

# Powder diffraction and cultural heritage

*Gilberto Artioli*

*Dip. Geoscienze UNIPD  
CIRCe Center for Cement Materials*

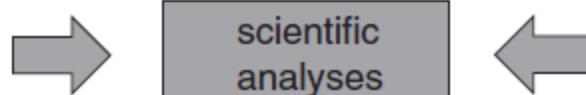


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Archaeologist  
Art historian  
Artist  
Conservation scientist  
Conservator  
Museum curator



Biologist  
Chemist  
Engineer  
Matematician  
Materials scientist  
Mineralogist  
Physicist

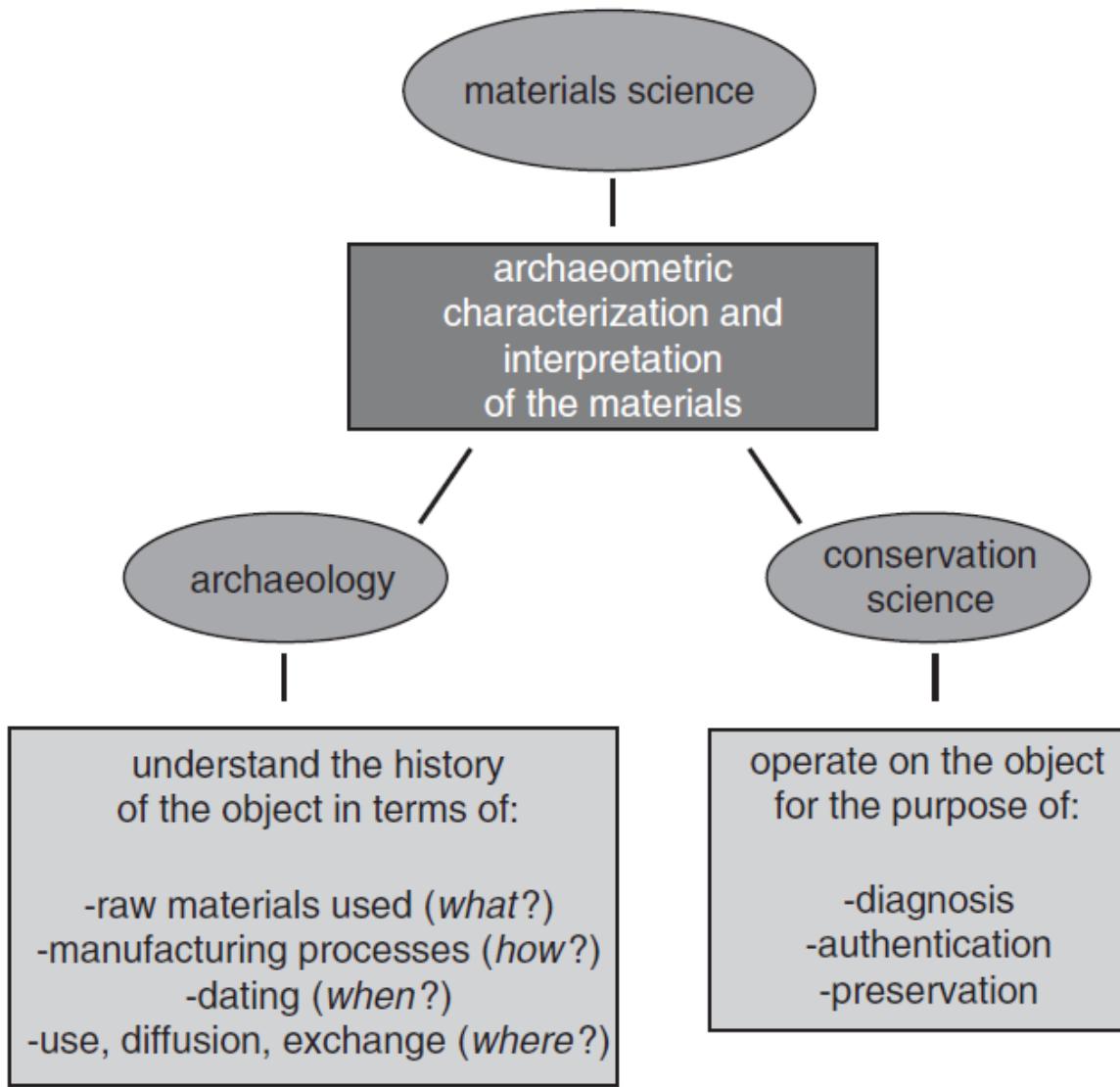
... from aerology to zymurgy ...  
(Goffer 2007)



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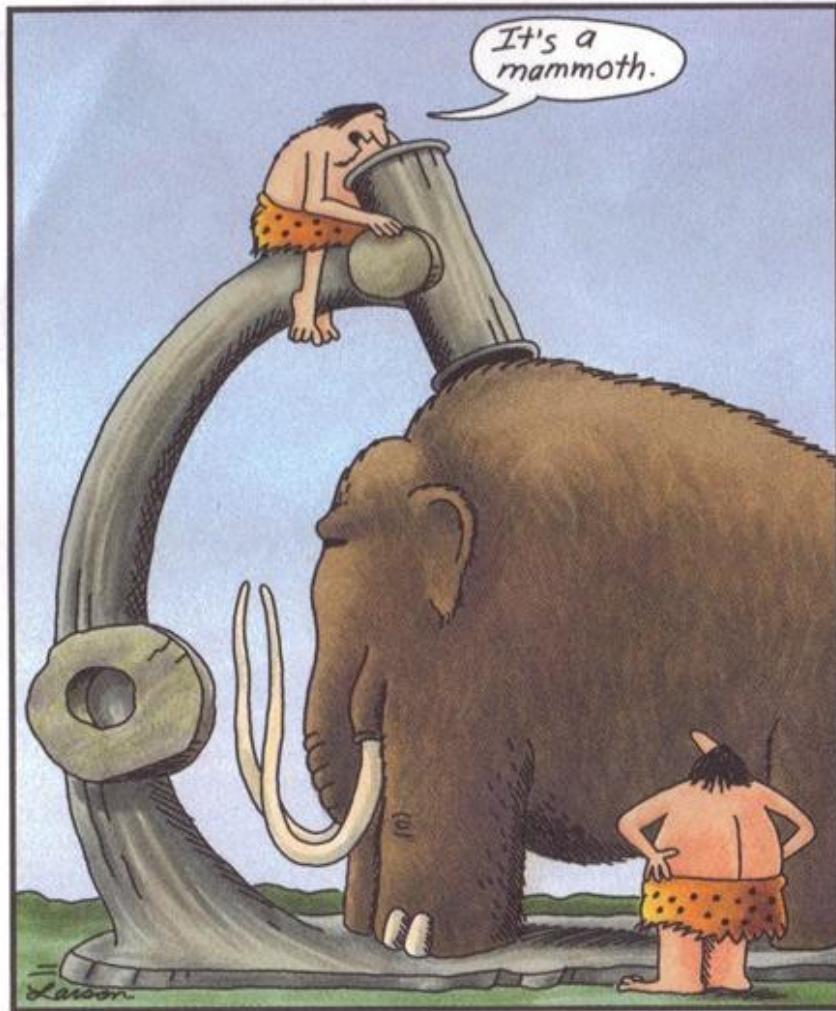
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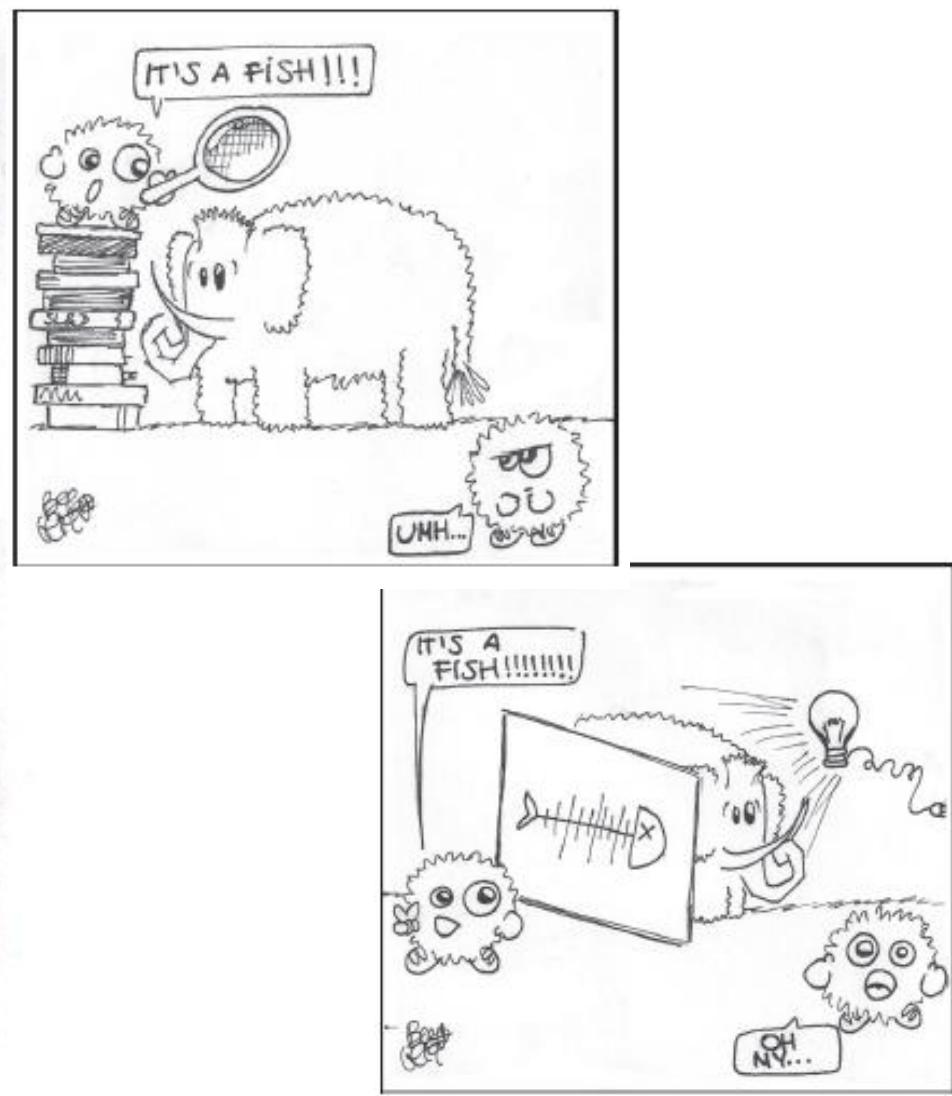
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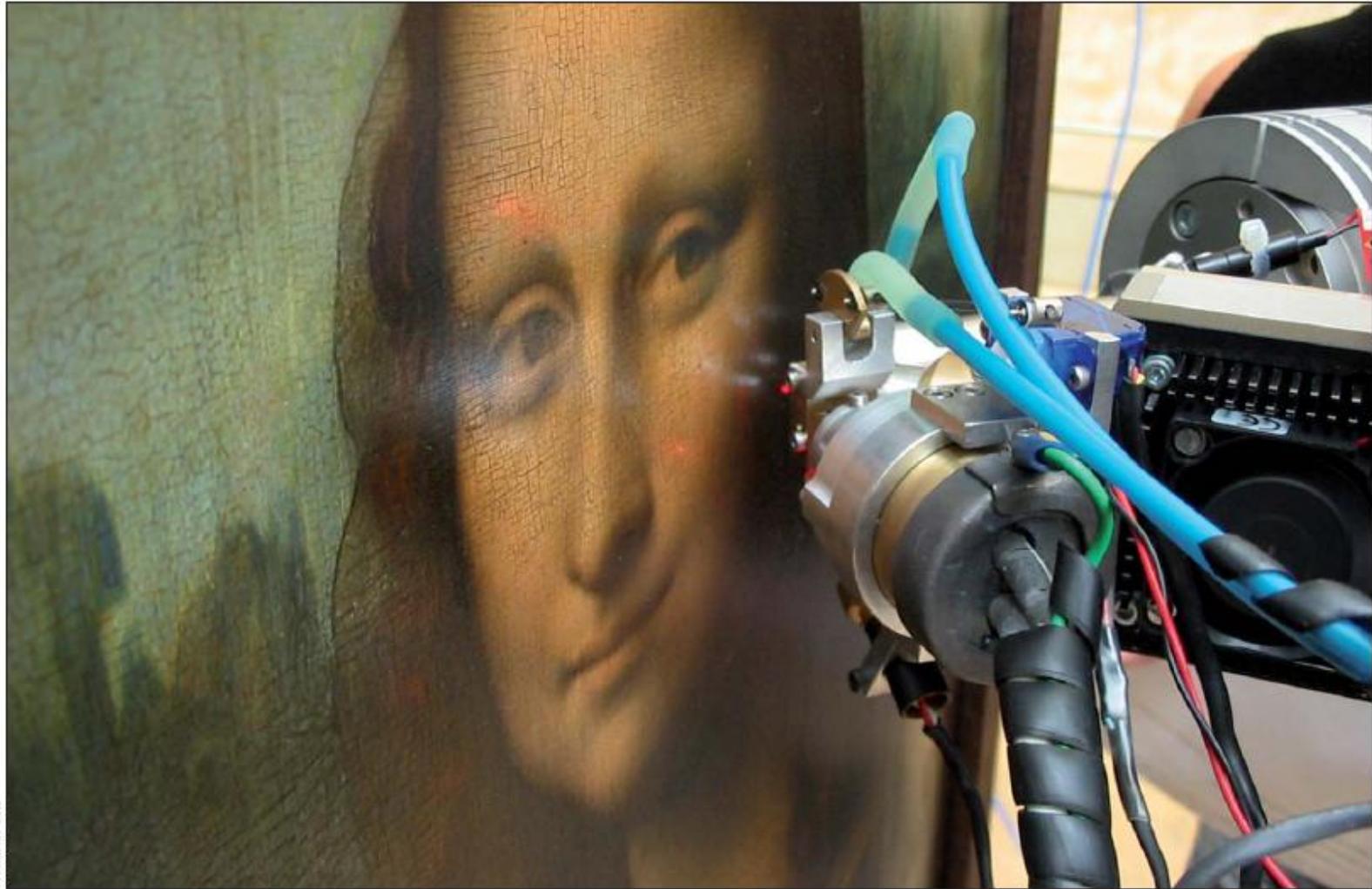
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Early microscope

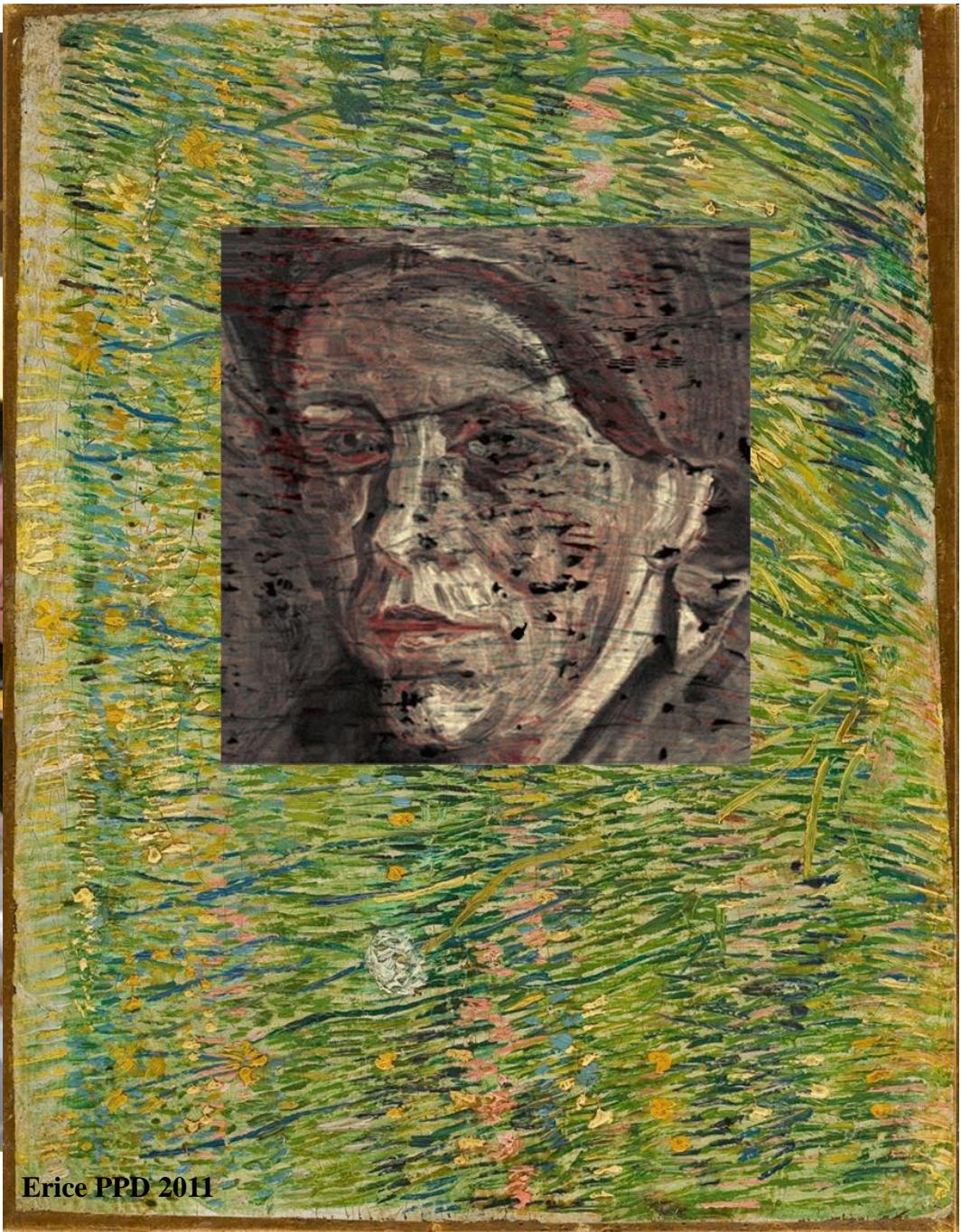




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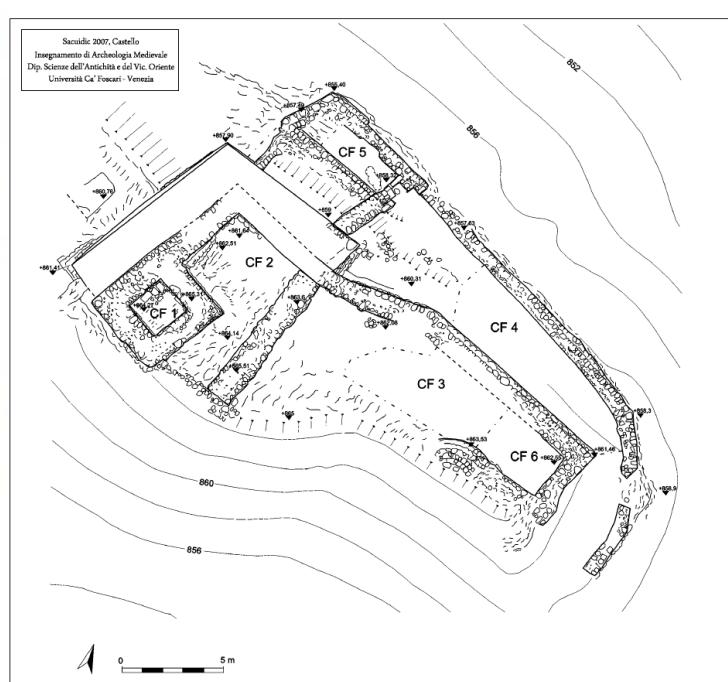
<http://www.vangogh.ua.ac.be/>



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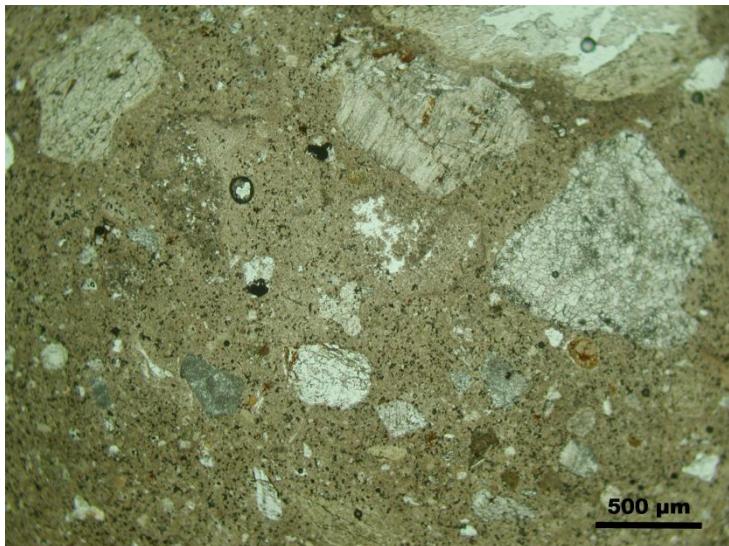
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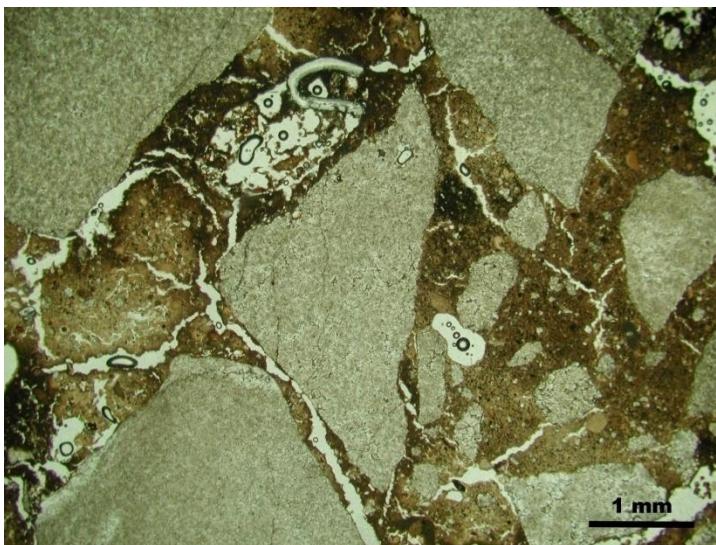
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Sample 24-1 (Phase 3)



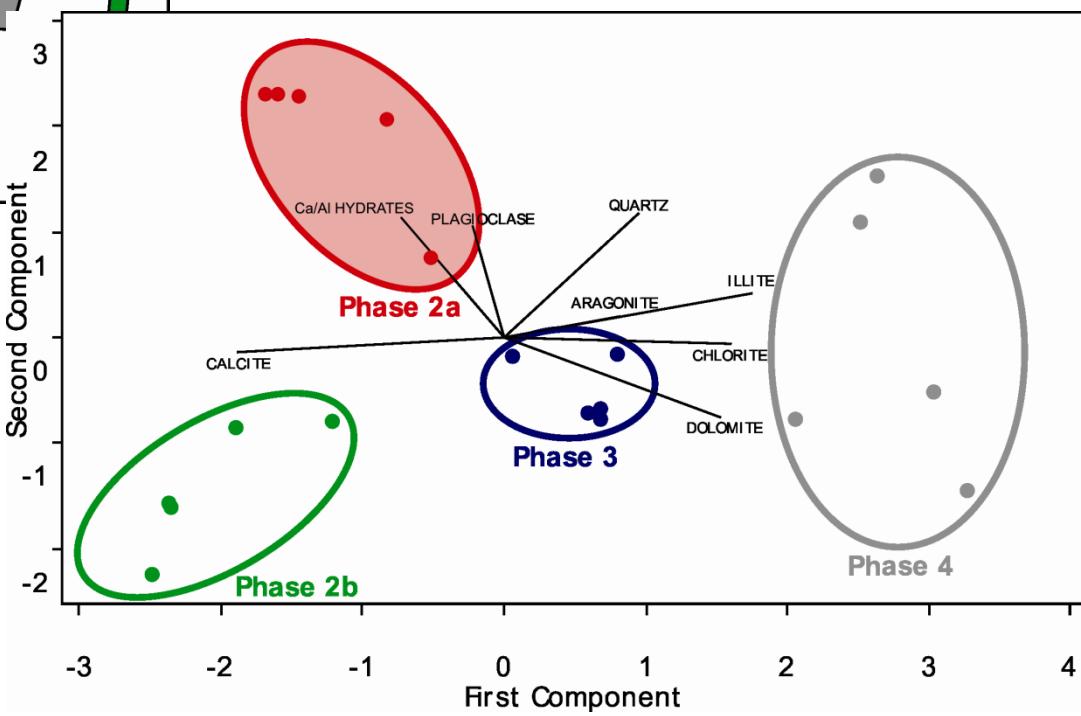
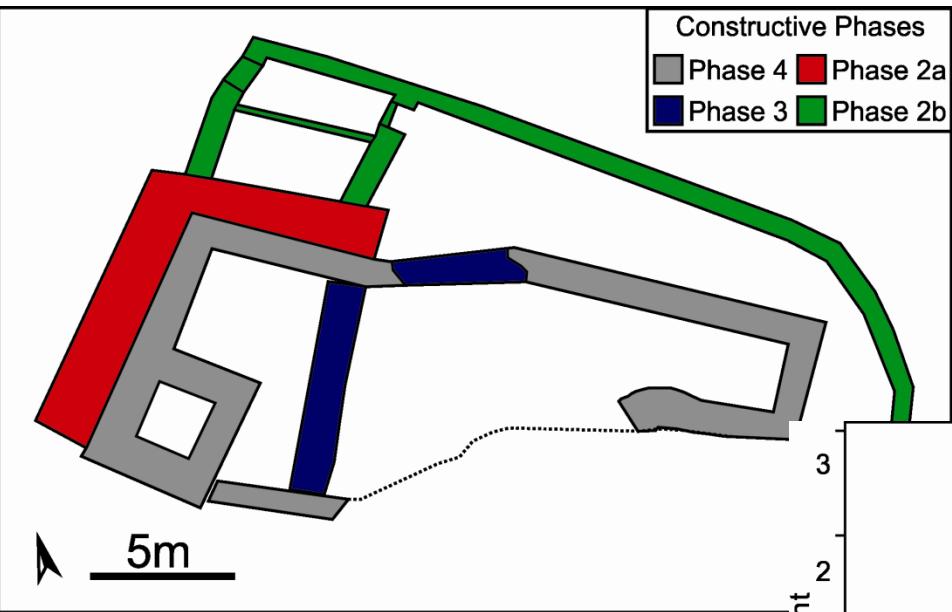
Sample 9-1 (Phase 2b)



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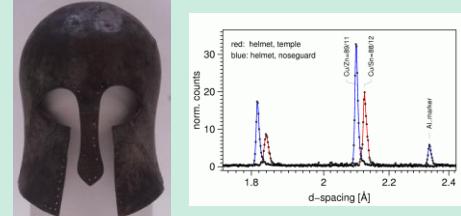
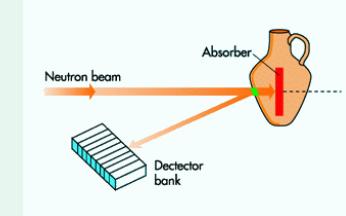
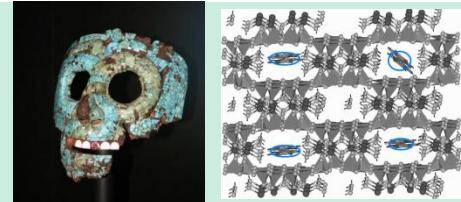
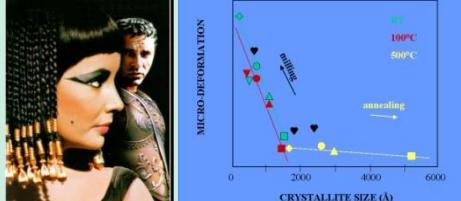
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XRPD	<i>information</i>	<i>example</i>	
<b>qualitative analysis</b>	identification of compounds	Ceramics, Pigments, Corrosion products, etc.	
<b>quantitative analysis</b>	production, provenancing, falsification, alteration		
<b>structure analysis</b>	production process, alteration	Maya Blue	
<b>texture analysis</b>	production, use	Metallography	
<b>peak broadening</b>	physical analysis	Egyptian cosmetics	

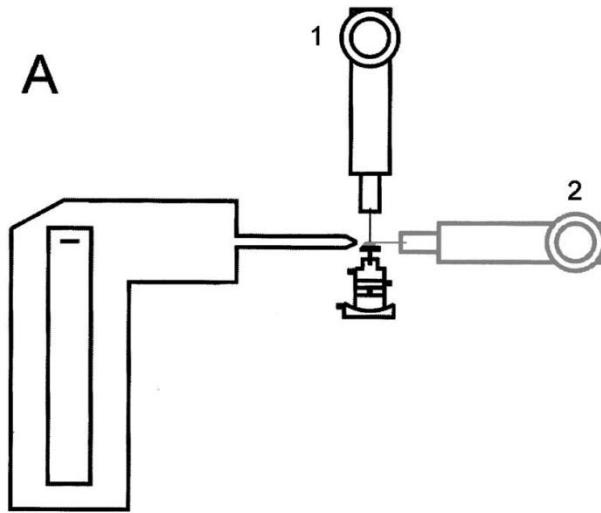
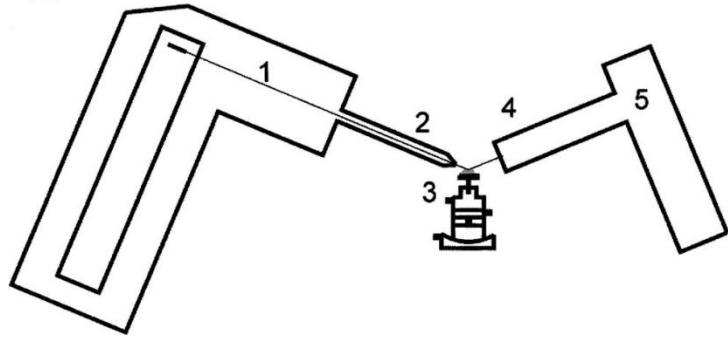
**A****B**

Figure 1. Setup with a microscope (a) to sample adjustment along the  $x$ ,  $y$  axes (position 1) and  $z$  axis (position 2). Diffraction experiment (b): (1) primary beam, (2) monocapillary, (3) sample stage, (4) antiscatter shield, (5) detector.

#### X-ray powder microdiffraction for routine analysis of paintings

Veronika Simova,<sup>a)</sup> P. Bezdička, J. Hradilová, D. Hradil, and T. Grygar  
Academic Laboratory of Materials Analysis of Paintings (ALMA), Institute of Inorganic Chemistry AS CR,  
250 68 Rež, Czech Republic Academy of Fine Arts in Prague, U Akademie 4, 170 22 Prague 7,  
Czech Republic

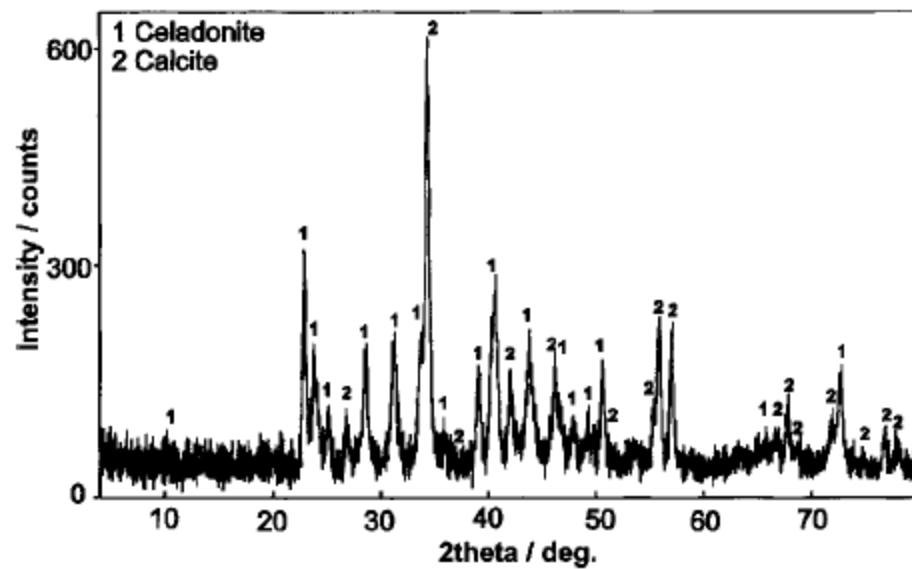
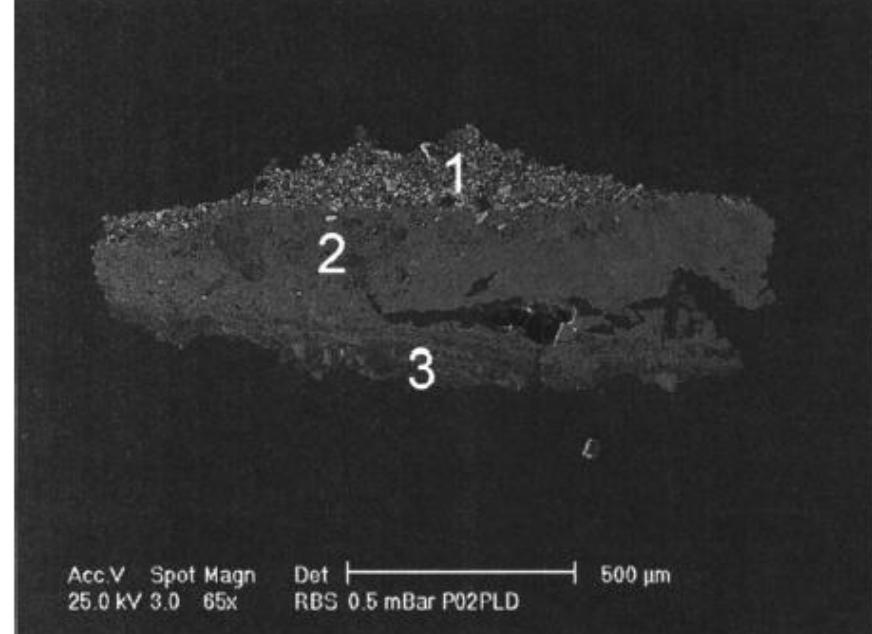
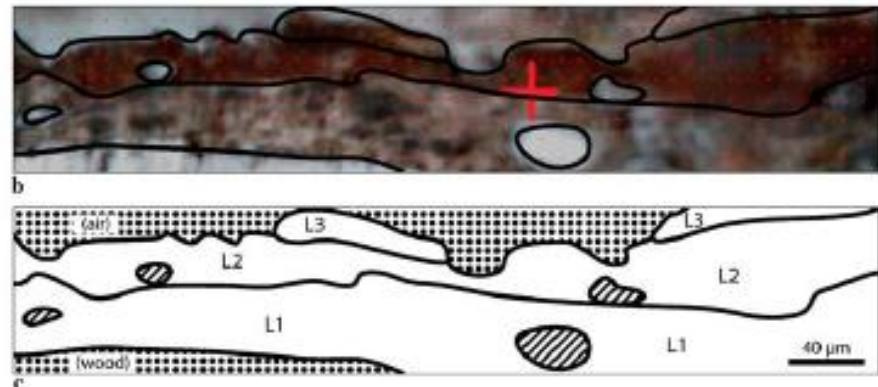


Figure 10. Diffraction pattern of the green layer in sample 5. Celadonite (phase 1) was identified as green pigment.



J.-P. EICHARD<sup>1,2,\*</sup>  
M. COTTE<sup>3,\*</sup>  
E. DOORYHEE<sup>4</sup>  
L. BERTRAND<sup>5</sup>

## Insights into the varnishes of historical musical instruments using synchrotron micro-analytical methods

<sup>1</sup> Laboratoire de Recherche et de Restauration, Musée de la Musique, Cité de la Musique, 221 avenue Jean Jaurès, 75019 Paris, France

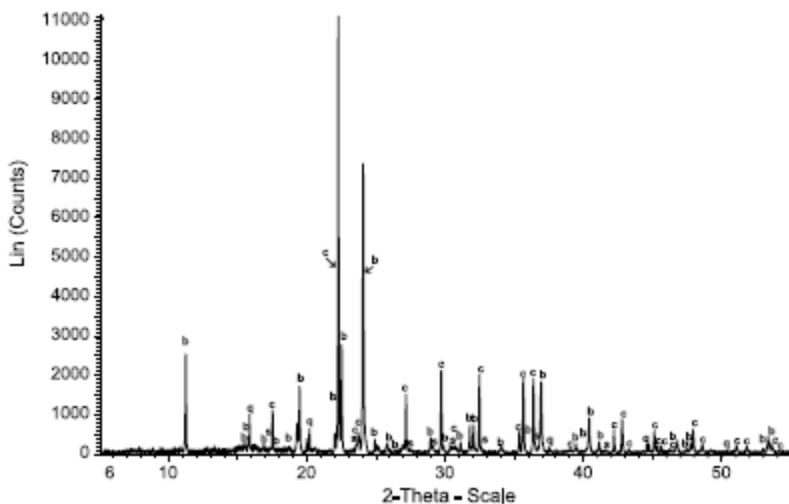
<sup>2</sup> Centre de Recherche sur la Conservation des Collections, CNRS UMR 7188, Muséum National d'Histoire Naturelle, 36, rue Geoffroy Saint-Hilaire, 75005 Paris, France

<sup>3</sup> European Synchrotron Radiation Facility, ESRF, ID21, BP 220, 38043 Grenoble Cedex, France

<sup>4</sup> Institut Néel, CNRS UPR 2940, 25, rue des Martyrs – Bâtiment F-BP166 – 38042 Grenoble Cedex 9, France

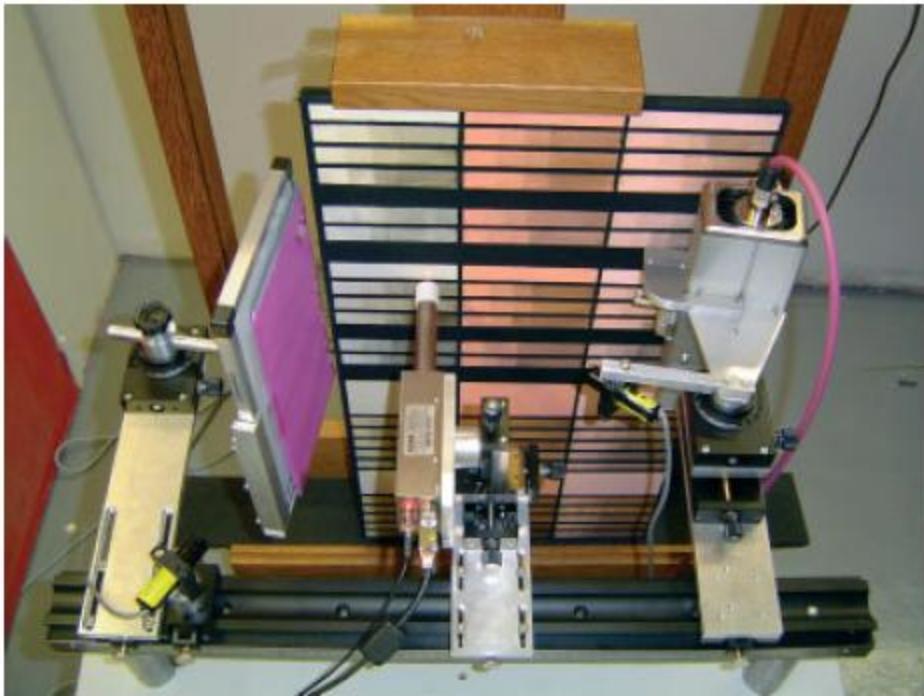
<sup>5</sup> Heritage and Archaeology Liaison Office, Synchrotron SOLEIL, Saint-Aubin, BP 48, 91192 Gif-sur-Yvette Cedex, France

Appl. Phys. A 92, 77–81 (2008)



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**Figure 2.** Photograph of the XRF/XRD system during the measurement on a white lead pigment (20–30 µm layer thickness), deposited on a 300-µm thick gypsum on a canvas. The x-ray source is on the right, the IP on the left and the XRF detector in between.

## A portable instrument for *in situ* determination of the chemical and phase compositions of cultural heritage objects<sup>†</sup>

A. Gianoncelli,<sup>1\*</sup> J. Castaing,<sup>1</sup> L. Ortega,<sup>2</sup> E. Dooryhée,<sup>2</sup> J. Salomon,<sup>1</sup> P. Walter,<sup>1</sup> J.-L. Hodeau<sup>2</sup> and P. Bordet<sup>2</sup>

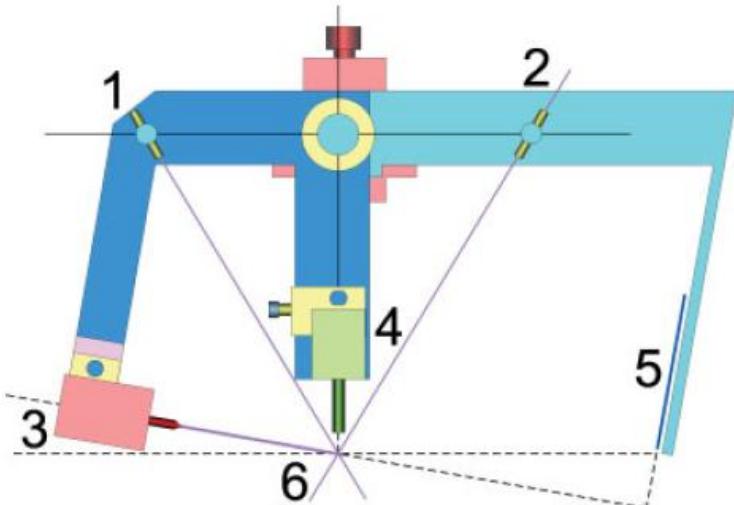
<sup>1</sup> Centre de recherche et de restauration des musées de France, CNRS UMR171, Palais du Louvre, Porte des Lions, 14 Quai François Mitterrand, 75001, Paris

<sup>2</sup> Institut Néel, CNRS and Université Joseph Fourier, BP 166, 38042 Grenoble Cedex 9, France

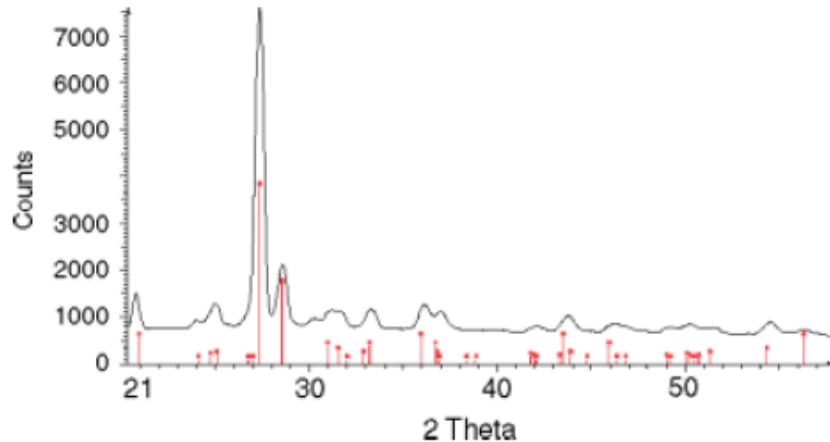
### X-RAY SPECTROMETRY

*X-Ray Spectrom.* 2008; **37**: 418–423

Published online 6 March 2008 in Wiley InterScience



**Figure 1.** Schematic view of the measurement head of the XRF/XRD portable system. 1 and 2: laser pointers; 3: x-ray tube; 4: XRF detector; 5: imaging plate (IP); 6: analysis position.



**Figure 4.** The IP-derived XRD diagram is given as diffracted intensity (arbitrary units) versus  $2\theta$ . It corresponds to  $\text{Pb}_4\text{O}_3(\text{SO}_4)$ ,  $\text{H}_2\text{O}$  (JCPDS reference data file 029–0781 shown) lead white pigment (20–30 µm layer thickness), deposited on a 300-µm thick gypsum on a canvas.

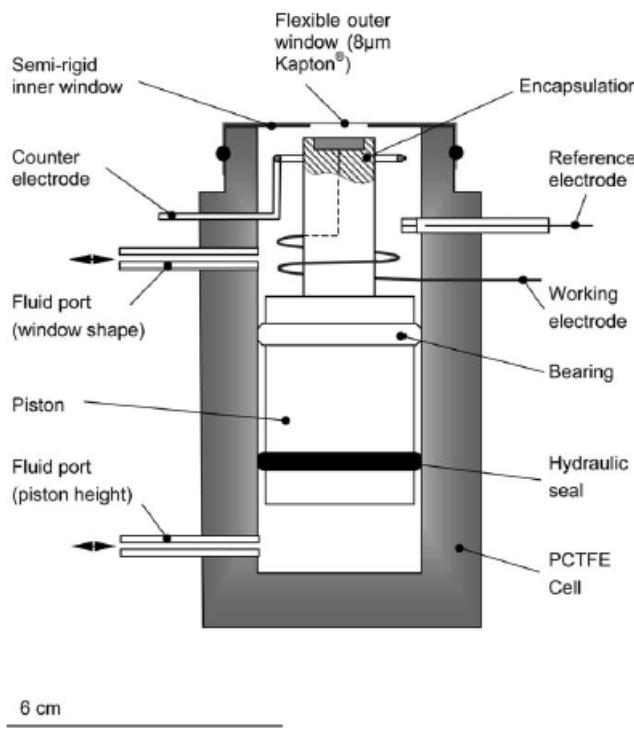


Fig. 1. Schematic drawing of the newly developed electrochemical cell.

Simultaneous in situ time resolved SR-XRD and corrosion potential analyses to monitor the corrosion on copper

K. Leyssens<sup>a</sup>, A. Adriaens<sup>a,\*</sup>, M.G. Dowsett<sup>b</sup>, B. Schotte<sup>a</sup>, I. Oloff<sup>b</sup>, E. Pantos<sup>c</sup>, A.M.T. Bell<sup>c</sup>, S.P. Thompson<sup>c,†</sup>

<sup>a</sup> Department of Analytical Chemistry, Ghent University, B-9000 Ghent, Belgium

<sup>b</sup> Department of Physics, University of Warwick, Coventry CV4 7AL, UK

<sup>c</sup> CCLRC, Daresbury Laboratory, Warrington WA4 4AD, UK

Electrochemistry Communications 7 (2005) 1265–1270



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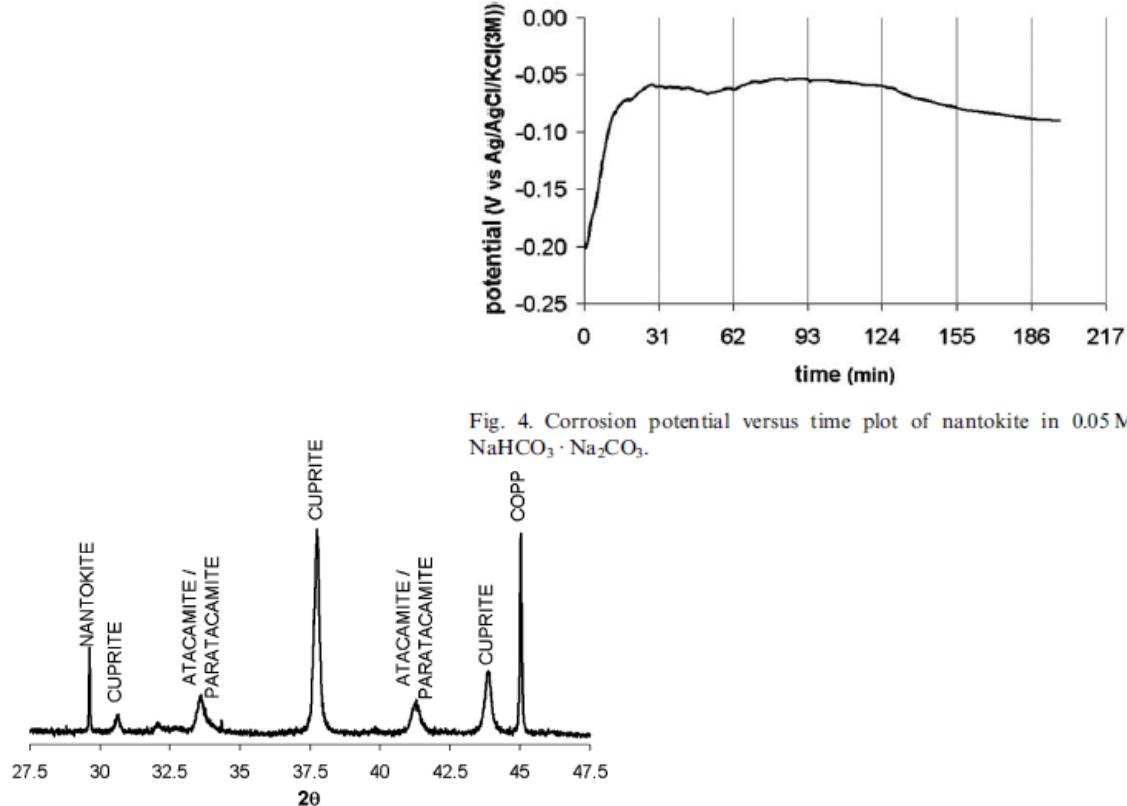


Fig. 4. Corrosion potential versus time plot of nantokite in 0.05 M  $\text{NaHCO}_3 \cdot \text{Na}_2\text{CO}_3$ .

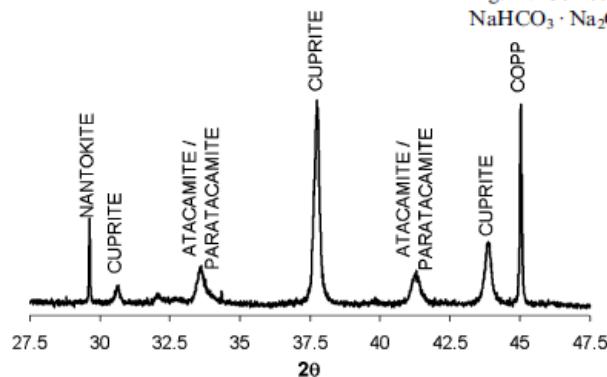


Fig. 6. SR-XRD spectrum of copper covered with a mixture of paratacamite, atacamite and cuprite.

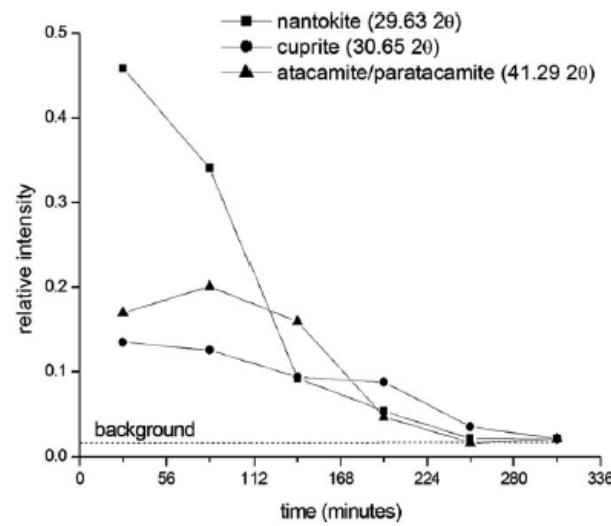
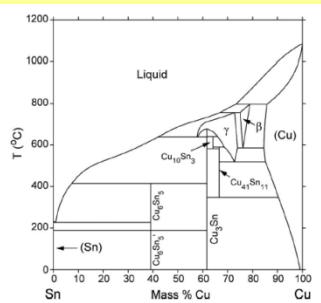


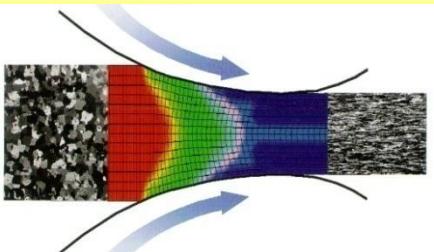
Fig. 7. Variation of the SR-XRD peak heights with time ( $2\theta$  for  $\lambda = 1.6 \text{ \AA}$ ). The signals are normalized versus the copper signal.

## Phase composition

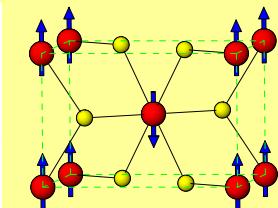
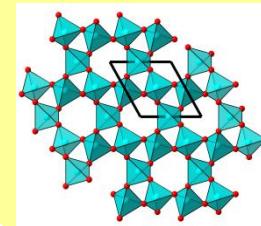


analysis of  
complex  
materials

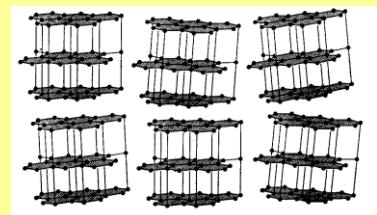
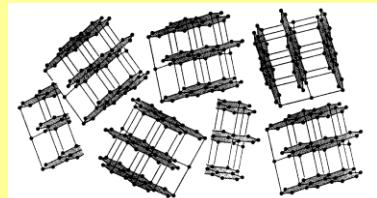
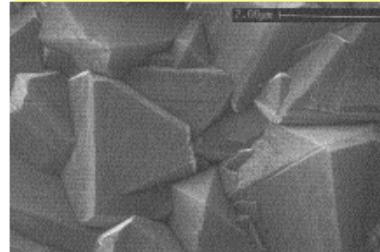
## Residual strains



## Crystal and magnetic structure



## Texture and microstructure



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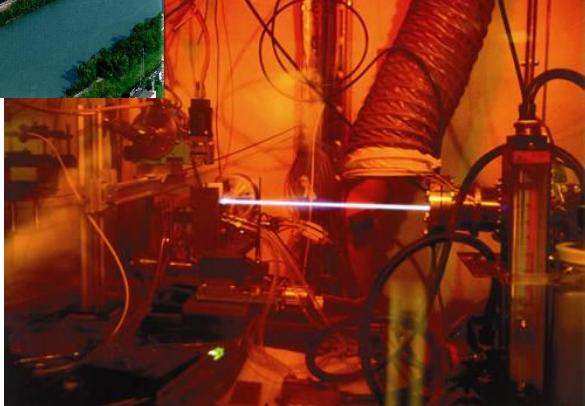
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Synchrotron  
X-rays



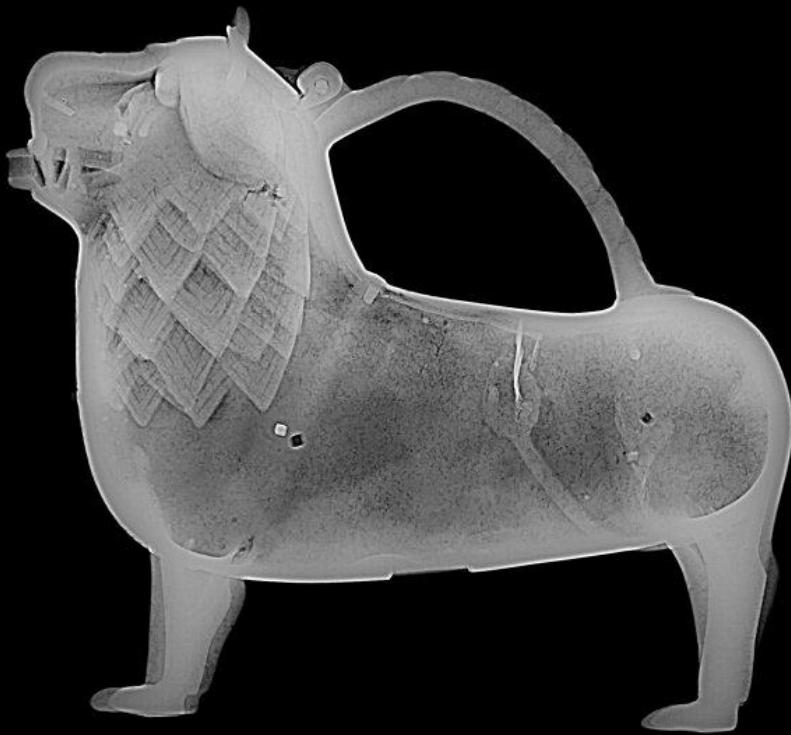
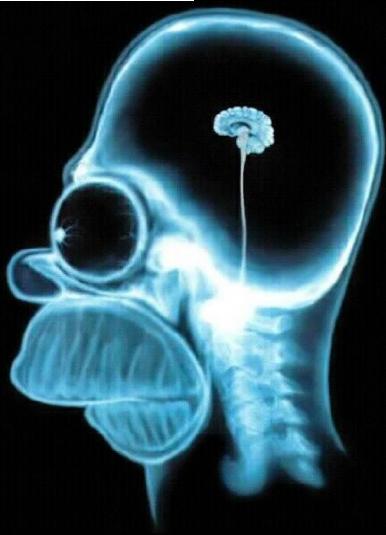
Penetrating beams  
Large objects  
Low spatial resolution  
Time of Flight mode



Thermal / pulsed  
neutrons



Microbeams  
High spatial resolution  
Small samples



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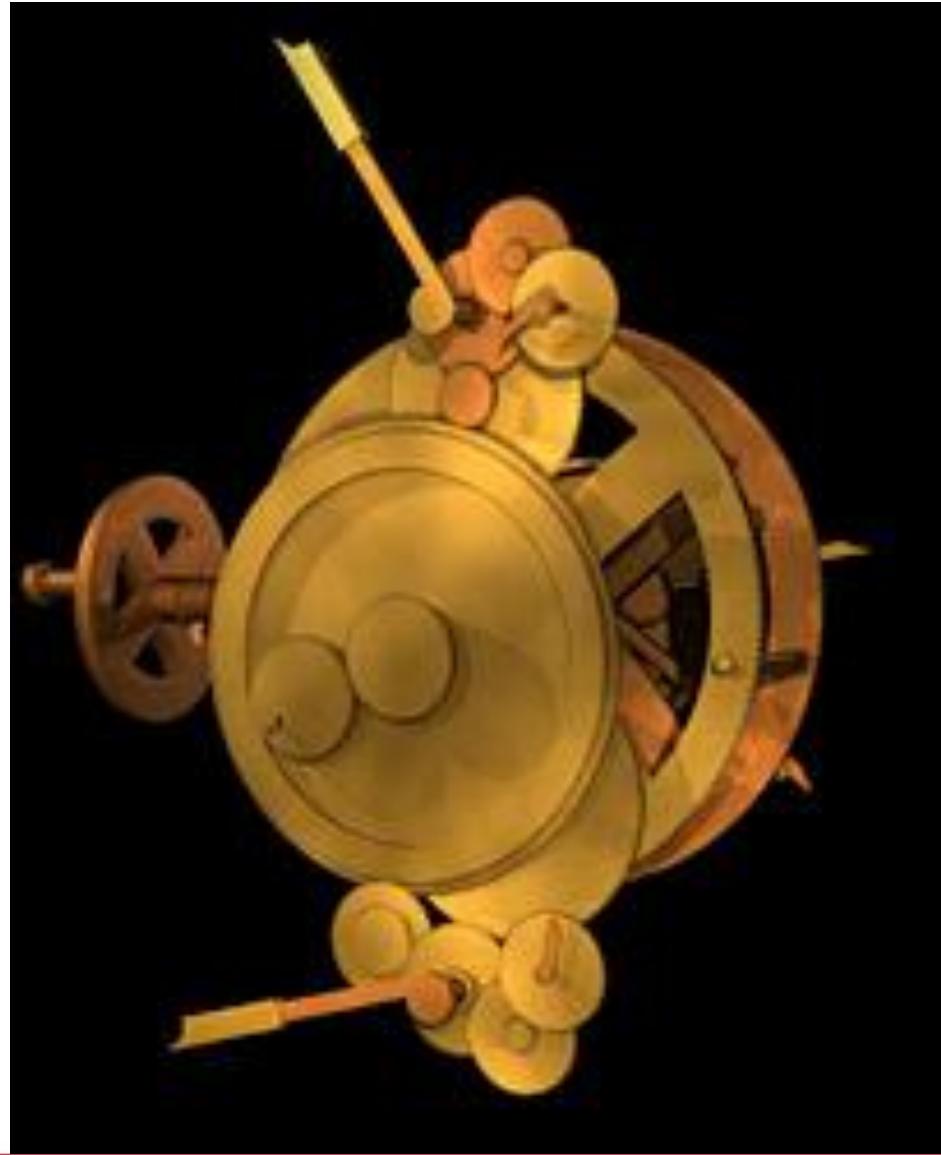


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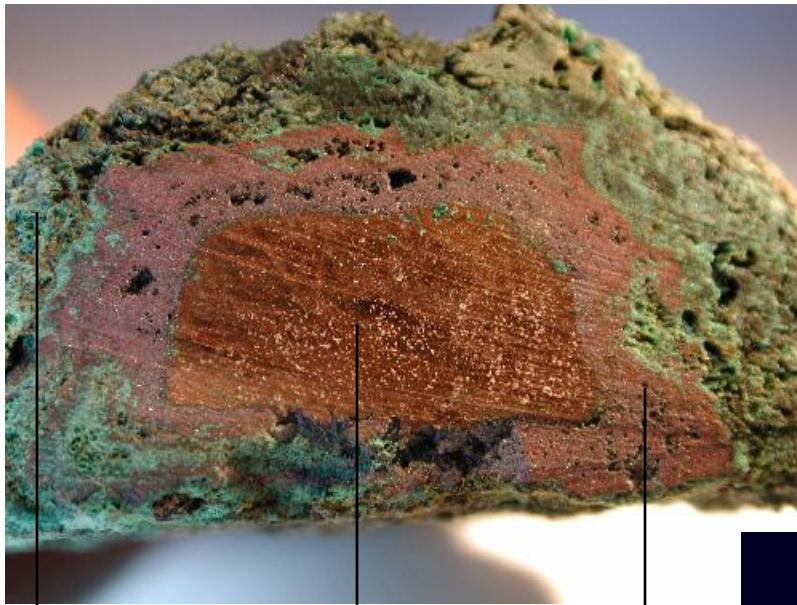
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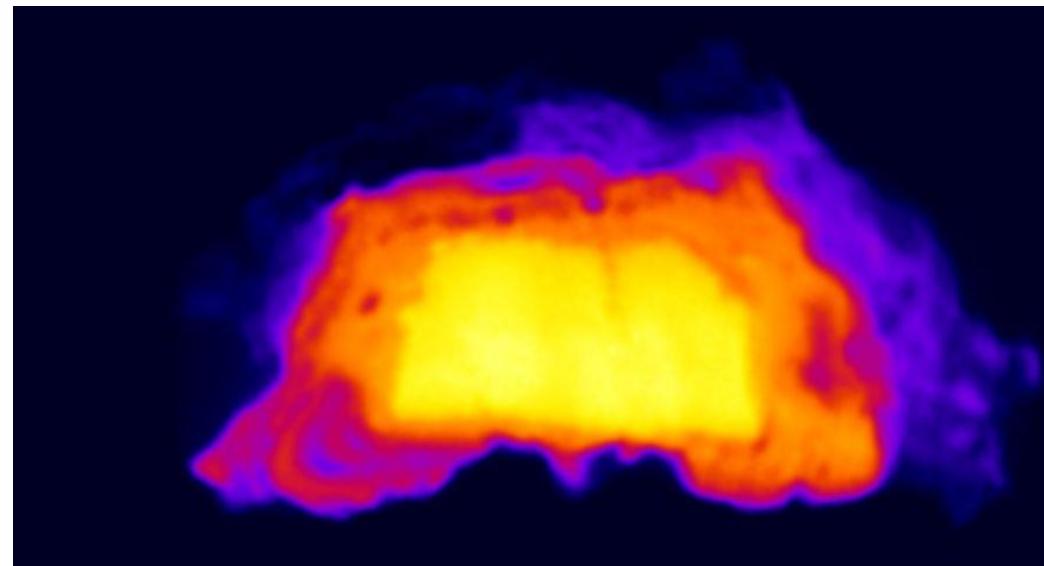


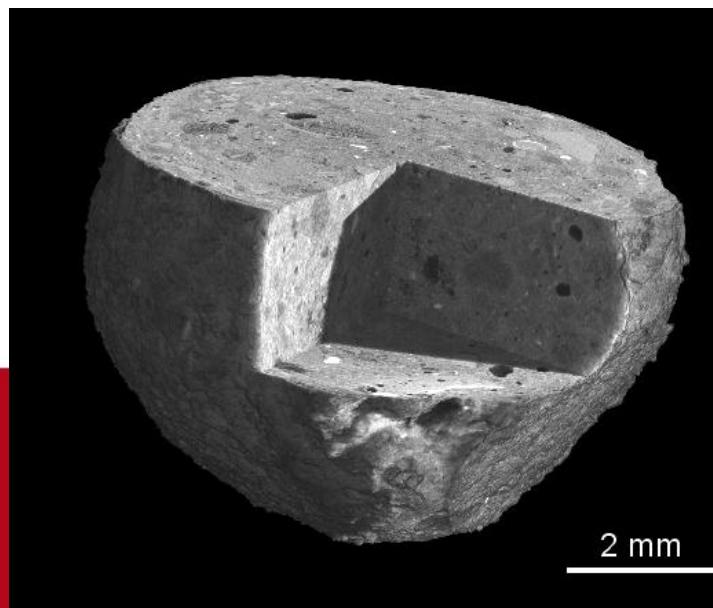
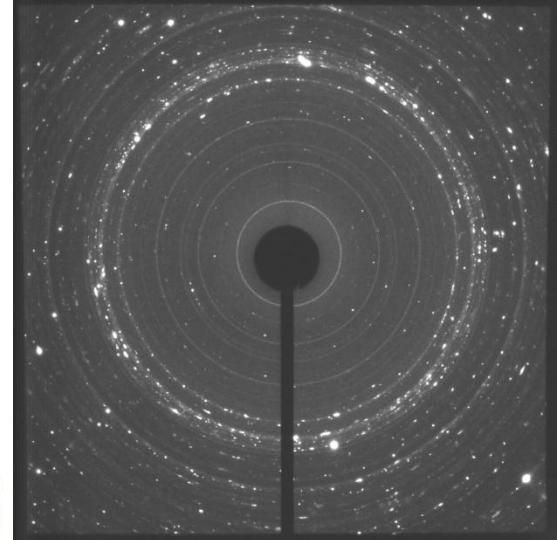
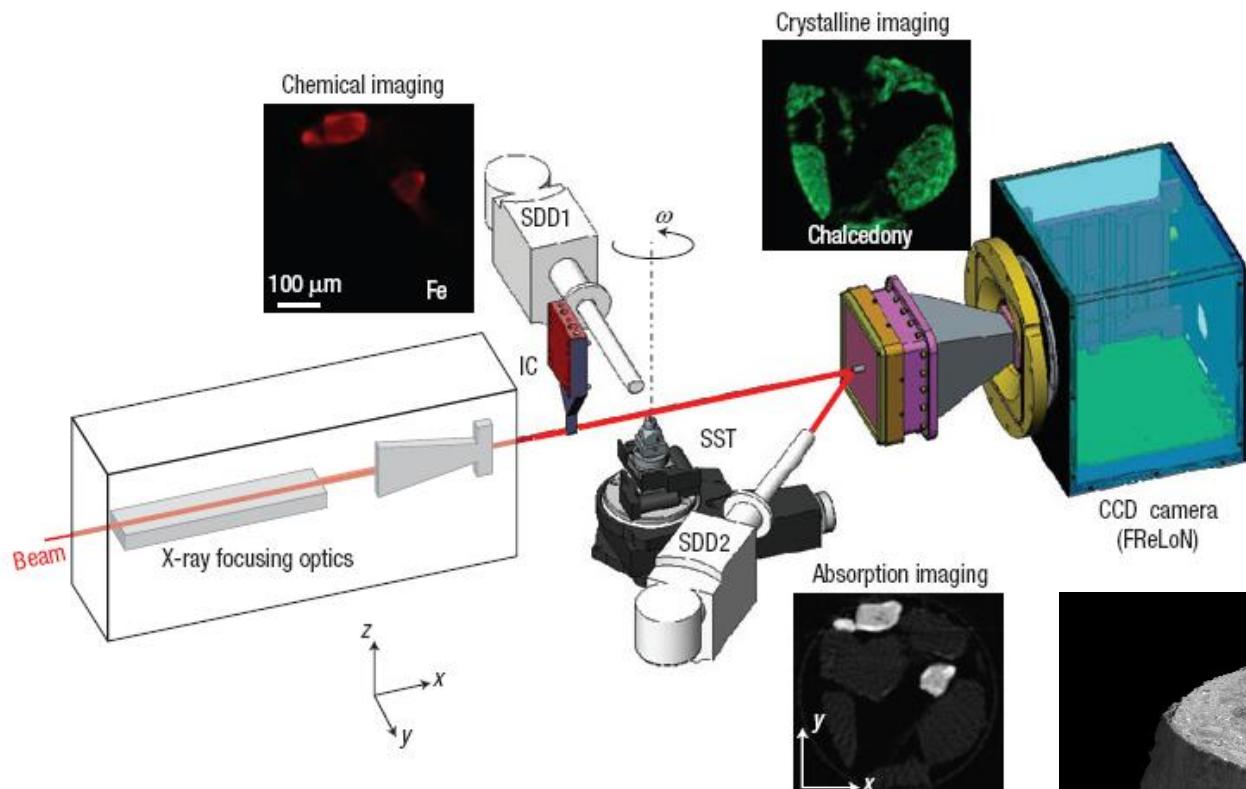
copper

cuprite

malachite,  
brochantite,  
etc.

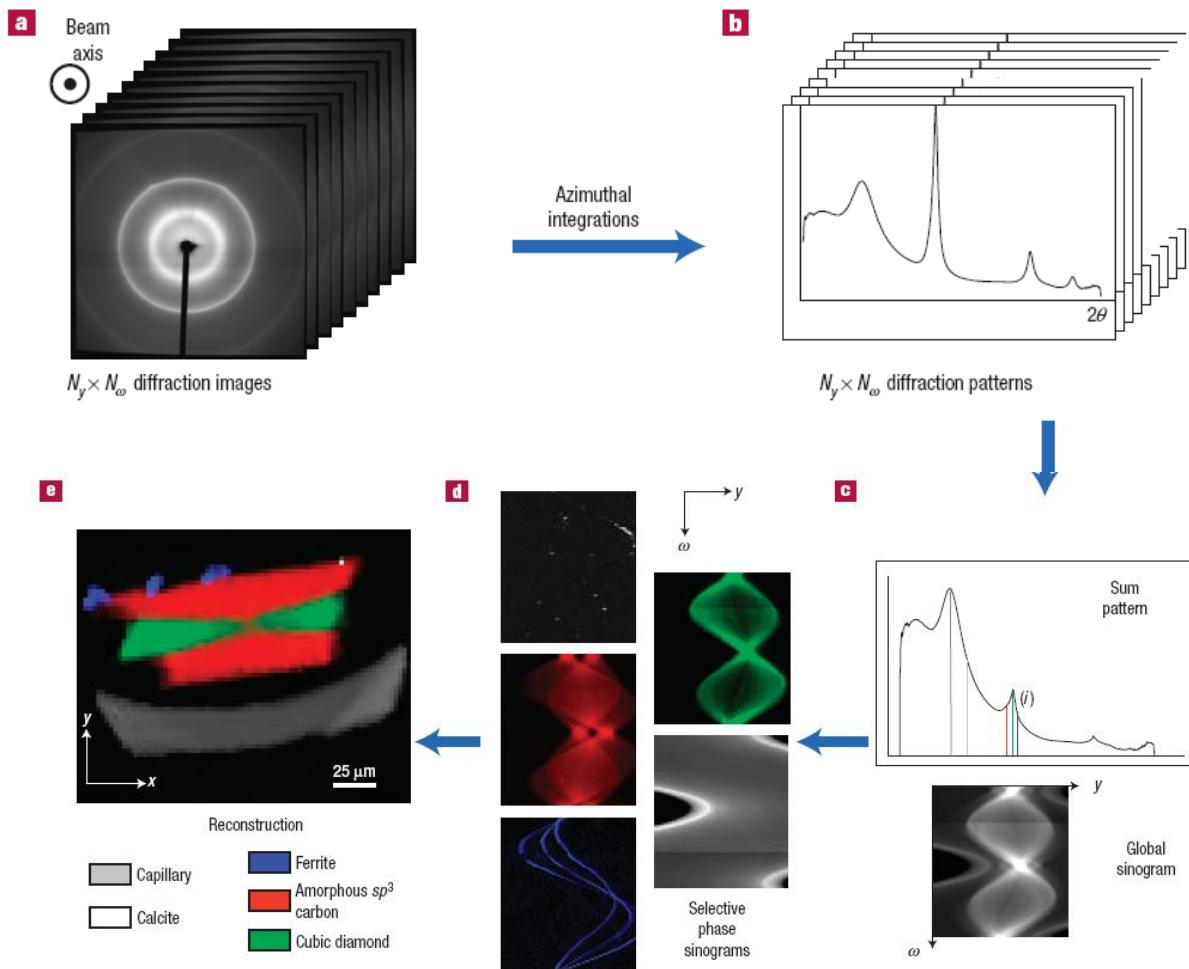
ANGELINI I., ARTIOLI G.: Studio archeometallurgico di noduli metallici da Santa Caterina Tredossi. In: Pizzi C. "L'abitato dell'età del bronzo di Santa Caterina Tredossi (Cremona)", Comune di Milano, Settore Cultura Musei e Mostre, New Press snc, Como; pp. 135-140, 2006.





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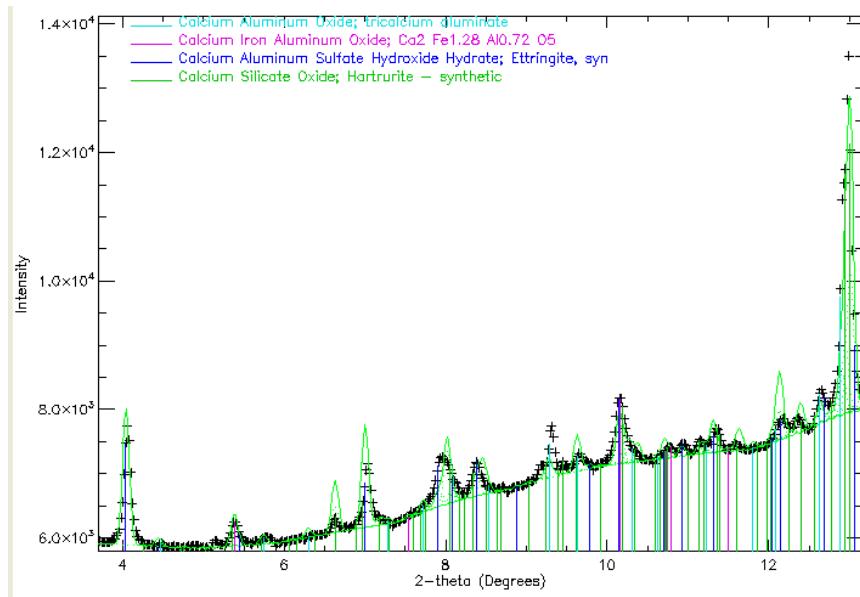
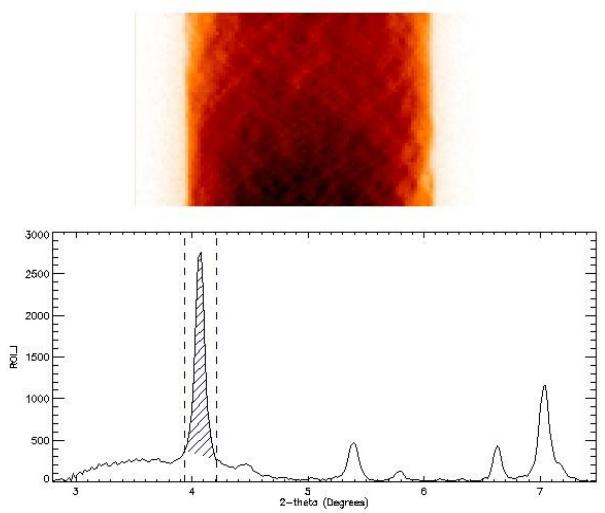
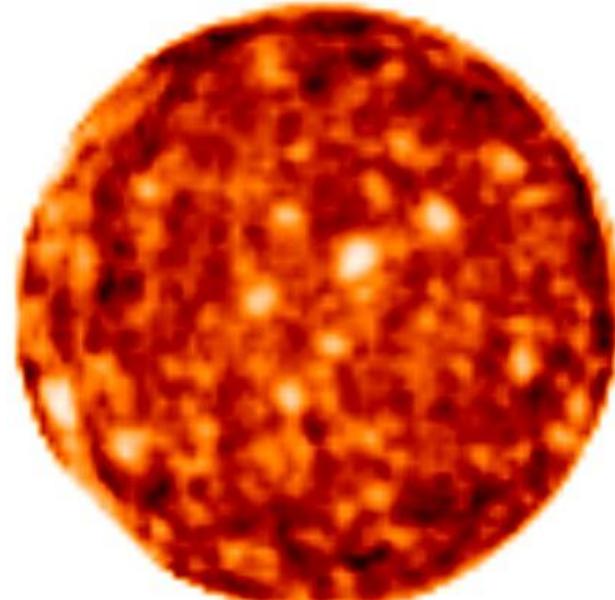
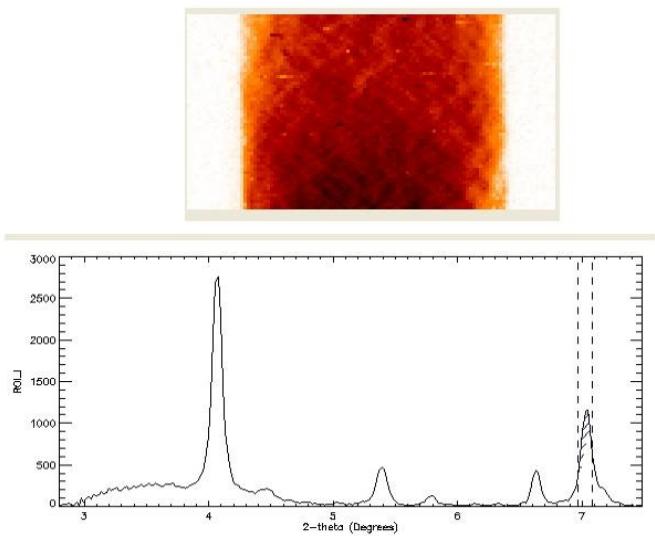
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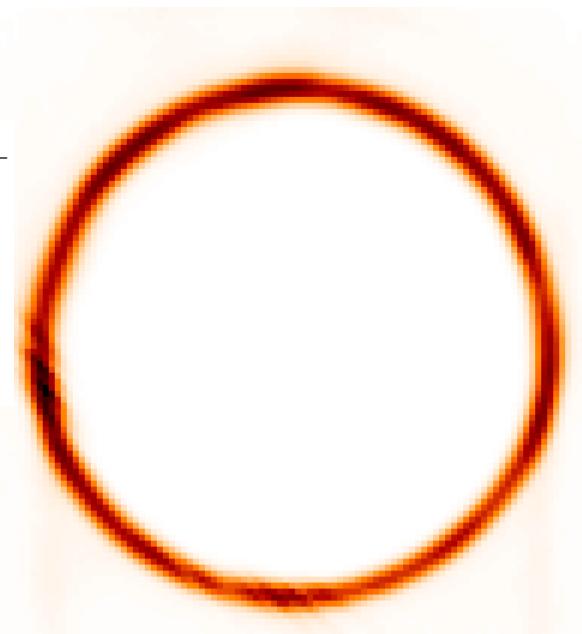
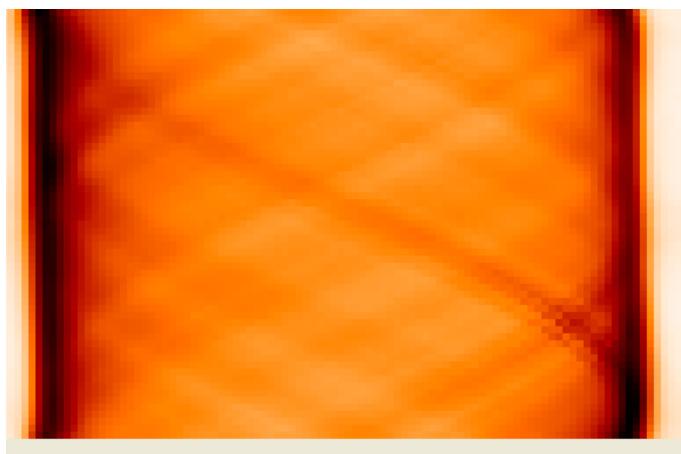
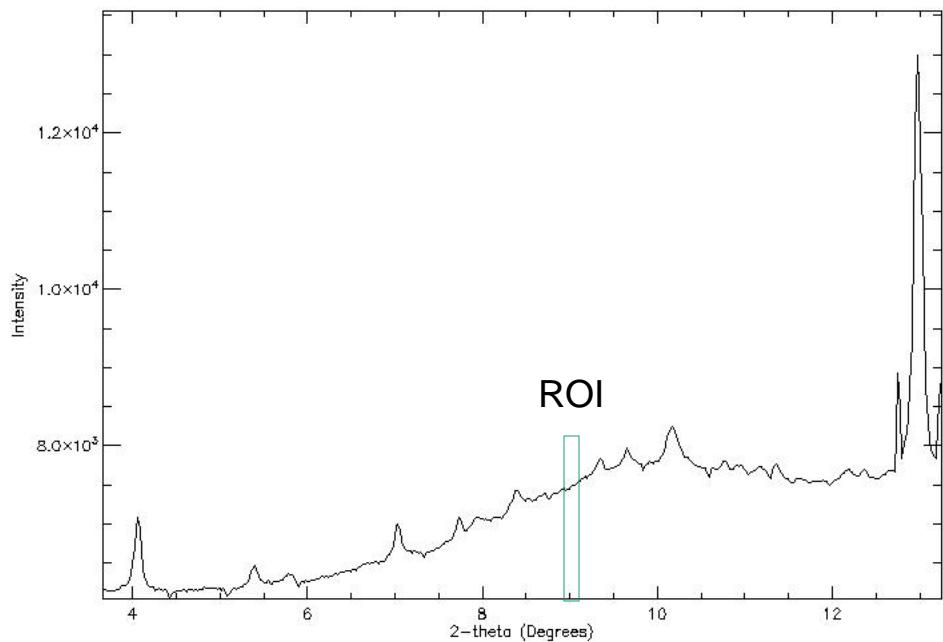
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# Sample2\_slice1\_glass capillary



## research papers

Journal of  
Applied  
Crystallography

ISSN 0021-8898

Received 13 July 2010  
Accepted 29 December 2010

### Towards three-dimensional quantitative reconstruction of cement microstructure by X-ray diffraction microtomography

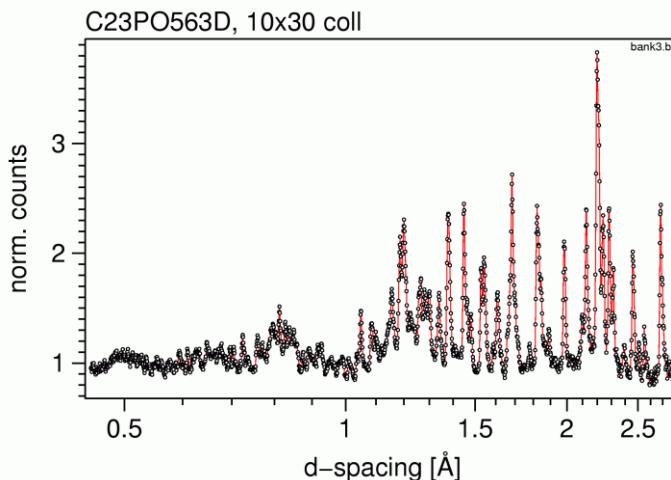
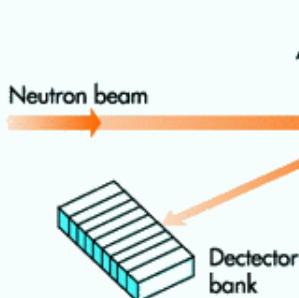
Luca Valentini,<sup>a,b\*</sup> Maria Chiara Dalconi,<sup>a,b</sup> Matteo Parisatto,<sup>a,b</sup> Giuseppe Cruciani<sup>c</sup> and Gilberto Artioli<sup>a,b</sup>

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# Many times we have to deal with precious archaeological or art works: **non invasive neutron diffraction** is very important !!!

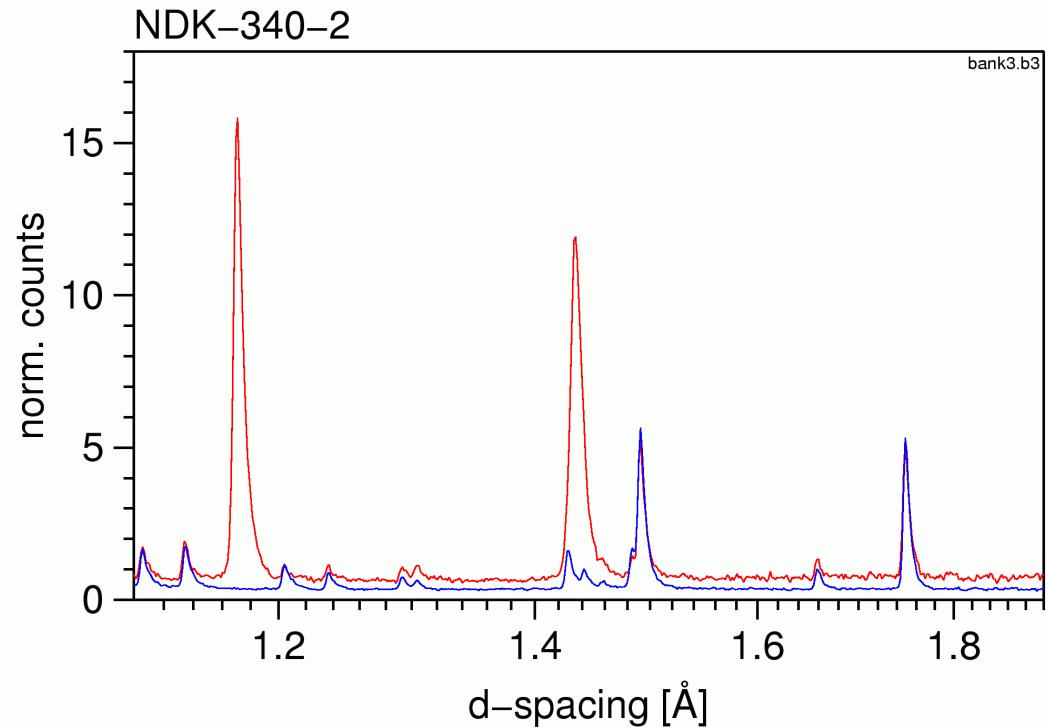
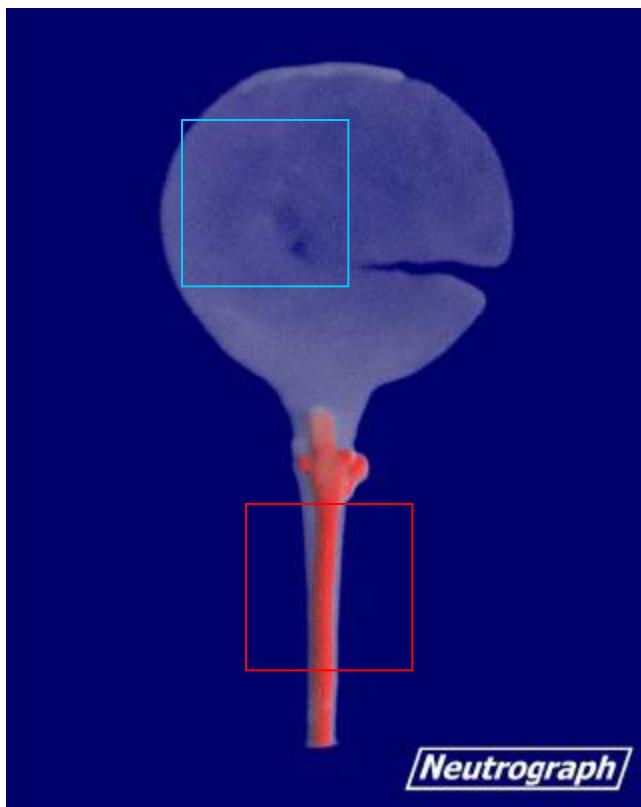


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# TOF neutron diffraction (ISIS)



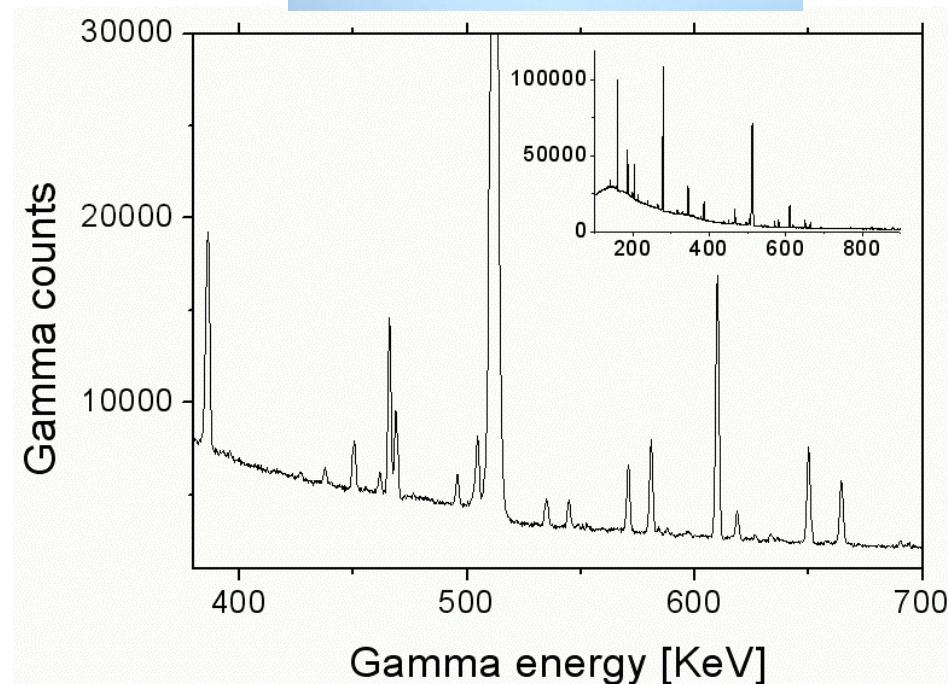
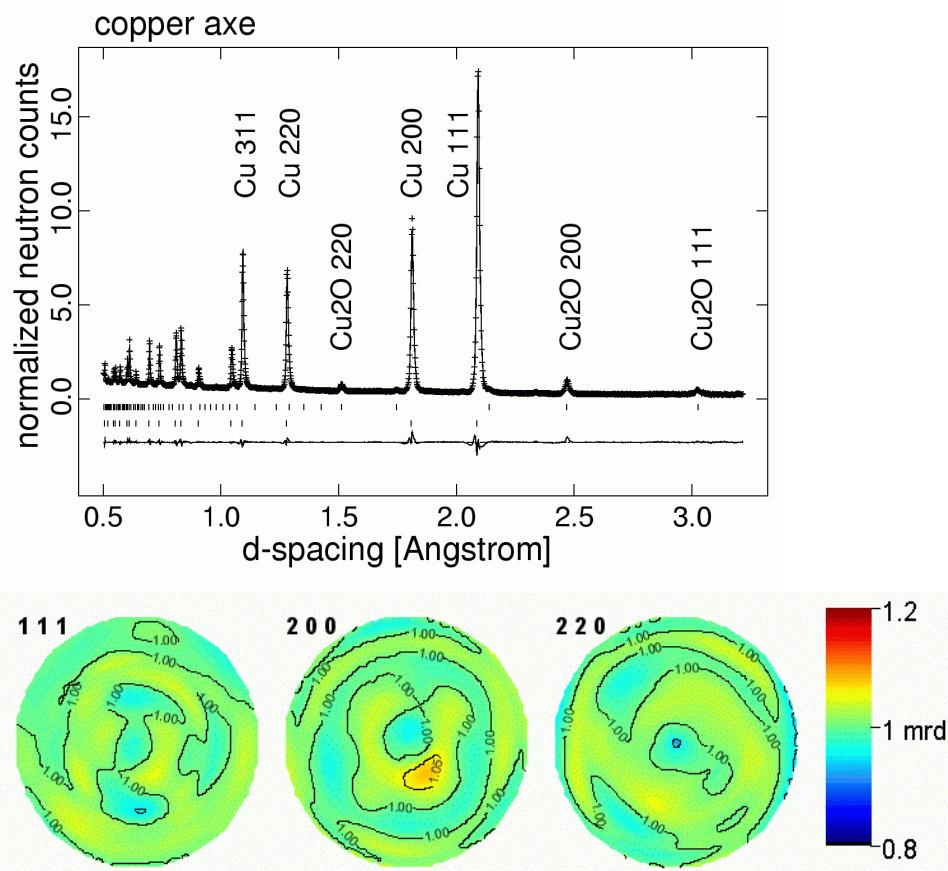
Sn, Pb, Sn-Pb, SnO, Fe

# Simultaneous complementary analysis

Diffraction

Chalcolithic axe,  
S. Shalev, Weizmann Institute, Israel

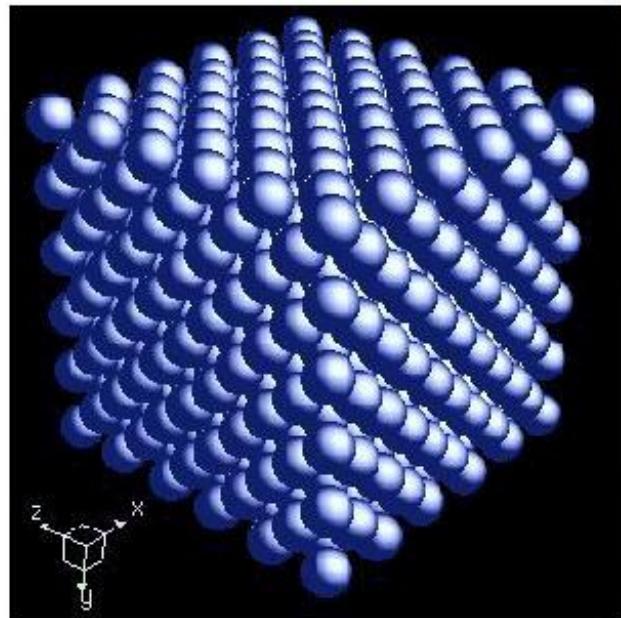
PGAA



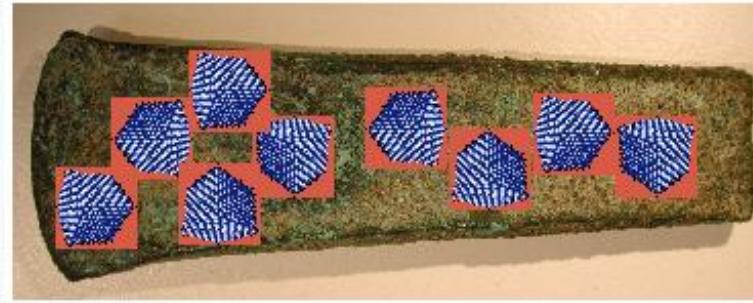
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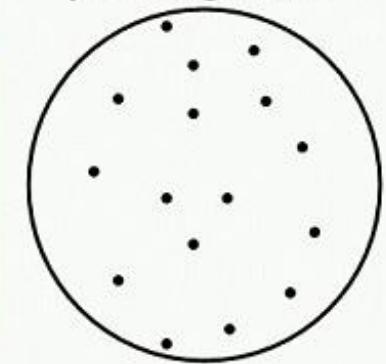




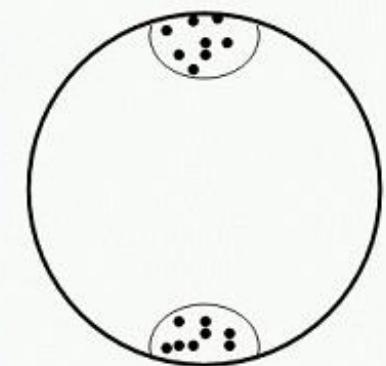
random  
crystallite distribution



(hkl)  
pole figures



preferred orientation  
of crystallites



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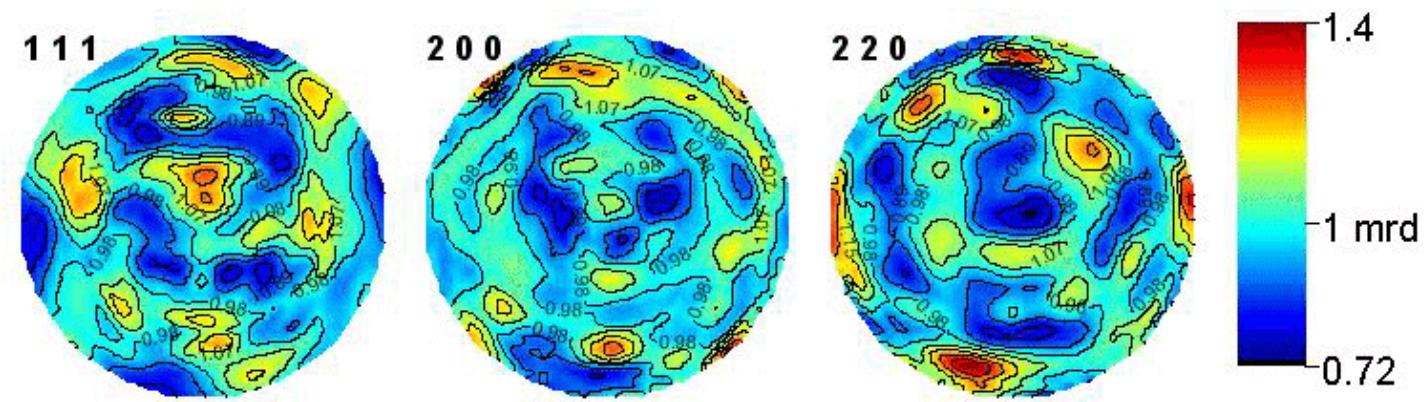
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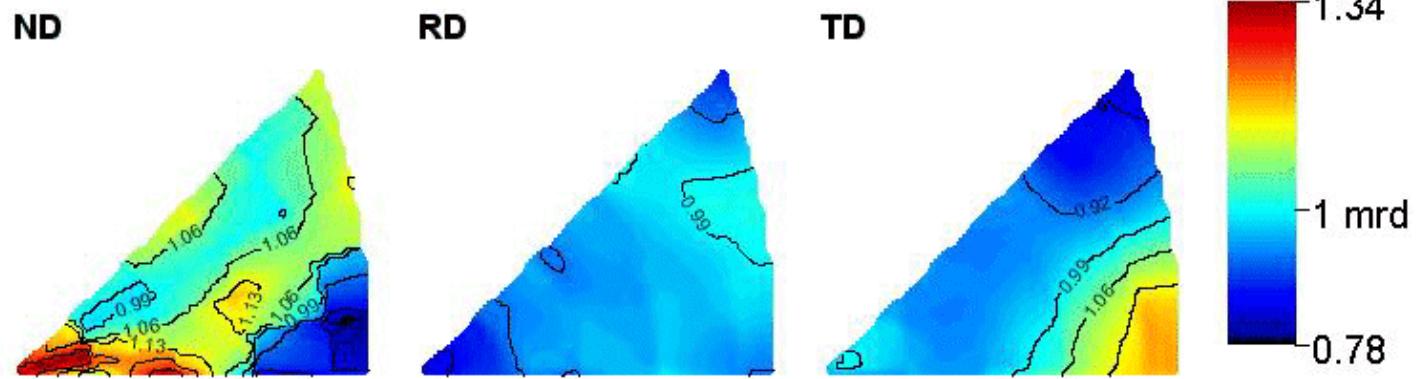


# Remedello Tomba 102

Reconstructed pole figures



Inverse pole figures

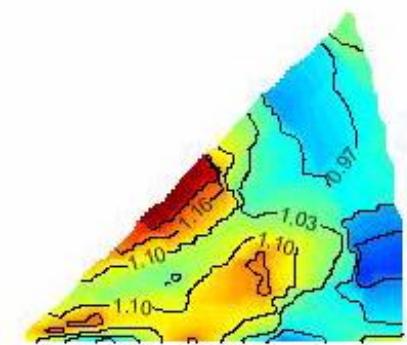
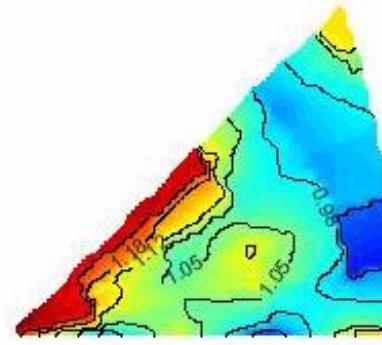
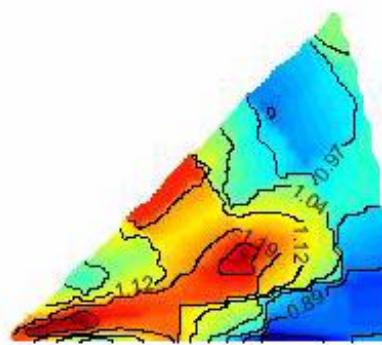
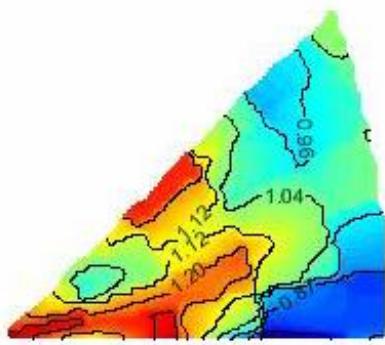


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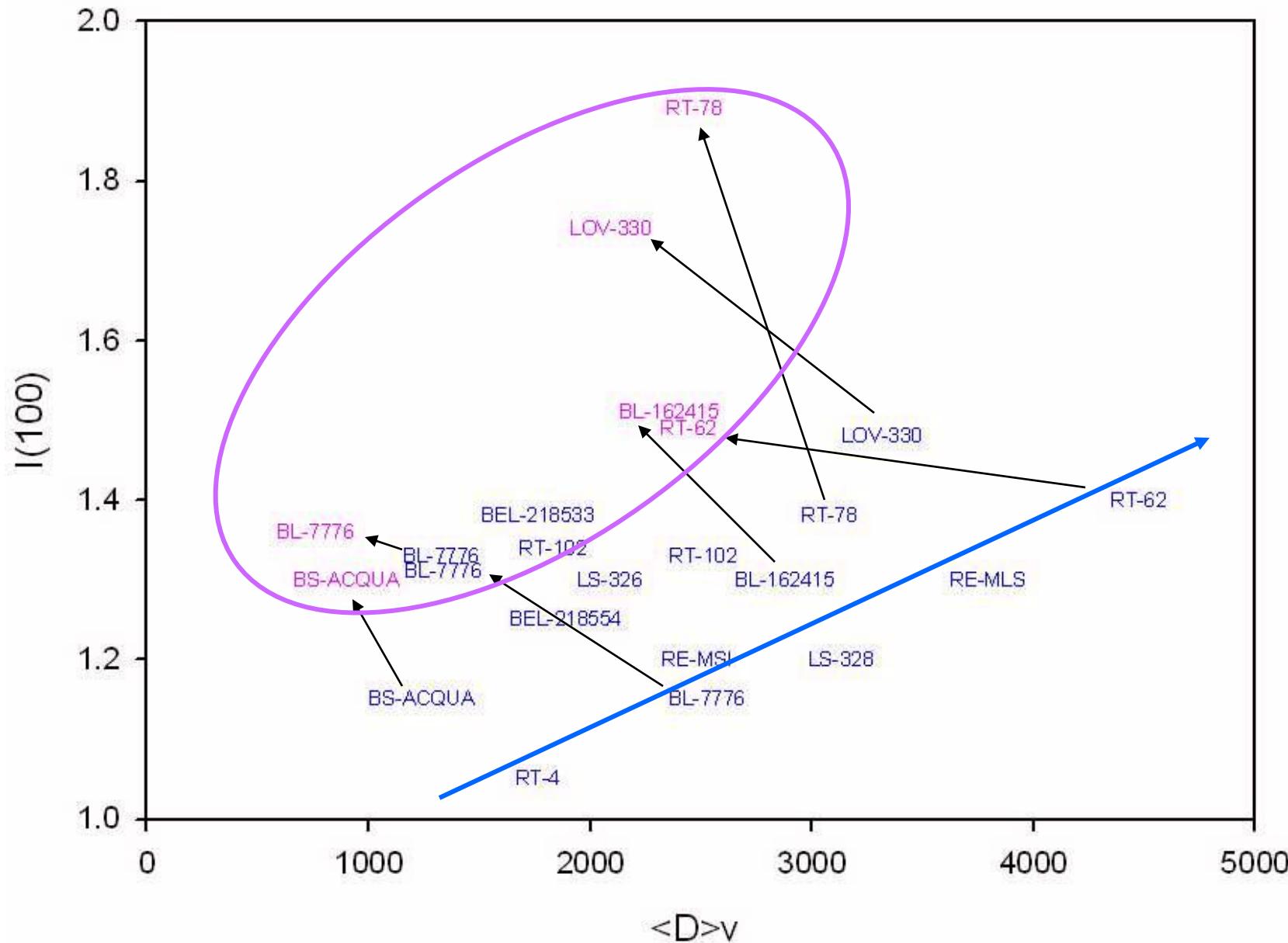
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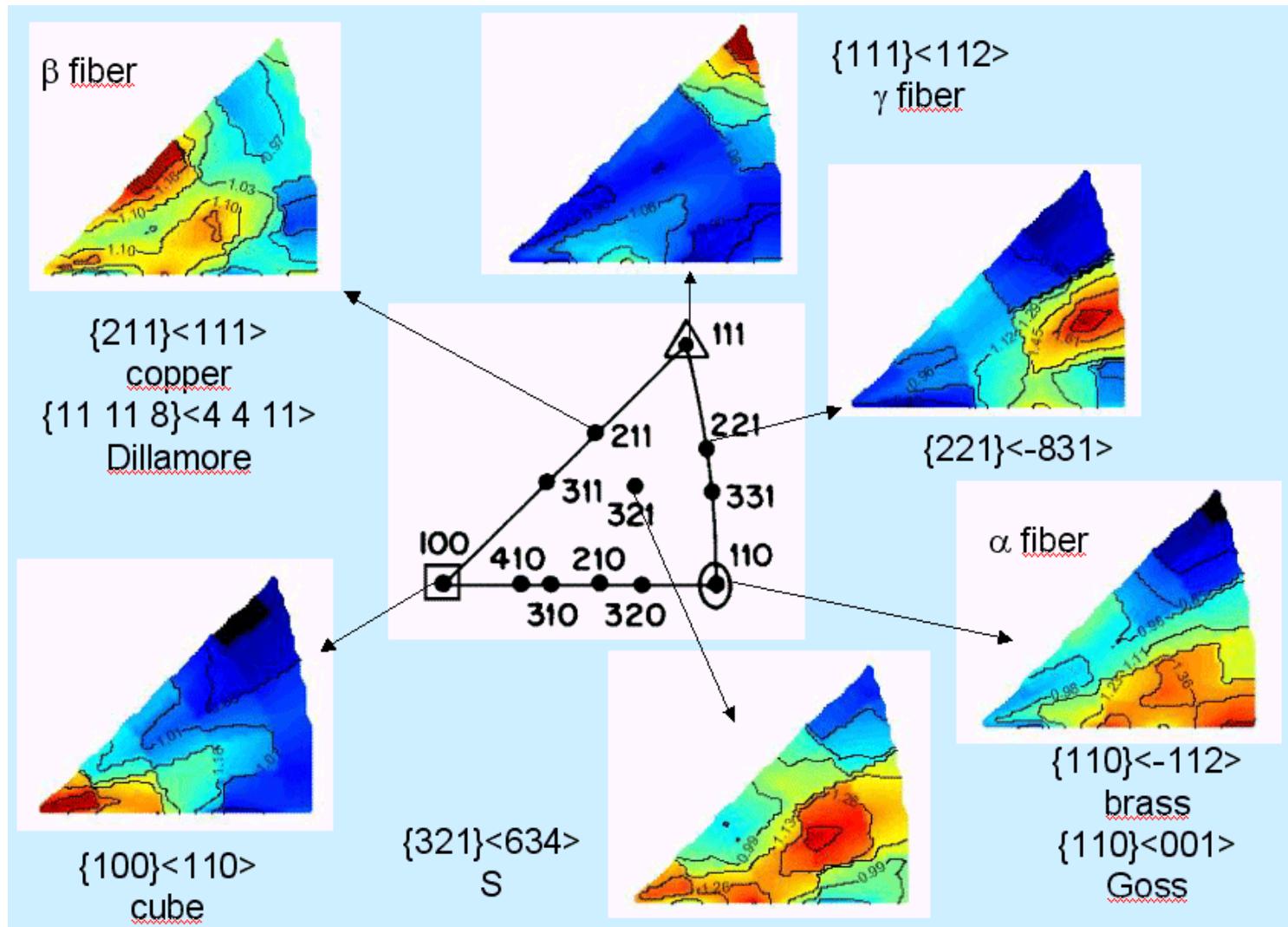


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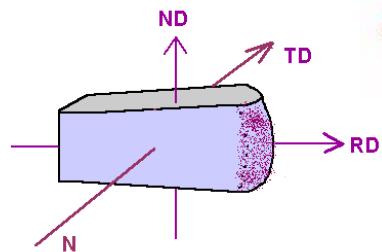
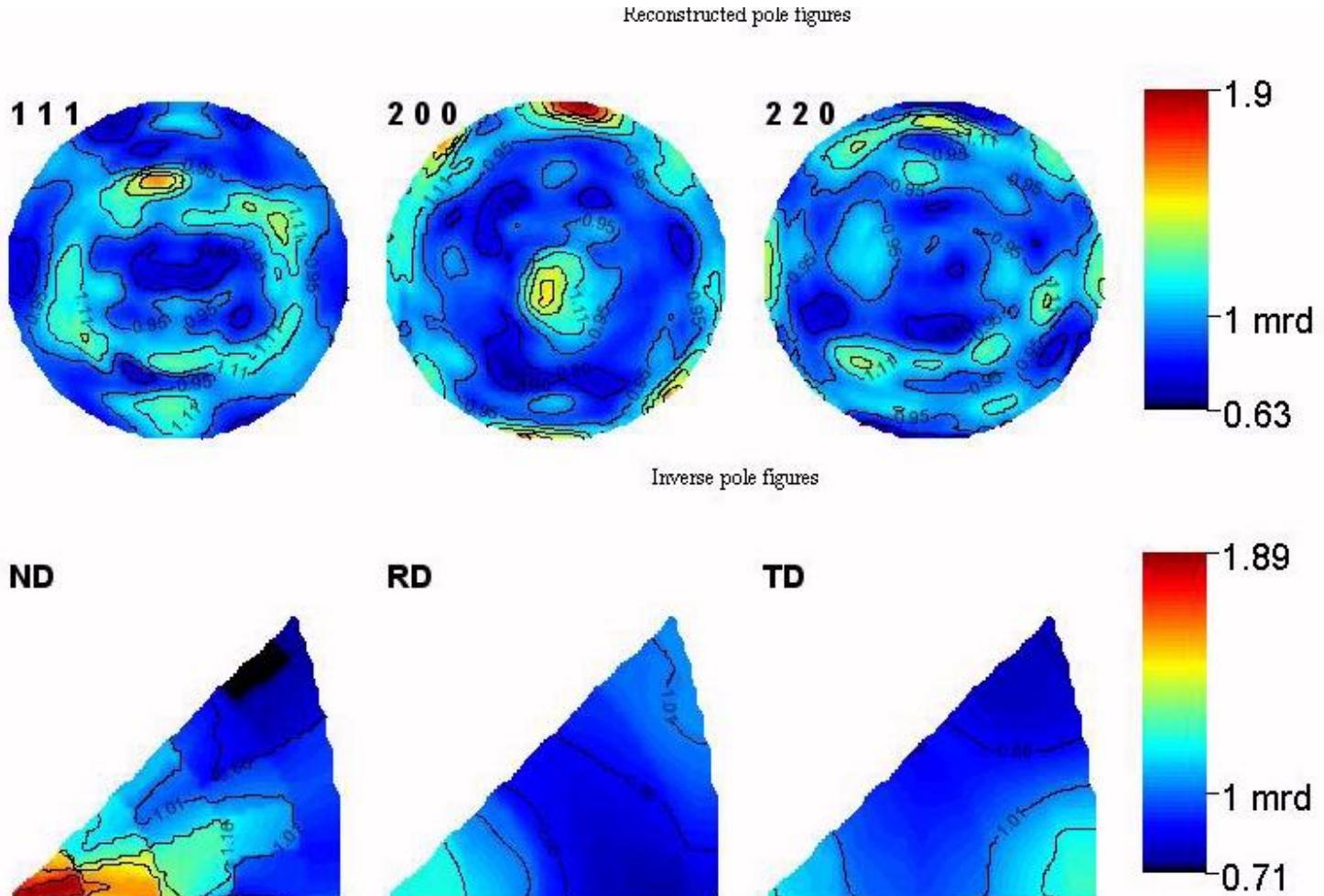


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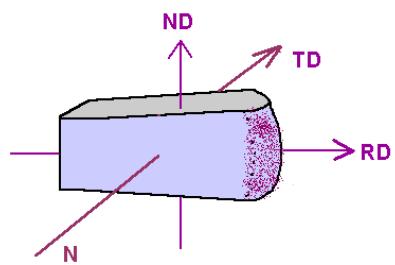
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# Remedello Tomba 78

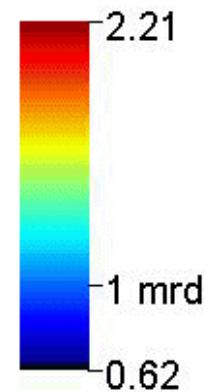
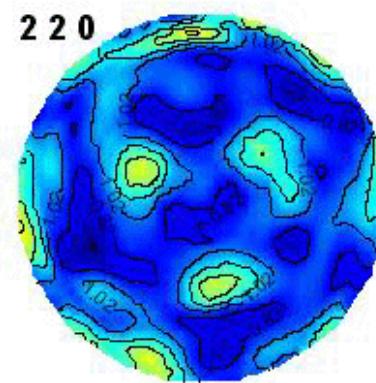
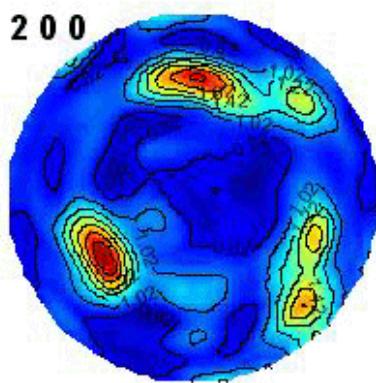
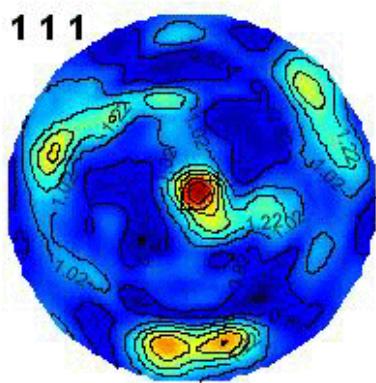


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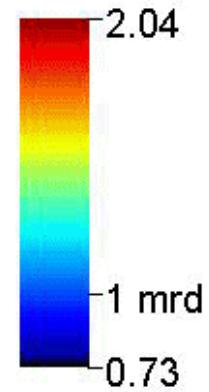
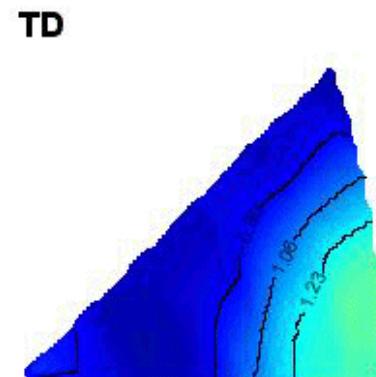
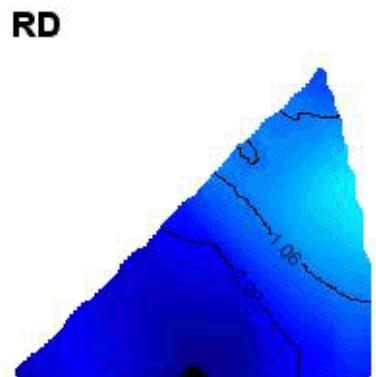
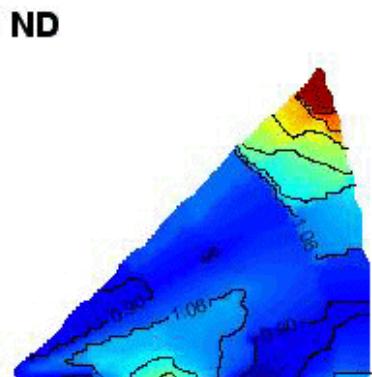
# Bolzano - Hirzlsteig



Reconstructed pole figures



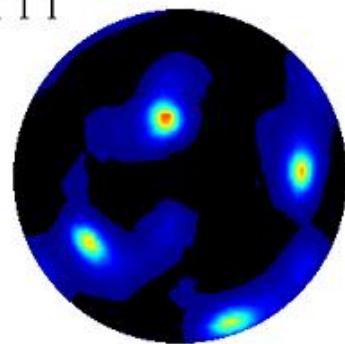
Inverse pole figures



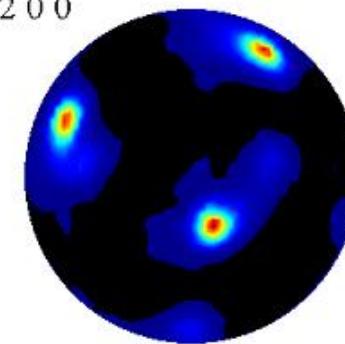
# Gamertinerhof Castelrotto/Kastelruth



1 1 1



2 0 0



2 2 0

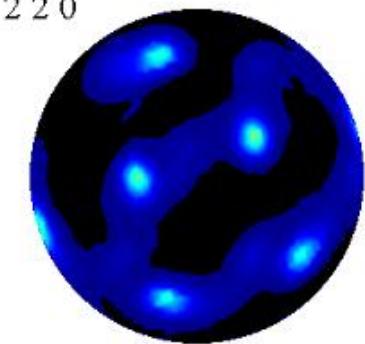
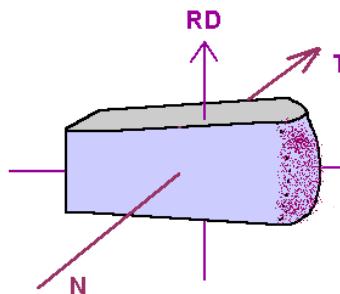
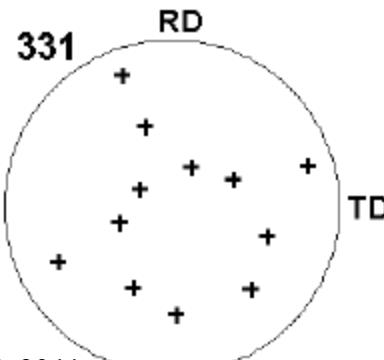
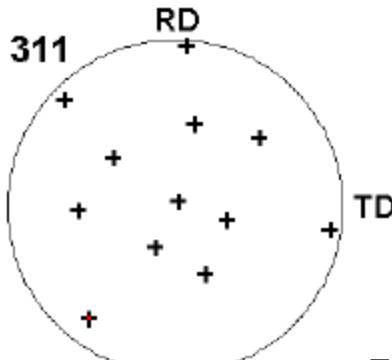
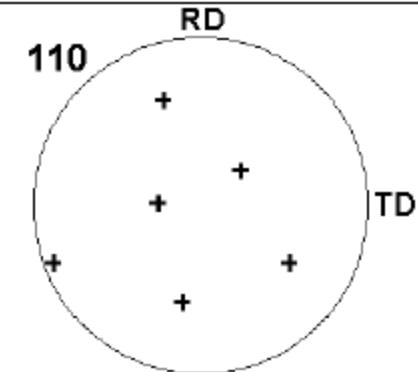
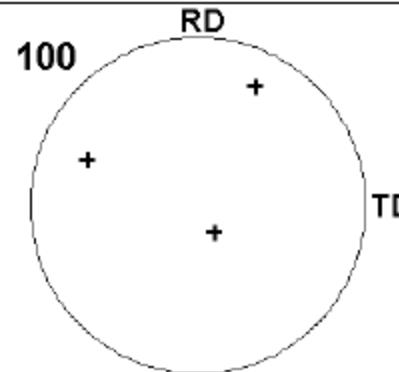
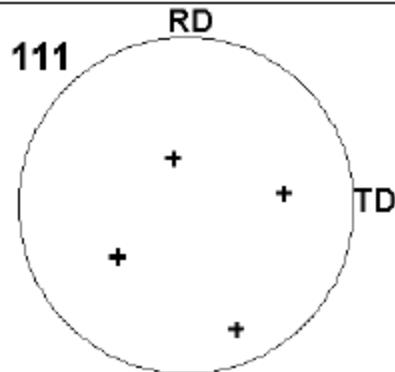


Fig. 15



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# Ötzi ~ 3200 BC



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# Iceman/Ötzi

Appl. Phys. A 89, 899–908 (2007)

DOI: 10.1007/s00339-007-4215-2

G. ARTIOLI

Applied Physics A  
Materials Science & Processing

## Crystallographic texture analysis of archaeological metals: interpretation of manufacturing techniques

Dipartimento di Geoscienze, Università degli Studi di Padova, Via Giotto 1, 35137 Padova, Italy



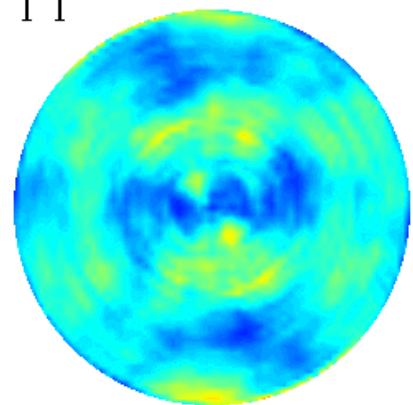
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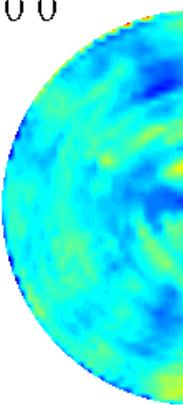
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# Iceman's axe

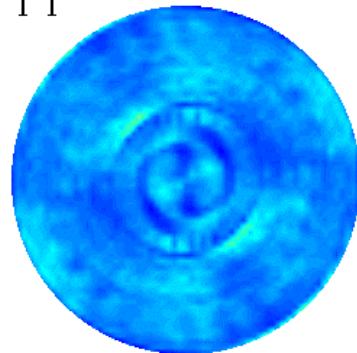
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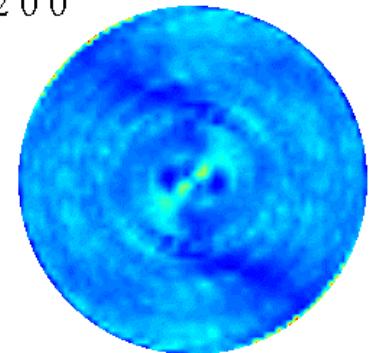
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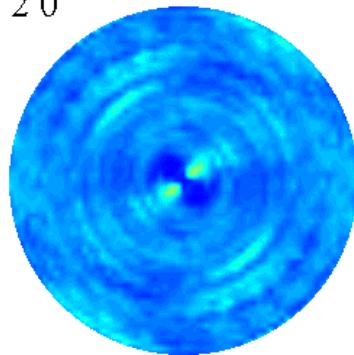
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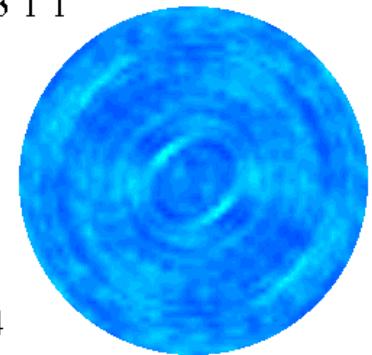
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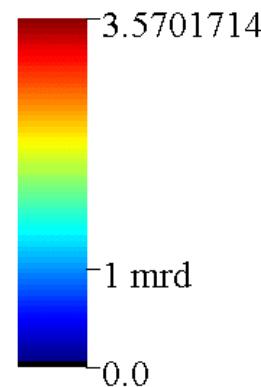
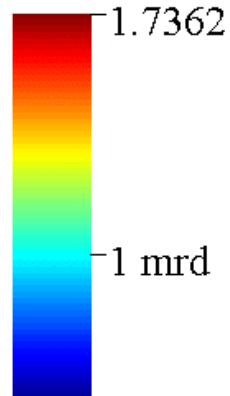
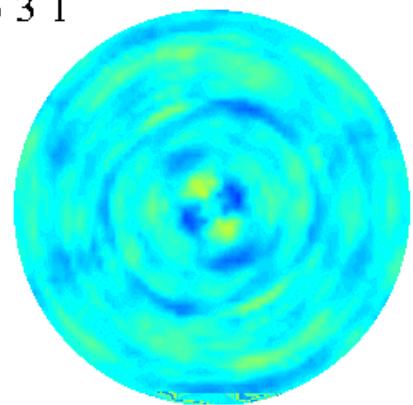
2 2 0



3 1 1



3 3 1



body

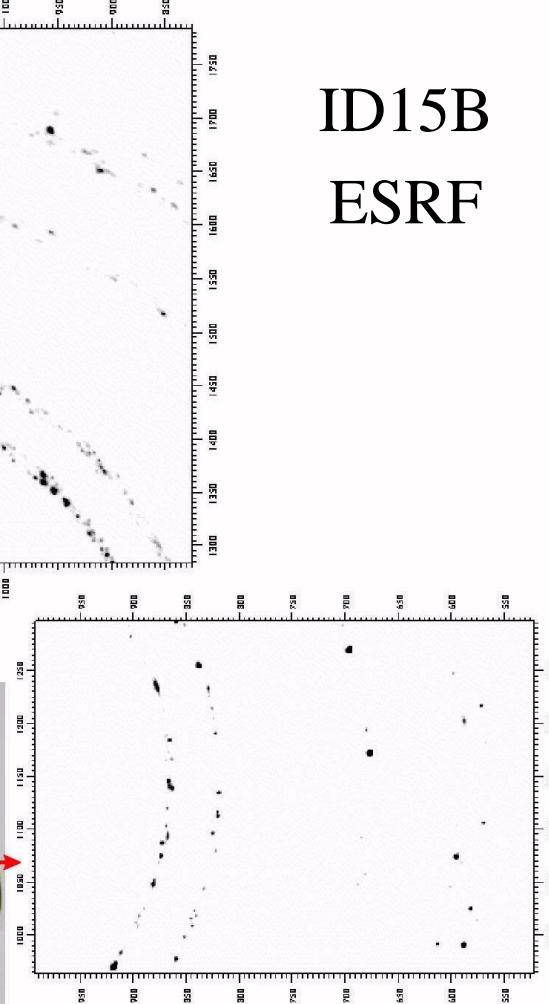
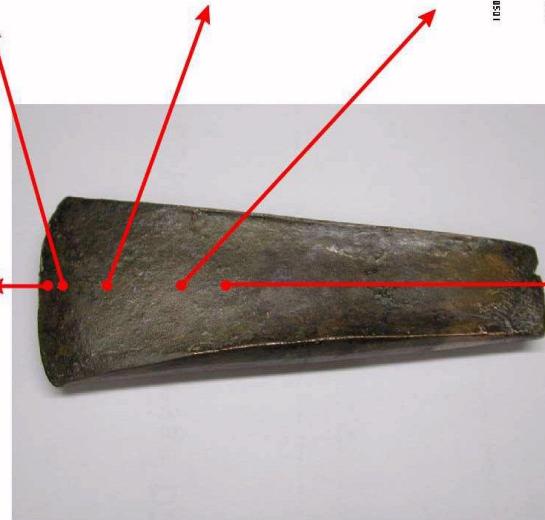
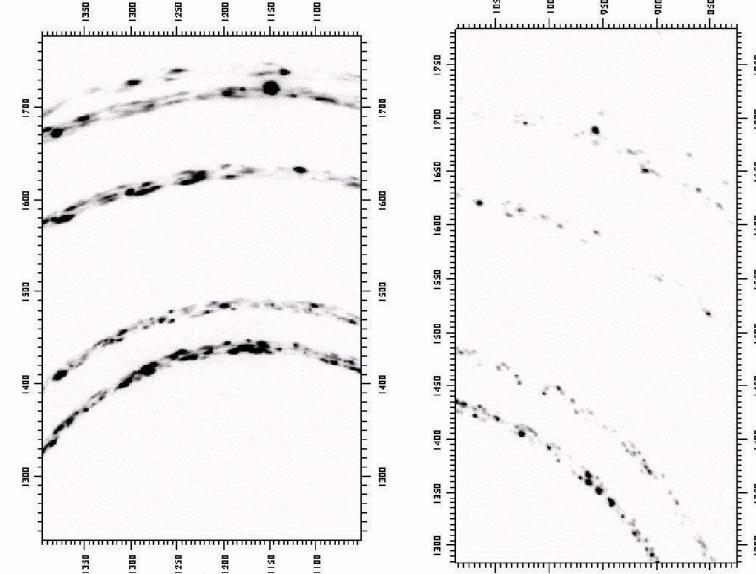
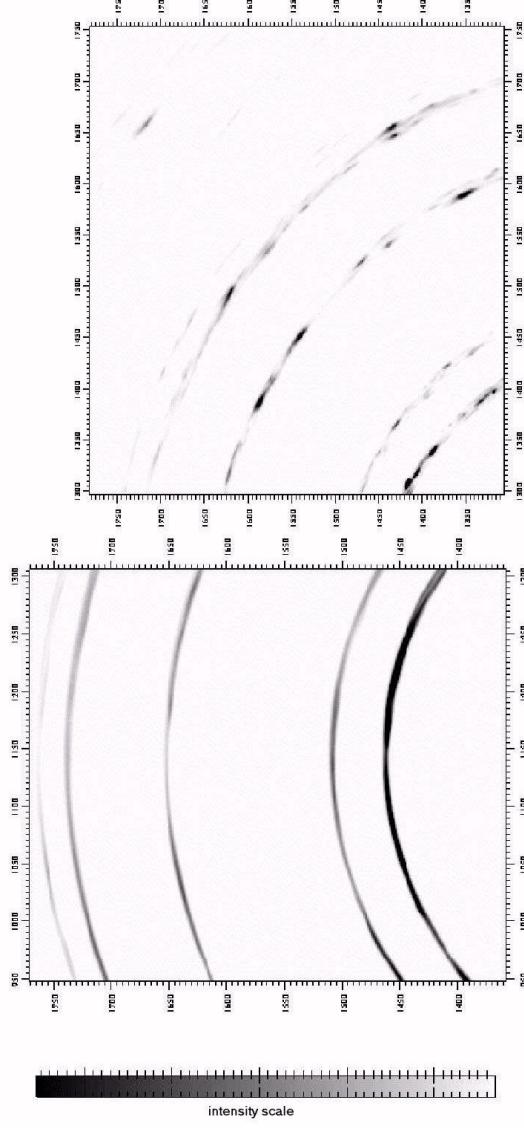


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# high energy X-ray scanning



ID15B  
ESRF

# Tales on the shades of BLUE



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# BLUE tale 2

- Sicilian Baroque glass



Chiesa di S. Francesco Saverio - Palermo



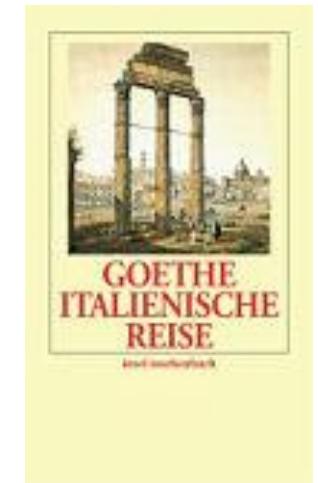
Chiesa della Immacolata Concezione al "Capo" - Palermo

# Johann Wolfgang Goethe „Italienische Reise“

«...Palermo, Freitag, den 13 April 1787. Vorgearbeitet in dem Steinreiche Siziliens hat uns Graf Borch sehr emsig, und wer nach ihm gleichen Sinnes die Insel besucht, wird ihm recht gern Dank zollen. ...Indessen ist sein Heft in Quart, ganz dem sizilianischen Steinreich gewidmet, mir von großem Vorteil, und ich konnte, dadurch vorbereitet, die Steinschleifer mit Nutzen besuchen, welche, früher mehr beschäftigt, zur Zeit als Kirchen und Altäre noch mit Marmor und Achaten überlegt werden mußten, das Handwerk doch immer forttreiben. ... **Doch wissen sie außer diesen beiden sich noch viel mit einem Material, einem Feuererzeugnis ihrer Kalköfen.**



*In diesen findet sich nach dem Brande  
eine Art Glasfluß, welcher von del  
hellsten blauen Farbe zur dunkelsten, ja  
zur schwärzesten übergeht. Diese  
Klumpen werden wie anderes Gestein in  
dünne Tafeln geschnitten, nach der Hohe  
ihrer Farbe und Reinheit geschätzt und  
anstatt Lapislazuli beim Furnieren von  
Altären, Grabmälern und andern  
kirchlichen Verzierungen mit Glück  
angewendet ...».*



«...Palermo, Friday April 13, 1787. Count Borch has very diligently worked before us in the mineralogy of Sicily, and whoever of the same mind visits the island after him, must willingly acknowledge his obligations to him. ... Nevertheless, his essay in quarto, which is exclusively devoted to the mineralogy of Sicily, has been of great use to me; and, prepared by it, I was able to profit by my visit to the Quarries which formerly, when it was the custom to case the churches and altars with marble and agate, were more busily worked, though even now they are not idle. ... But, besides these, **they have still another for a material which is the produce of the fire of their kilns. In these, after each burning, they find a sort of glassy flux, which in colour varies from the lightest to the darkest, and even blackest blue.** These lumps are, like other stones, cut into thin lamina, and then pierced according to the height of their colour and their purity, and are successfully employed in the place of lapis lazuli, in the decoration of churches, altars, and sepulchral monuments. ...»

(*English translation from “Goethe’s travels in Italy”, London, George Bell and Sons, 1885*)

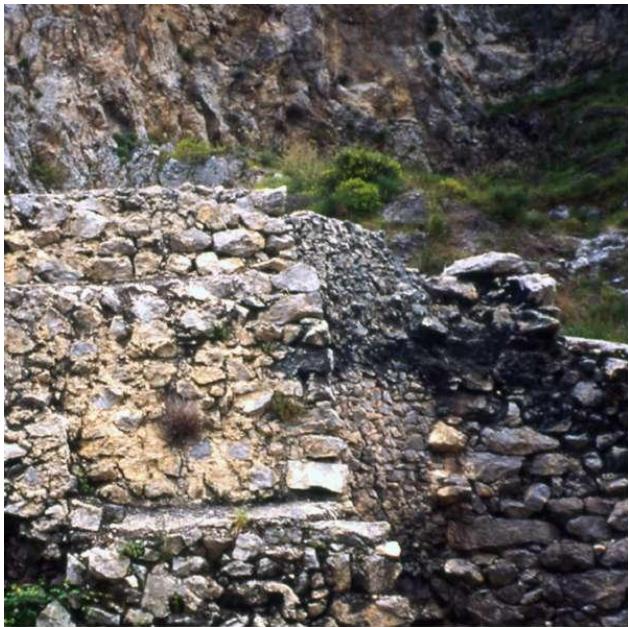


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*Abbazia S. Martino alle Scale  
- Palermo*

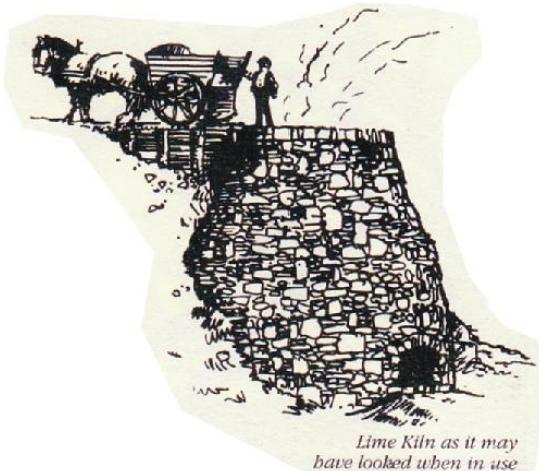


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*Calcare*  
*Near Boccadifalco*



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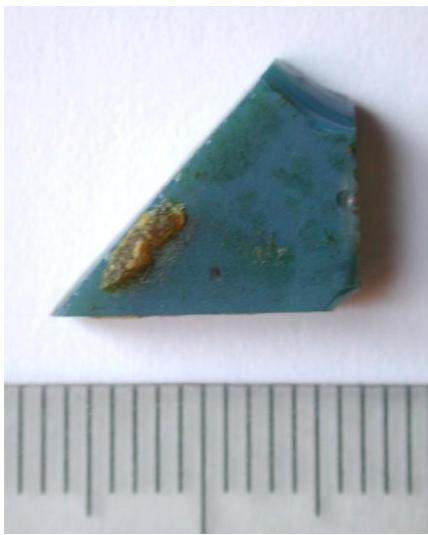
1cm



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	Sigla	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	TiO <sub>2</sub>	MnO	FeO	CoO	NiO	CuO	TOT
Scorie Vetrose	SMdSO1	2,84	5,50	2,61	67,02	1,89	9,03	10,95	0,15	0,17	0,96	0,00	0,00	0,00	101,12
	SMdSO3	0,73	7,15	3,39	62,52	1,90	7,07	16,42	0,18	0,14	1,08	0,00	0,00	0,00	100,00
	SMMG9	0,00	3,17	3,33	69,02	1,26	5,87	12,40	0,30	0,00	1,26	0,00	0,12	0,00	96,73
	SMMG10	0,00	2,64	4,42	74,16	1,16	5,98	10,05	0,29	0,00	1,57	0,00	0,03	0,12	100,41
	SMMG11	0,00	3,85	3,25	66,24	1,20	5,85	13,43	0,10	0,00	1,15	0,00	0,16	0,14	95,37
	SNP2	0,50	5,76	2,82	67,88	1,72	8,72	11,20	0,12	0,14	1,40	0,00	0,00	0,00	100,26
	SNP5	0,03	2,80	4,52	73,56	1,21	5,65	10,65	0,26	0,00	1,76	0,00	0,02	0,11	100,57
Smaltini	SMSI8	0,02	7,97	3,74	59,18	1,44	5,98	17,38	0,32	0,00	1,54	0,00	0,00	0,00	97,57
	SS12	5,64	6,70	12,10	41,68	5,51	3,30	21,93	0,59	0,09	4,33	0,00	0,00	0,00	101,88
	SS13	5,67	7,00	11,45	40,59	5,61	3,35	23,54	0,61	0,07	4,26	0,00	0,00	0,08	102,23
	SS14	5,81	7,11	11,20	40,03	5,68	3,25	23,41	0,61	0,10	4,11	0,00	0,00	0,09	101,39

	<b>Sigla</b>	<b>Co</b>	<b>Cu</b>	<b>Fe</b>
ICP	SMdSO1	2.52	21.81	5 277.14
	SMMG10	3.29	26.73	6 775.62
	SNP2	2.92	30.84	5 974.62
	SNP5	3.46	21.57	7 495.23
ICP-MS	SMdSO3	0.96	8.27	1 404.60
	SS12	1.62	11.63	3 599.80

3 problems:

- **the source of silica**
- **the source of potash**
- **the origin of blue colour**



## Legend

- Clays, marly clays and quartzarenites  
"Flysch Numidico" (lower Langhian-Oligocene)
- Mudstones and calcareous marls  
"Scaglia Auct." (middle Eocene-upper Cretaceous)
- Siliceous shales, radiolarites, radiolaritic marls  
"Fm. Crisanti" (middle Cretaceous-upper Lias)
- Grained and laminated dolomites and dolorudites  
"Fm. Fanusi" (Lias upper-Triassic)
- Dolostones and calcarenites with nodules and beds of  
"Fm. Mirabella" (upper Triassic)
- Shales, marls, limestones and calcarenites  
"Fm. Mufara" (upper Triassic)



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## Domenico Schiavo

Unedited manuscript dated 1756 located in the Biblioteca Comunale di Casa Professa, Palermo

«...Spezzati che abbiano con grossi martelli o picconi que' duri macigni, ed in un luogo raccortili, preparata infine gran quantità di legna e tra queste della **genista** e molti fasci dell'erba chiamata **spartum**, che in abbondanza ivi nasce, compongono certe camerette a volta delle pietre ben chiuse tolto che da un sol lato, in cui lasciano un piccolo spiraglio di quattro o cinque palmi per introdurvi le legna. Rassettata così la fornace, v'appiccano il fuoco, proseguendo di continuo più uomini a vicenda notte e giorno a buttarvi legna per sei o sette giorni, secondo la grandezza della fornace, fin a tanto che si calcino perfettamente que' grossi macigni per mezzo di quel continuo fuoco di riverbero...».

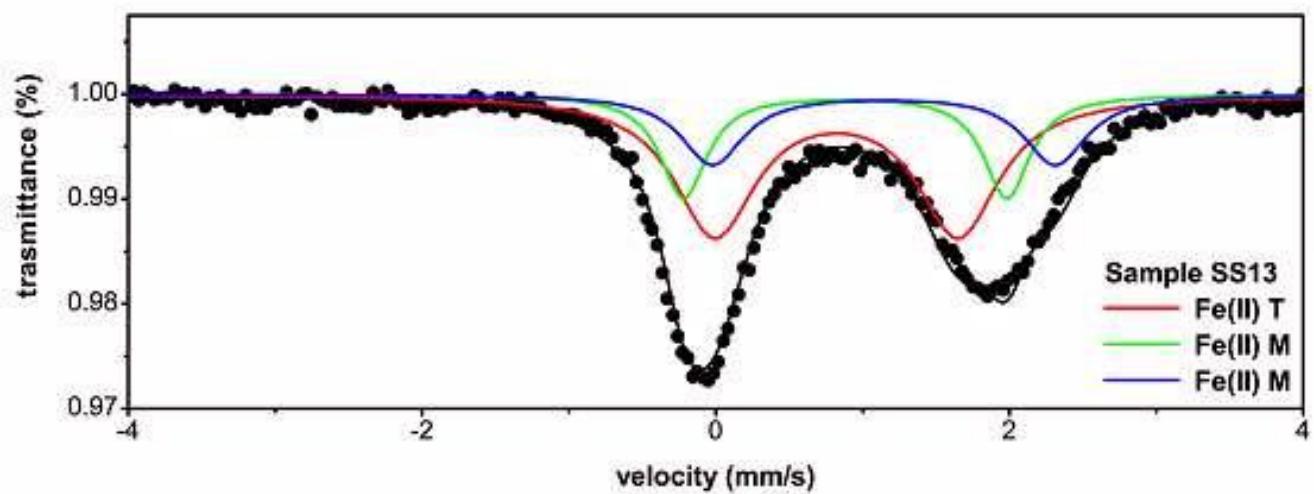
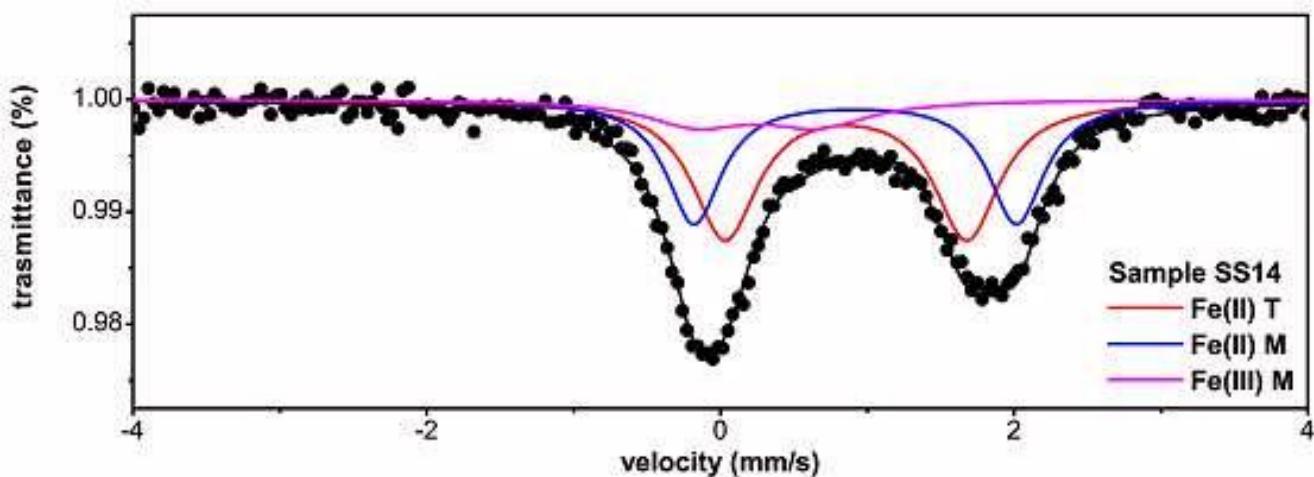


*Spartium junceum* syn. *Genista juncea* (Ginestra, Spanish broom)

*Ampelodesmos mauritanicus* (Disa)



plant	MgO	CaO	Na2O	K2O
<i>Ampelodesmos mauritanicus</i> (parte sup, foglie)	2.09	2.20	0.69	5.10
<i>Ampelodesmos mauritanicus</i> (parte inf, gambo)	2.19	2.78	0.75	22.54
<i>Spartium junceum</i> (totale)	11.51	71.40	3.20	4.69



Blue colour caused by a very distorted octahedral environment of  $\text{Fe}^{+2}$



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Archaeometry 51, 2 (2009) 197–213

doi: 10.1111/j.1475-4754.2008.00414.x



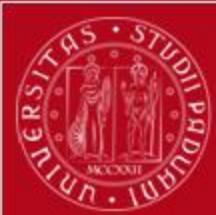
**THE BLUE ENAMELS IN THE BAROQUE DECORATIONS  
OF THE CHURCHES OF PALERMO, SICILY:  
FE<sup>2+</sup>-COLOURED GLASSES FROM LIME KILNS\***

**Erice PPD 2011**

G. ARTIOLI,<sup>1</sup> C. NICOLA,<sup>2</sup> G. MONTANA,<sup>3</sup> I. ANGELINI,<sup>1</sup>  
L. NODARI<sup>4</sup> and U. RUSSO<sup>4</sup>

BLUE tale 3

# The mystery of the “avatar” flints



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LA STORIA | IL COMUNE CEDE DUE PALAZZI STORICI. L'ARCHEOLOGA: DISTRUTTO UN PATRIMONIO

## Verona e il mistero delle selci blu Venduto il museo, marciscono in cantina *Reperti preistorici coperti di muffa. I rischi del federalismo demaniale*

Nel frattempo, tutto il materiale preistorico che non potendo essere esposto per mancanza di spazio era in deposito parte a Castel San Pietro e parte da palazzo Gobetti, è stato sgomberato dagli edifici venduti e accatastato in due stanzoni al piano terra e al primo piano dell'Arsenale che magari domani, ristrutturati, saranno stupendi. Ma oggi sono né più né meno che due magazzini semi-diroccati. Cosa sia successo non si sa. C'è chi ipotizza, come Gilberto Artoli del dipartimento di Geoscienze di Padova, che il magazzino al piano terra fosse impregnato di qualche sostanza non ancora ben definita. Chi ritiene occorrono nuove analisi per capirci qualcosa. Chi ancora si avventura nell'immaginare un sabotaggio. Vero? Falso? Si vedrà.

IL CASO

## Allarme reperti Neanderthal con quella strana luce blu

Un'inchiesta della rivista *Nature* punta il dito sulle condizioni di conservazione di alcuni importanti frammenti di osso di Neanderthal rinvenuti in Verona. L'appello dei ricercatori al ministro Bondi di *LUIGI BIGNAMI*

La curatrice della collezione Laura Longo ha declinato ogni commento a *Nature*, in quanto dal Museo le è stato chiesto di non parlare sull'argomento. Ma Longo aveva già mostrato perplessità sul modo con il quale erano stati sistemati i materiali, tant'è che recentemente aveva chiesto a Gilberto Artoli, un geo-archeologo dell'Università di Padova di individuare la sostanza che produce lo strano effetto di luce bluastra sui campioni di fossili. Dalle prime analisi sembrerebbe che i campioni siano stati coperti da una patina di idrocarburi, forse lubrificanti, che un tempo venivano usati per pulire le armi presenti nell'arsenale. "Ma questo non spiega il colore blu presente sui reperti", ha spiegato il ricercatore a *Nature*. Che dunque deve avere un'altra origine ancora da determinare. Artoli sostiene che non sarebbe difficile individuare l'altro inquinante, ma questo potrebbe creare una vera e propria bomba politica, in quanto se si scoprisse che il materiale si trova sulle pareti o sul pavimento dell'edificio vorrebbe dire che si sono trasferiti i materiali paleontologici senza un'adeguata pulizia dell'edificio.

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 Teresa Rook I Flintstones si sono accoppiati con i puffi!!!!  
domenica alle 8.02

# Ancient Italian artefacts get the blues

Scientists accuse officials of neglect as chemicals discolour stored relics.



Selci blu, la scienza si mobilita



## New Molecule Turns Italian Artifacts—And International Scientists—Blue

by Ann Gibbons on July 22, 2010 2:10 PM | [Permanent Link](#) | [0 Comments](#)



April 4, 2011

Volume 89, Number 14  
pp. 32 - 33

## Blue Whodunit

Artifact-staining dye structures revealed, but case far from closed

[Carmen Drahl](#)

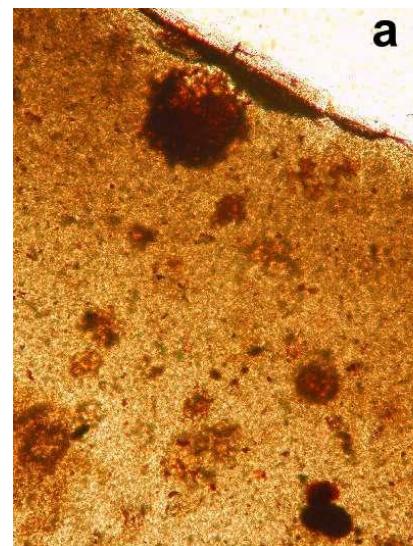


<http://www.laboratoryequipment.com/news-artifact-staining-leaves-chemical-questions-040611.aspx>

## Artifact Staining Leaves Chemical Questions

April 6, 2011

This winter, Gilberto Artioli's team reported the structures of three new pigment molecules. Because the molecules came from samples that originated near Verona, Italy, the [Univ. of Padua](#) gearchaeologist named two of the brilliant blue dyes after Verona's Shakespearean star-crossed lovers, Romeo and Juliet. Artioli's dyes are also the protagonists of a drama of their own. And for some researchers, things might have been better if the pigments had never existed.



Anal Bioanal Chem (2011) 399:2389–2393

DOI 10.1007/s00216-010-4625-4

SHORT COMMUNICATION

## The mystery of the discolored flints. New molecules turn prehistoric lithic artifacts blue

Andrea Tapparo · Gilberto Artioli · Ivana Angelini ·  
Gabriella Favaro



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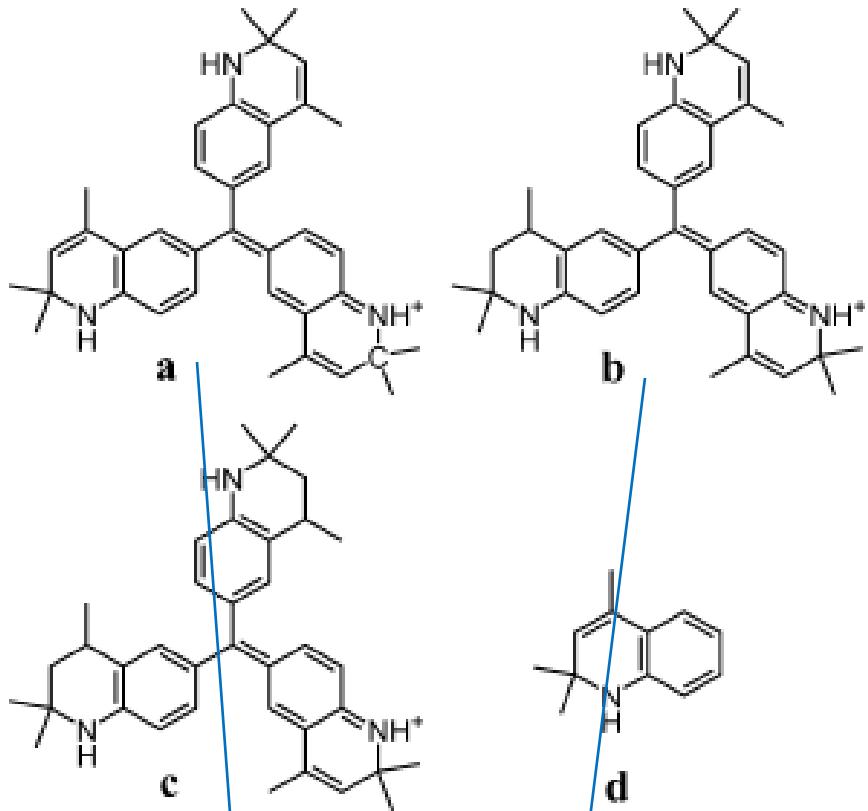
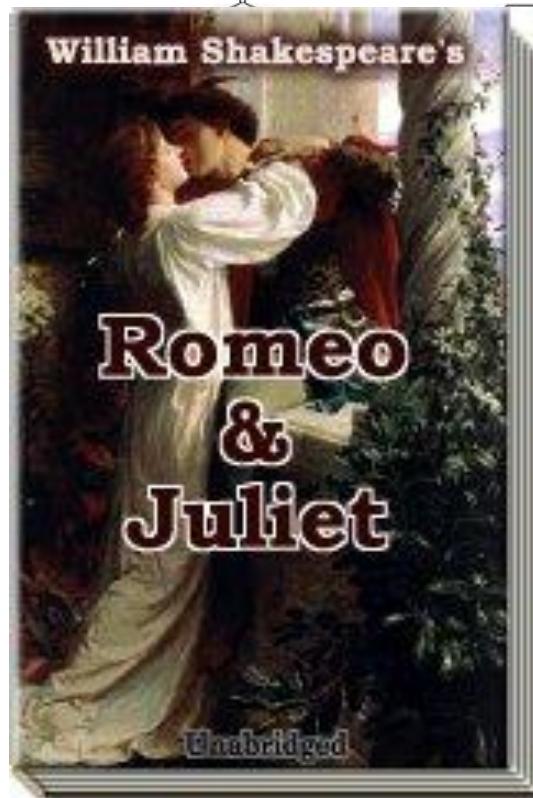
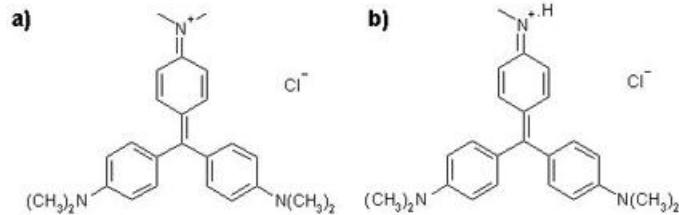


Fig. 4 Structures of a–c the novel blue pigmenting molecules and d the hypothesized precursor 2,2,4-trimethyl-1,2-dihydroquinoline (TMQ). Proposed names: a Juliet Blue; b Romeo Blue; and c Flint Blue

Juliet blue / Romeo blue



es /  
 atives  
*Victoria blue*  
 e



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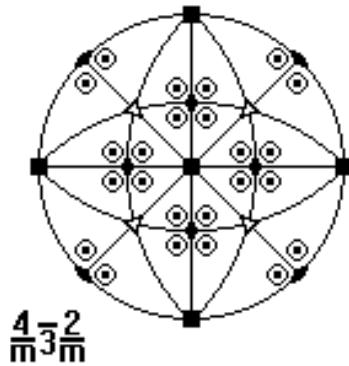
# GAMBLING WITH ETRUSCAN DICE: A TALE OF NUMBERS AND LETTERS\*

G. ARTIOLI,<sup>1†</sup> V. NOCITI<sup>2</sup> and I. ANGELINI<sup>1</sup>

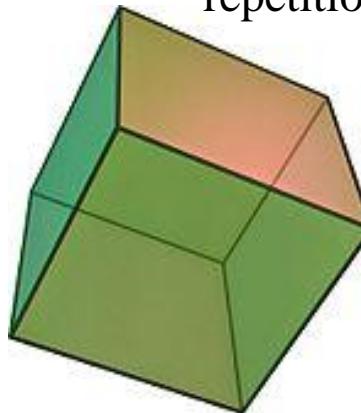
<sup>1</sup>Dipartimento di Geoscienze, Università di Padova, Via Giotto 1, I-35137 Padova, Italy

<sup>2</sup>Via Pascoli 3, 20121 Milano, Italy

theory of **random permutations** tells us that 6 numbers can be distributed on the 6 faces of the cube in **6!** **permutations**, thus offering **720** independent combinations containing no repetitions



$\frac{4}{\bar{m}} \frac{2}{\bar{m}} \frac{3}{\bar{m}}$



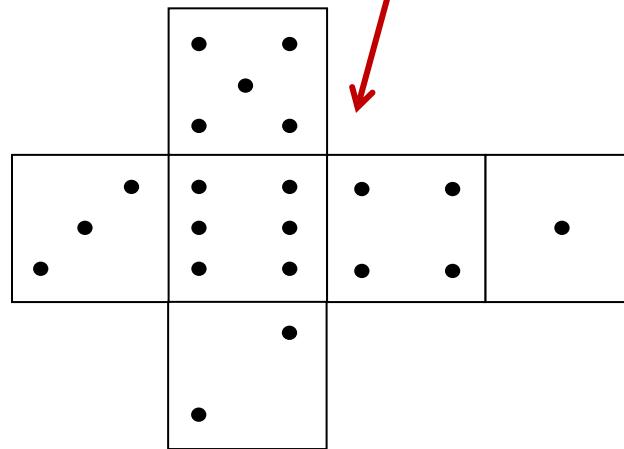
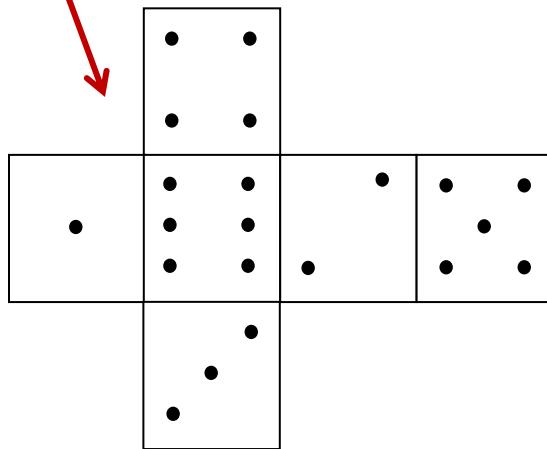
$$6!/48 = 720/48 = 15$$



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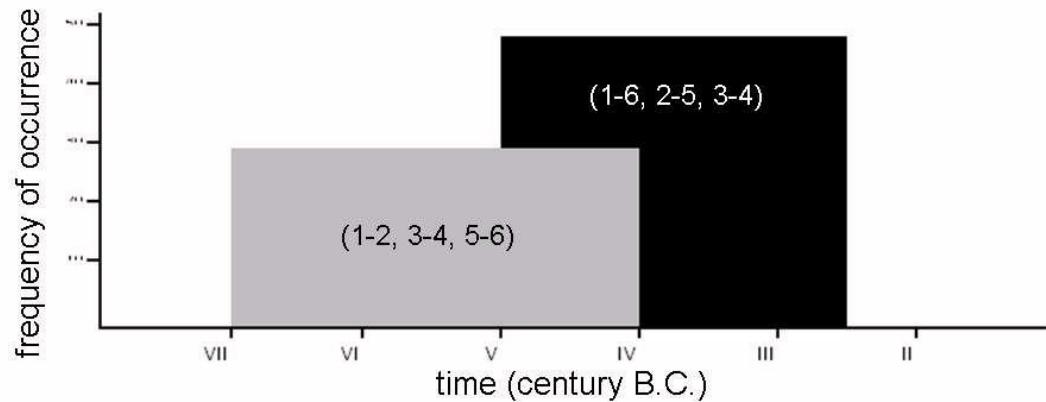


(1-2, 3-4, 5-6)	(1-3, 2-4, 5-6)	(1-4, 2-3, 5-6)	(1-5, 2-3, 4-6)	(1-6, 2-3, 4-5)
(1-2, 3-5, 4-6)	(1-3, 2-5, 4-6)	(1-4, 2-5, 3-6)	(1-5, 2-4, 3-6)	(1-6, 2-4, 3-5)
(1-2, 3-6, 4-5)	(1-3, 2-6, 4-5)	(1-4, 2-6, 3-5)	(1-5, 2-6, 3-4)	(1-6, 2-5, 3-4)



Difference = 1

Sum = 7



# Etruscan numerals

From Wikipedia, the free encyclopedia

The **Etruscan numerals** were used by the ancient Etruscans. The system was adapted from the Greek Attic numerals and formed the inspiration for the later Roman numerals.

Etruscan	Decimal	Symbol *
θu	1	I
may	5	Λ
śar	10	X
muvalx	50	↑
?	100	☒ or C

There is very little surviving evidence of these numerals. Examples are known of the symbols for larger numbers, but it is unknown which symbol represents which number.

Thanks to the numbers written out on the **Tuscania dice**, there is agreement about the fact that **zal**, **ci**, **huθ** and **śa** are the numbers up to 6 (besides 1 and 5). The assignment depends on the answer to the question whether the numbers on opposite faces on Etruscan dice add up to seven, like nowadays. Some dice found do not show this proposed pattern.

## The general consensus

[edit]

Despite the continuing debate specifically about which of **huθ** and **śa** are "four" and "six", the general agreement among Etruscologists nowadays is the following:

Etruscan	Decimal
θu	1
zal	2
ci	3
huθ	4
max	5
śa	6



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Year	Author	Numerical assignment					
		1	2	3	4	5	6
1968	Olzscha	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth</i>	<i>mach</i>	<i>sa</i>
1969	Pfiffig	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>sa</i>	<i>mach</i>	<i>huth</i>
1973	Cristofani	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth (sa?)</i>	<i>mach</i>	<i>sa (huth?)</i>
1976	Savelli	<i>thu</i>	<i>huth</i>	<i>zal</i>	<i>mach</i>	<i>Ci</i>	<i>sa</i>
1983	Bonfante	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>sa</i>	<i>mach</i>	<i>huth</i>
1984	Pallottino	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth (sa?)</i>	<i>mach</i>	<i>sa (huth?)</i>
1989	Rix	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth</i>	<i>mach</i>	<i>sa</i>
1990	Pittau	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth</i>	<i>mach</i>	<i>sa</i>
1991	Morandi	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>huth</i>	<i>mach</i>	<i>sa</i>
1995	Agostiniani	<i>thu</i>	<i>zal</i>	<i>ci</i>	<i>sa</i>	<i>mach</i>	<i>huth</i>



mach = 5



sa = 4  
 huth = 6  
 ci = 3  
 zal = 2  
 thu = 1

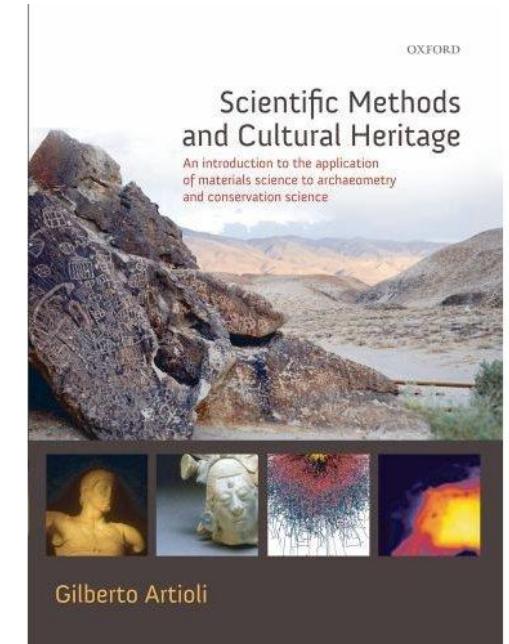




# Thank you for your attention !

**Scientific Methods and Cultural Heritage**  
*An introduction to the application of materials science to archaeometry and conservation science*  
**Gilberto Artioli**

552 pages | 200 b/w line and halftone figures, 8pp colour plates | 246x189mm  
978-0-19-954826-2 | Hardback | 08 July 2010



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