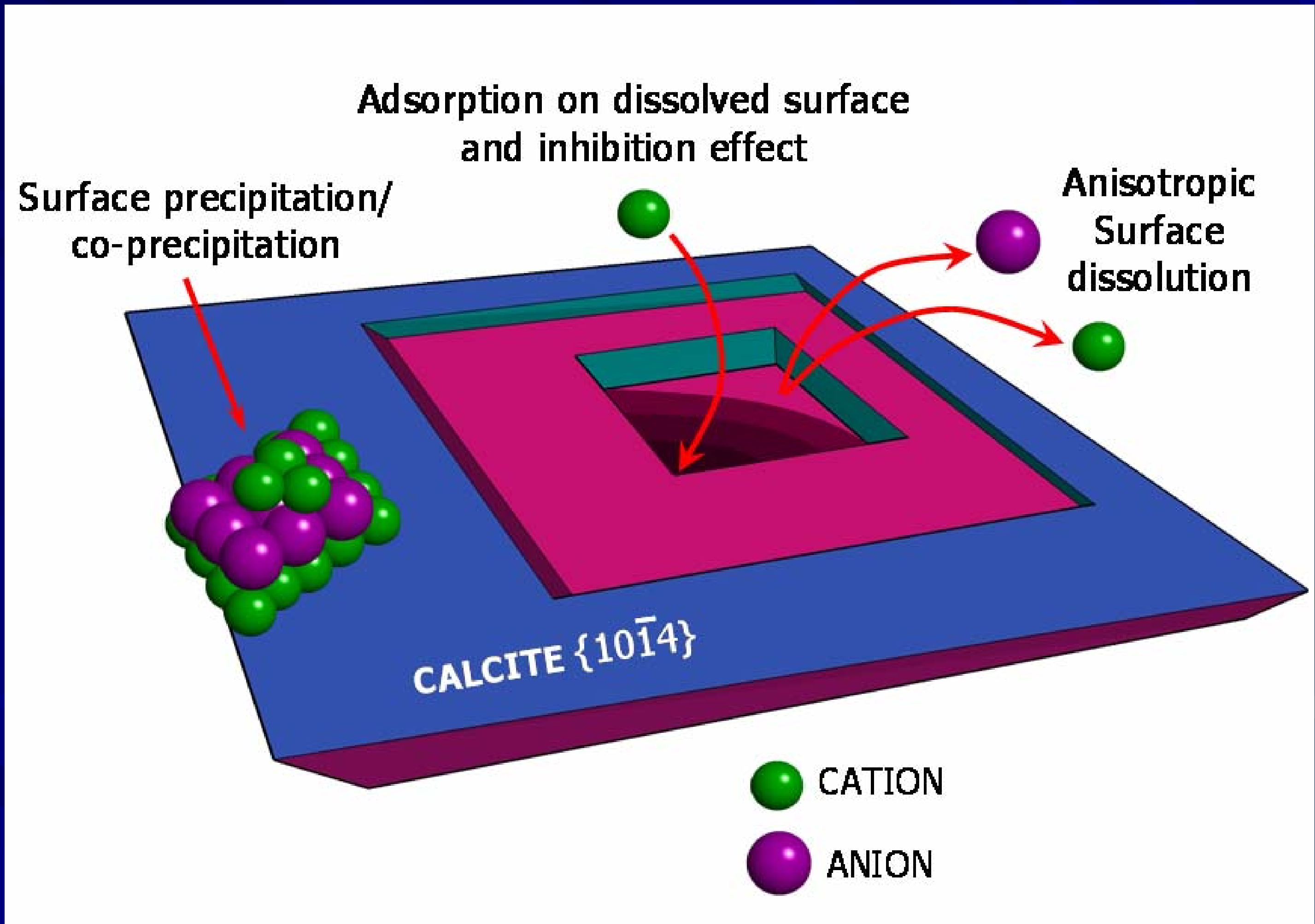

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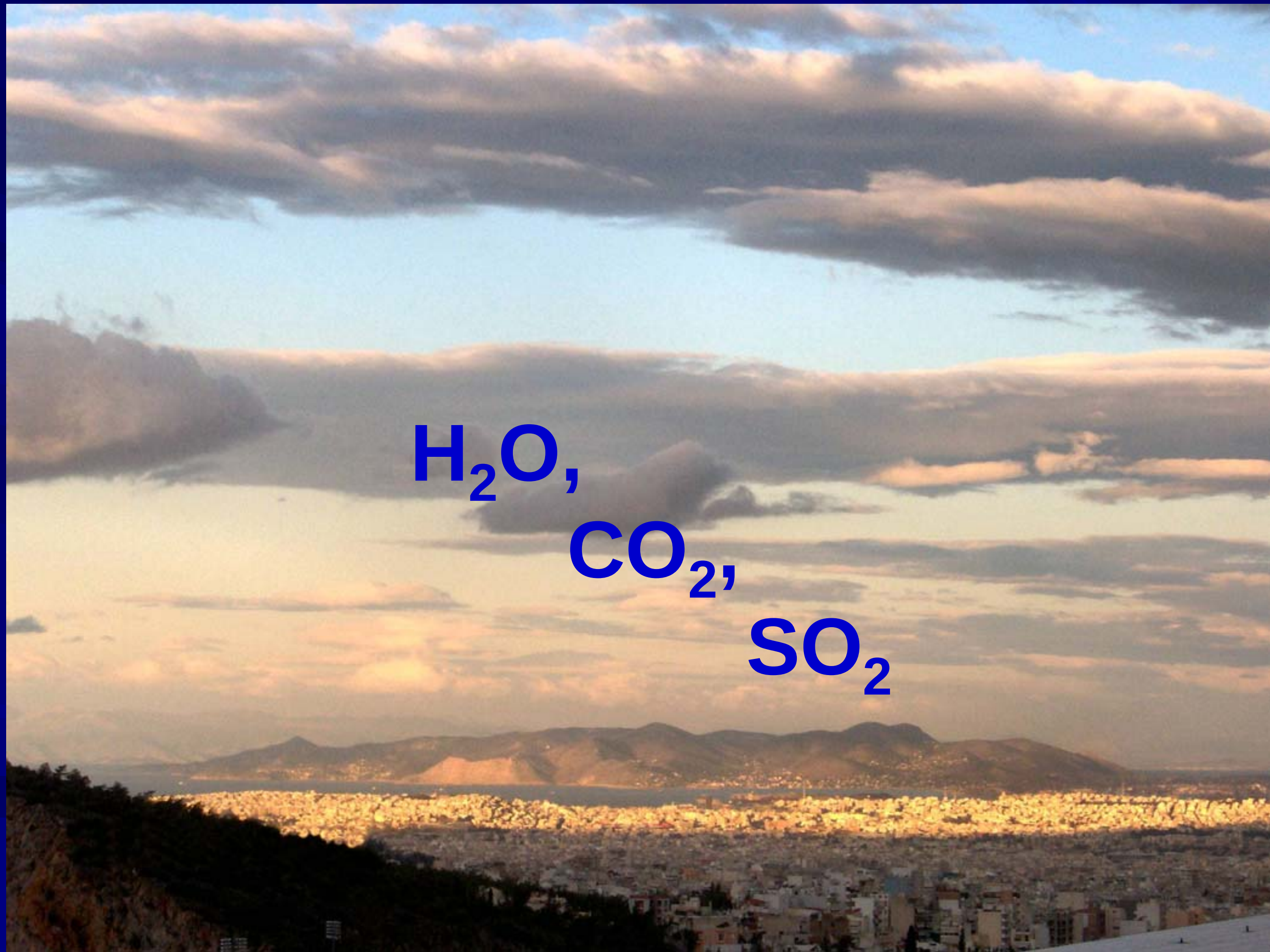
Metallic Pb patination in the atmosphere of Athens



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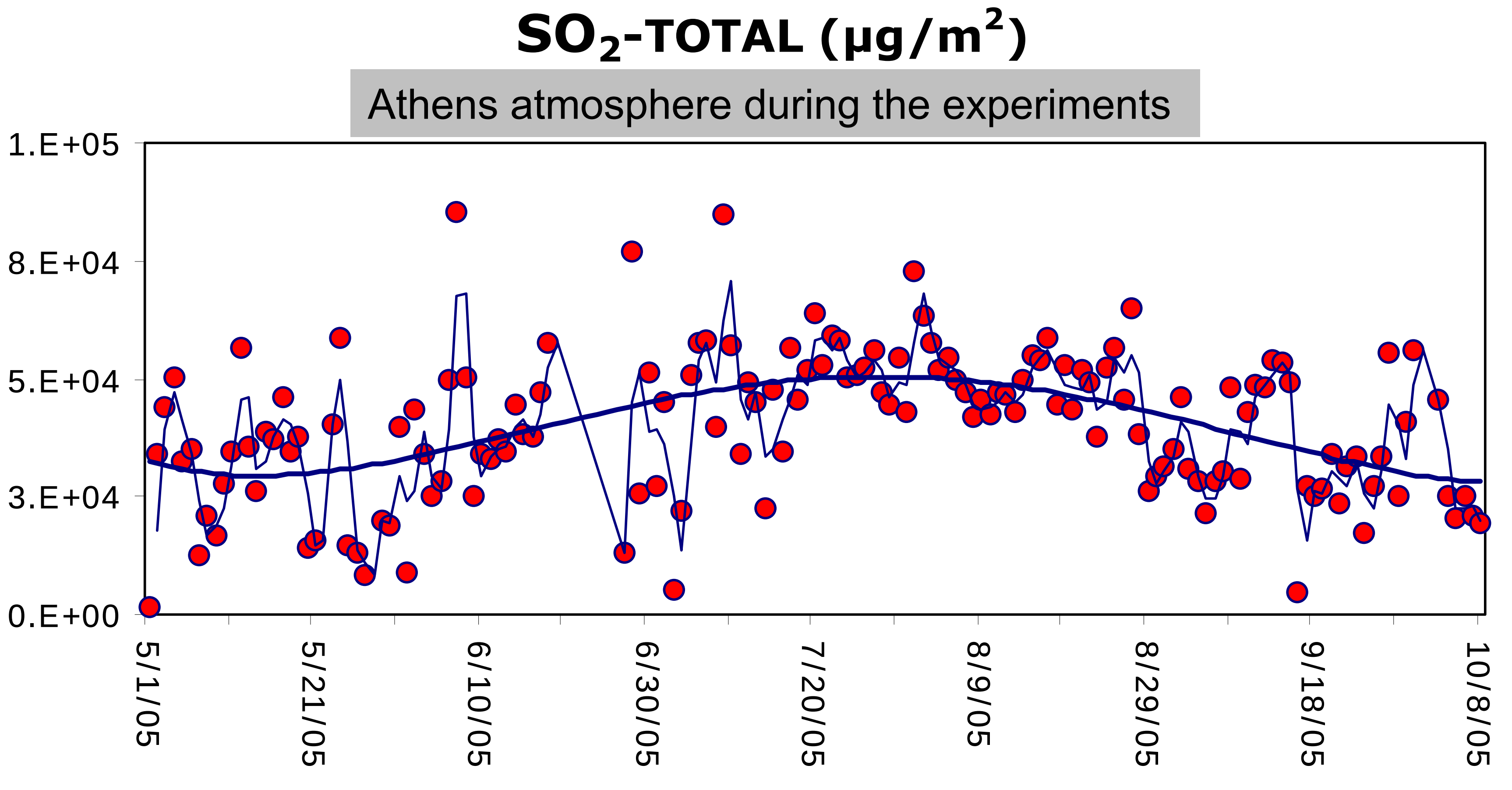

Metallic Pb patination in the atmosphere of Athens

192 British Corrosion Journal 1999 Vol. 34 No. 3

Nature of lead patination

L. BLACK
G. C. ALLEN

A study of the factors influencing lead patination is reported. Raman spectroscopy has been used to determine the composition of patinas, while weight gain measurements and scanning electron microscopy have followed their physical development. The mechanism of the patination process follows a route during which the initially formed oxide film converts to a basic lead carbonate (hydrocerussite, $2PbCO_3.Pb(OH)_2$), which, under the influence of sulphur dioxide, ultimately forms lead sulphate, via intermediate tetrabasic lead sulphate and lead sulphite phases. Levels of atmospheric pollution were observed to play an important role in the rate of formation of the stable end product.

At the time the work was carried out, the authors were at the Interface Analysis Centre, University of Bristol, Oldbury House, 121 St Michael's Hill, Bristol BS2 8BS, UK. Dr Black is now with the Commission of the European Communities, Joint Research Centre, Institute for Transuranium Elements, Postfach 2340, D–76125 Karlsruhe, Germany.
Manuscript received 4 November 1998; accepted 4 February 1999.

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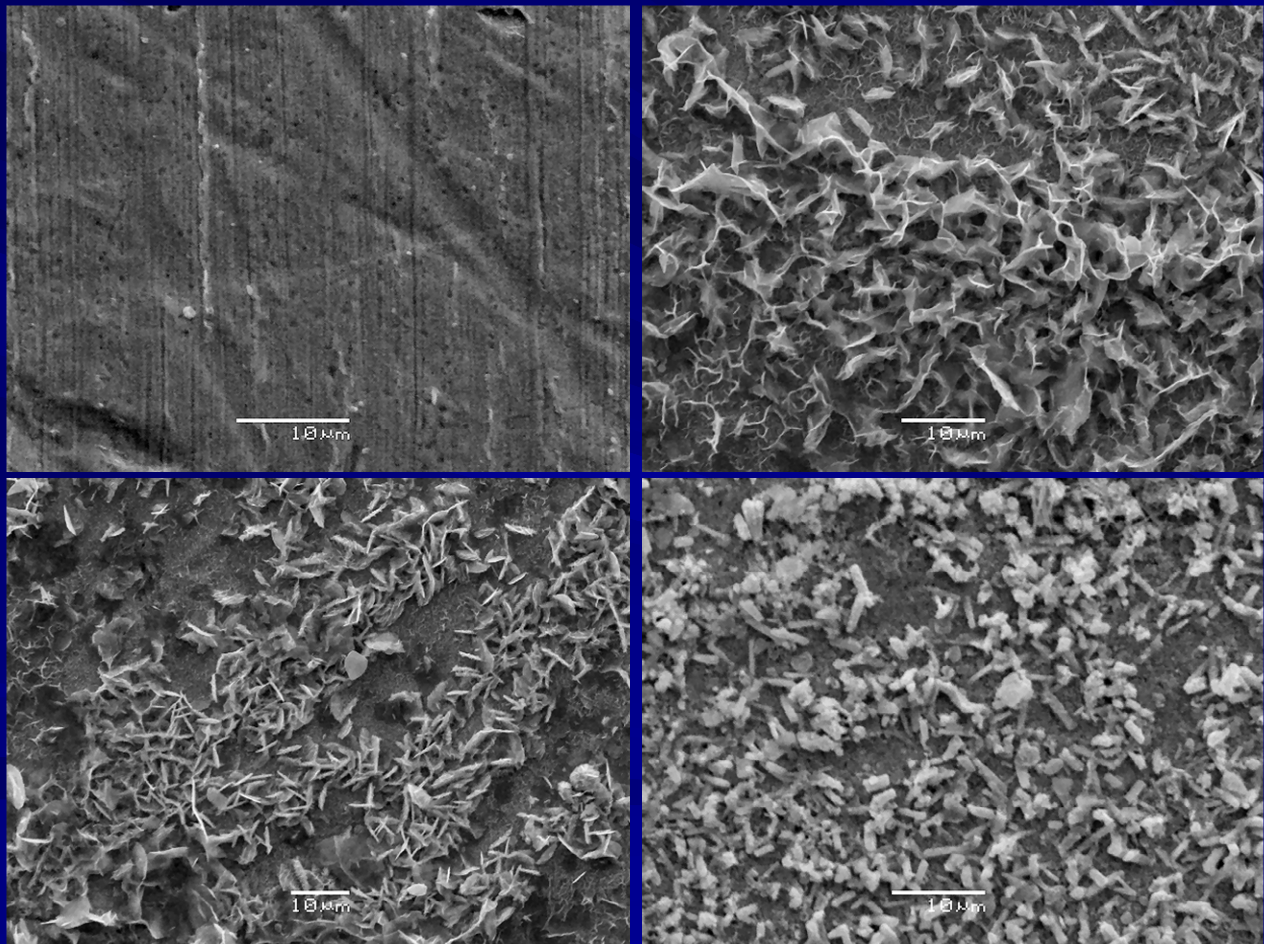
Metallic Pb patination - **University area, PAN samples** (1 week – 6 months)



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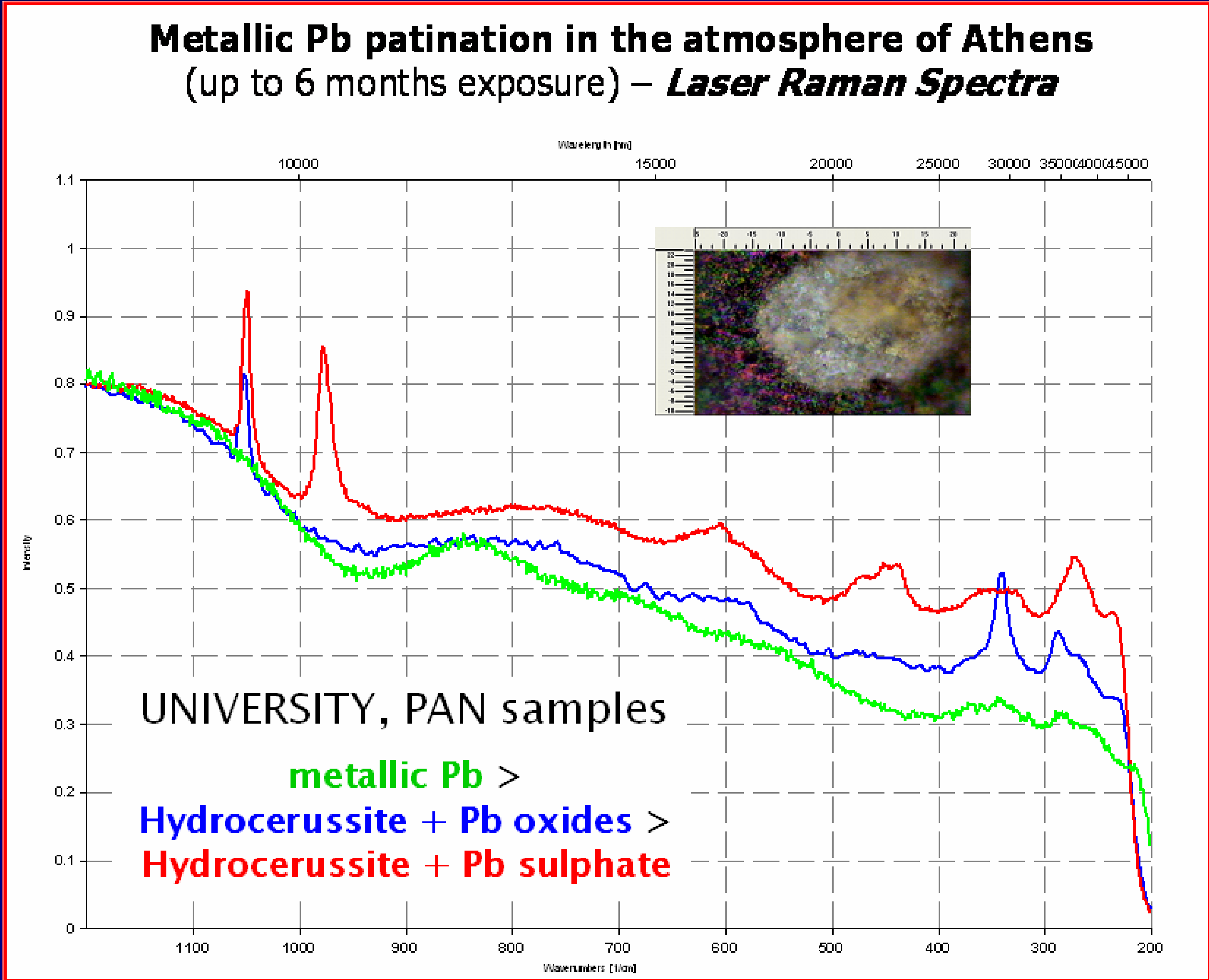

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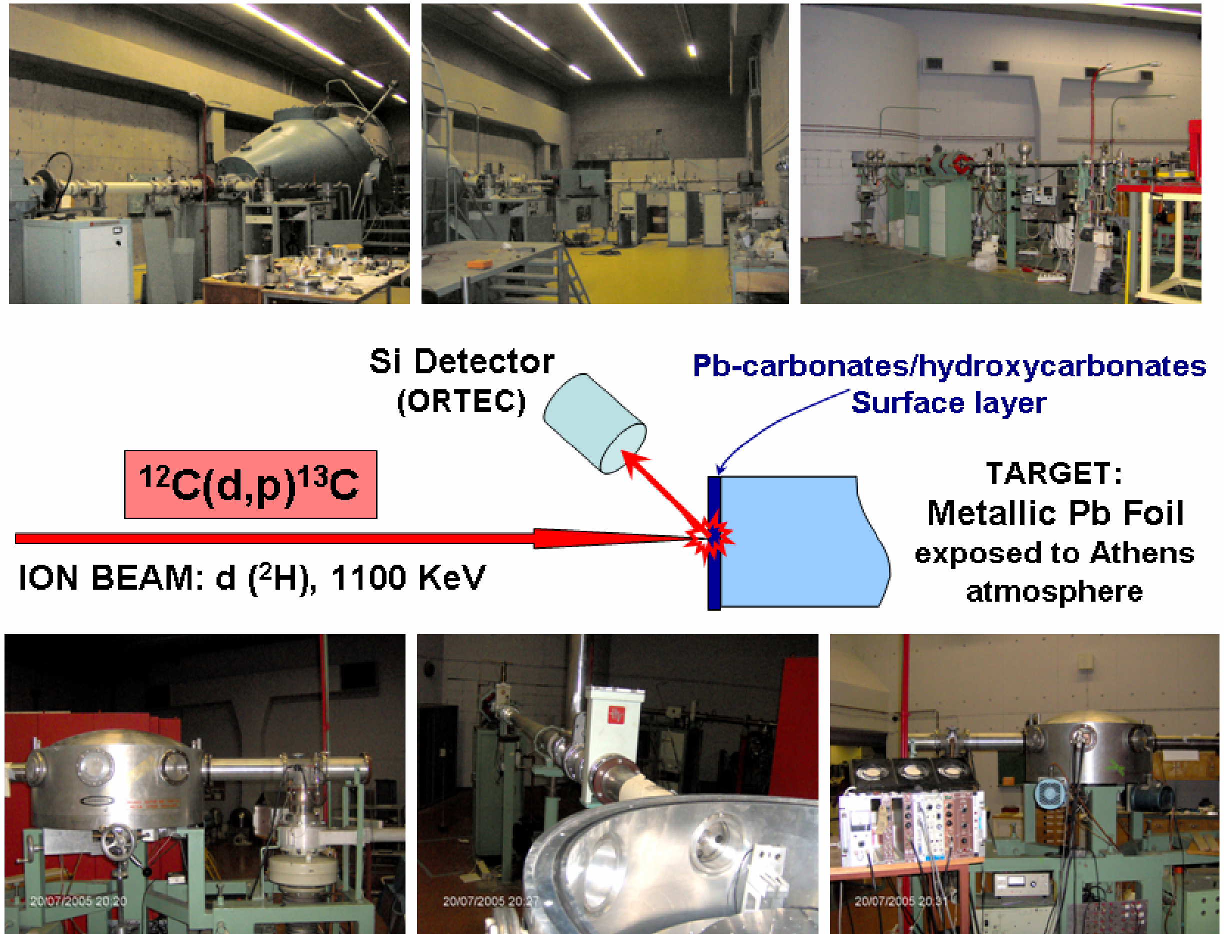
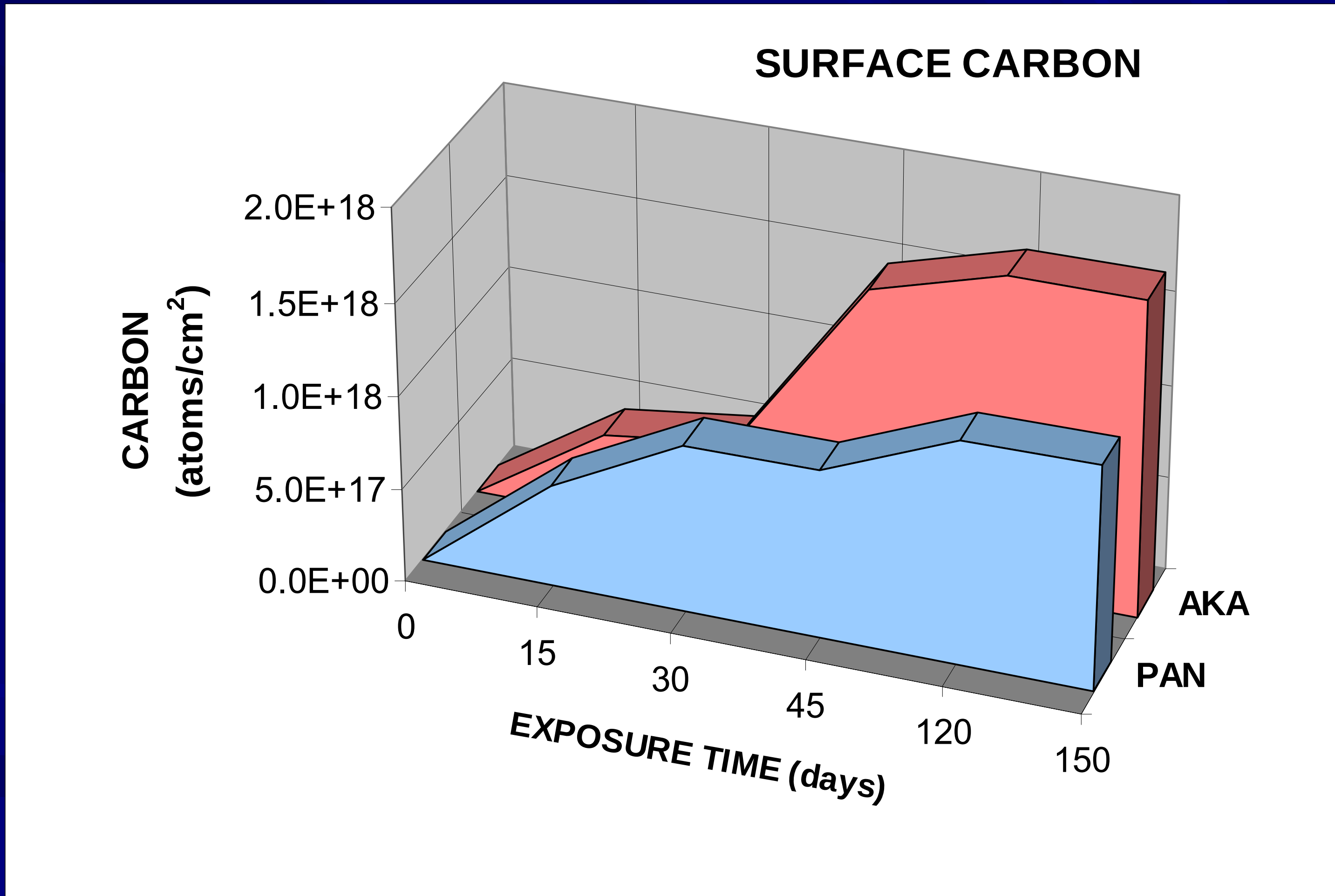
EXPERIMENTAL SET-UP (“DEMOKRITOS” NCSR Tandem Accelerator)



Metallic Pb patination in the atmosphere of Athens



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THANK YOU !

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