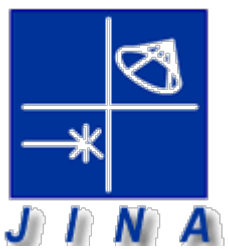
Applications for PIXE and other Ion Beam Analysis

PIXE-PAN Summer Science Program

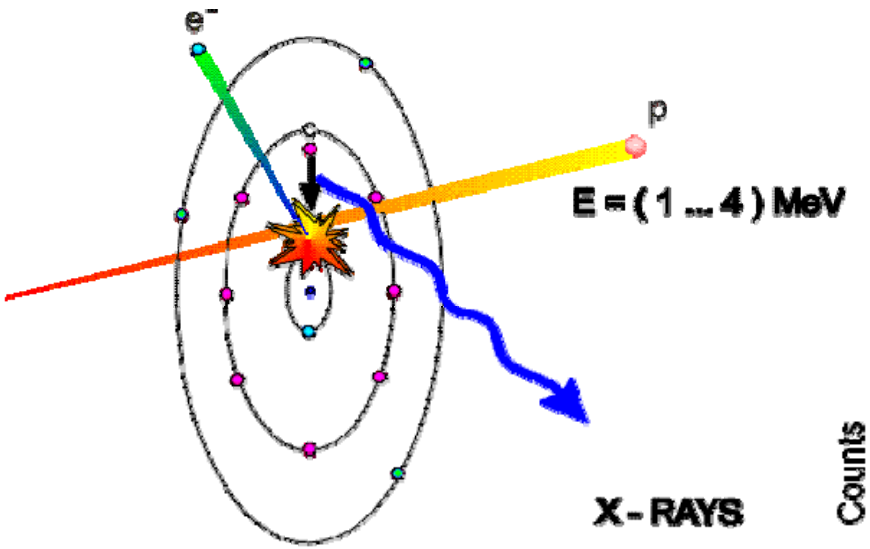
Notre Dame

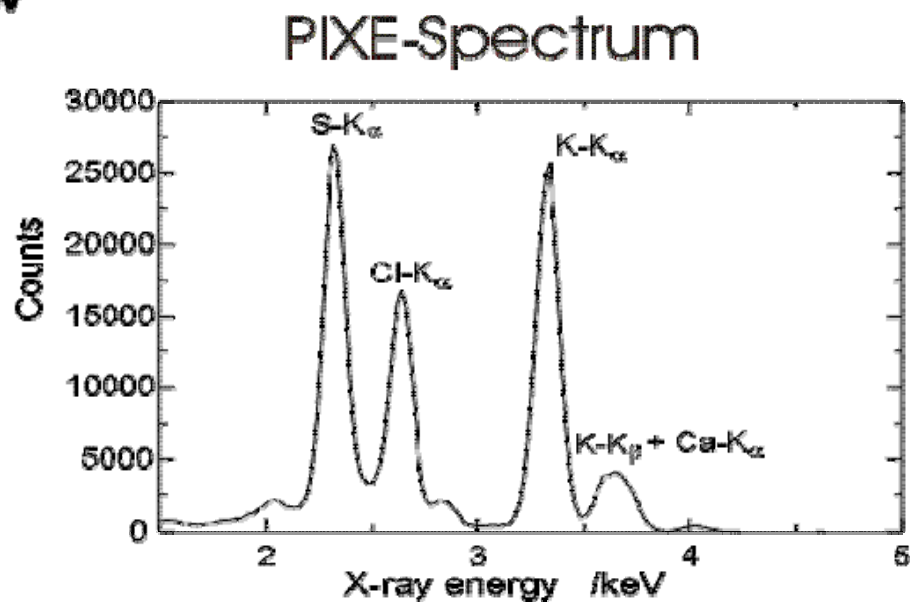
June, 2006

Larry Lamm, Research Professor



PIXE
(Proton Induced Xray Emission)

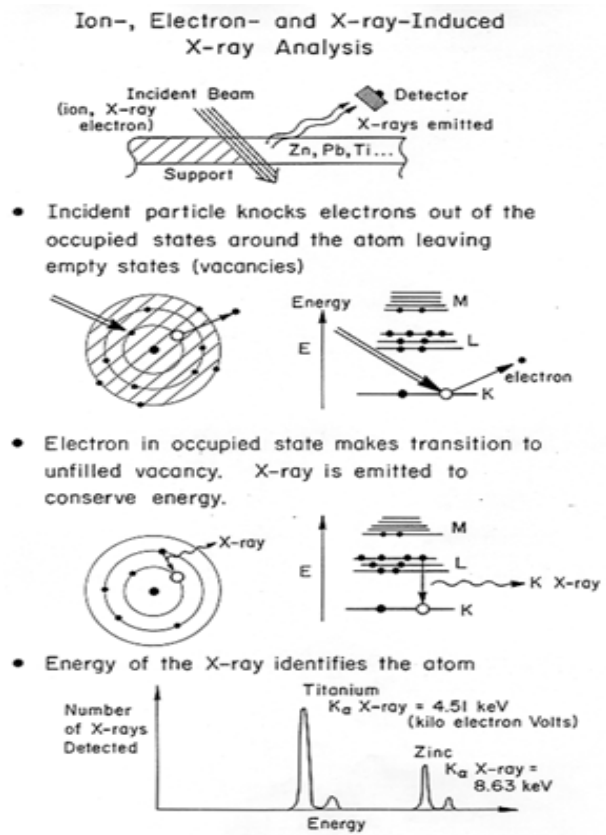




from the Division of Nuclear Solid State Physics at University of Leipzig)

Ion Beam Analysis (IBA)
Material Analysis

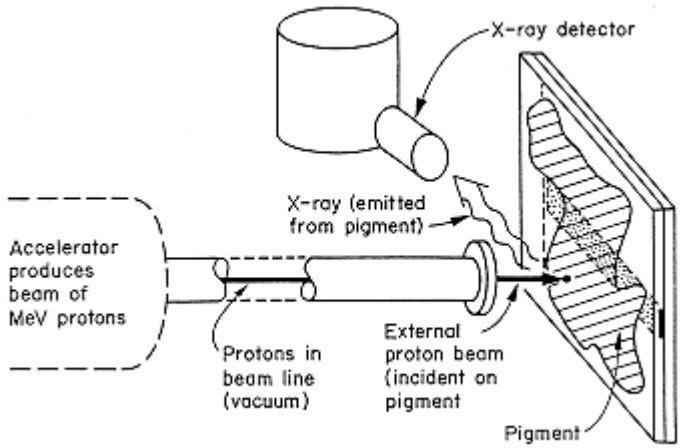
A major advantage of PIXE is that it is non-invasive, and it does not damage the material being studied. It can be done in air, directly upon the item to be studied.



http://acept.la.asu.edu/PiN/rdg/pixe/pixe.shtml

PIXE Experimental Setup

As you have recently experienced first-hand, PIXE can be roughly done with a very simple laboratory setup, requiring only a controlled, accelerated proton beam, a decent X-ray detector, and some skilled analysis.

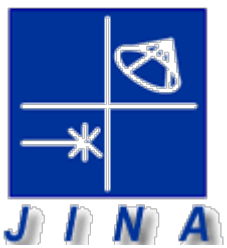


http://acept.la.asu.edu/PiN/rdg/pixe/pixe.shtml

Applications of PIXE

Because PIXE is relatively easy to do, and because it can be done in a non-invasive manner, the technique has been and is currently being applied to a wide range of material analysis problems.

It should be noted that PIXE is nearly always used as a tool to analyze materials, and generally not as a tool to explore for new physics.



Very Active Field of Study

PIXE 2004

PROCEEDINGS

10th International Conference on Particle-induced X-ray Emission and its Analytical Applications

4-8 June 2004, Portorož, Slovenia

Home | Foreword | Table of Contents | Index of Authors | Participants | Pictures | Poster Award | Committees | Sponsors | Financial Support | Organizer

Topics

- Opening
- Physics of Fundamental PIXE Processes
- Experimental Methodology
- Environmental and Atmospheric Science
- Archaeometry and Conservation
- Material Sciences
- Biomedical Sciences
- PIXE Facilities and Commercialization
- Public Lecture

Opening

PIXE and the Mars Mission
J.L. Campbell, M. Omand, J.A. Maxwell

Physics of Fundamental PIXE Processes

Higher-Order Processes in Ion-Atom Collisions
Takeshi Mukoyama

The Energy Loss of swift Ions in Matter
Helmut Paul

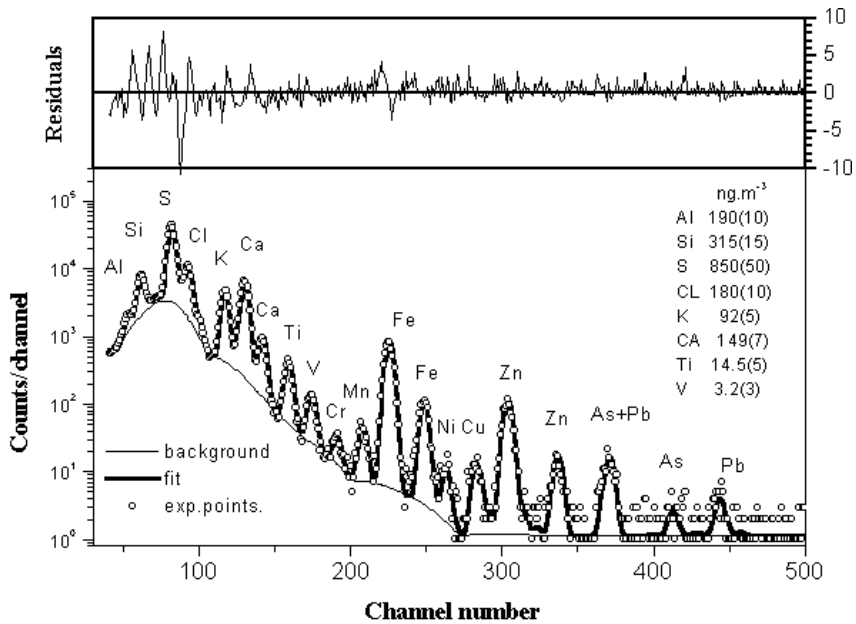
Chemical State Analysis Using High Resolution Measurement of Ka Diagram Line, the Case of Sulfur
Matjaž Kavčič, Andreas-Germanos Karydas, Ch. Zarkadas

JINA

The Joint Institute for Nuclear Astrophysics
www.JINAweb.org

Trace Element Analysis

PIXE is used (often provided as a commercial service) to perform trace element analysis of the environment to study pollution. PIXE can measure the presence of minute quantities, a key advantage to this technique.



http://omega.ujf.cas.cz/CFANR/pixe.html

PIXE for Envionmental Research

Applications: The PIXE technique can be applied to a wide variety of sample materials. At ANSTO, PIXE is often used for quantitative analysis in geology, archaeology, biology, materials science and environmental pollution. To find more about specific applications in various areas follow these links: Air Pollution, Archaeometry and Materials Science, or for more general information go to Projects, Capabilities, or Publications

JINA

ansto
Australian Nuclear Science and Technology Organisation

Sulfide Mineral Analysis

Evaluation of ore bodies and subsequent exploitation to recover silver, gold, platinum-group, and other elements, demand knowledge of the distribution of minor and trace elements in the various sulfide mineral species of the ore. The need to analyze well-characterized individual grains demands an in-situ microprobe technique. Analysis of co-existing minerals e.g. silicates may also be necessary in arriving at a complete understanding of elemental distribution.

Channeling PIXE

PIXE can be used to examine lattice structures in materials, by looking at the "channels" throughout the arrangement of atoms in the material, a technique which is very useful in solid state research and the development of microchip architectures.

High-resolution channeling contrast microscopy of compositionally graded $Si_{1-X}Ge_X$ layers

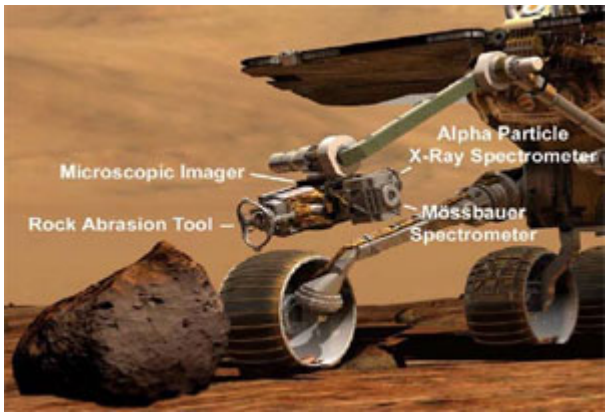
H.L. Seng [a,*], T. Osipowicz [a], T.C. Sum [a], M.B.H. Breese [a], F. Watt [a], E.S. Tok [b], J. Zhang [c]

[a] *Department of Physics, Block S12, Faculty of Science, Research Centre for Nuclear Microscopy, National University of Singapore, 2 Science Drive 3, Singapore, 117542 Singapore*

[b] *Department of Material Science, National University of Singapore, Singapore 117543, Singapore*

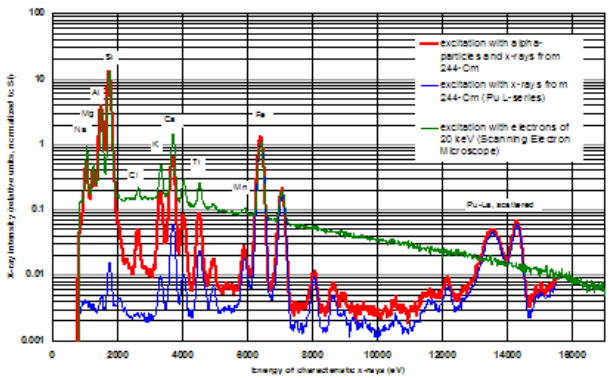
[c] *Department of Physics, Centre for Electronic Materials and Devices, Imperial College of Science, Technology and Medicine, London SW7 2BW, UK*

Martian PIXE



MARS APXS SIMULATIONS

Guelph PIXE Group



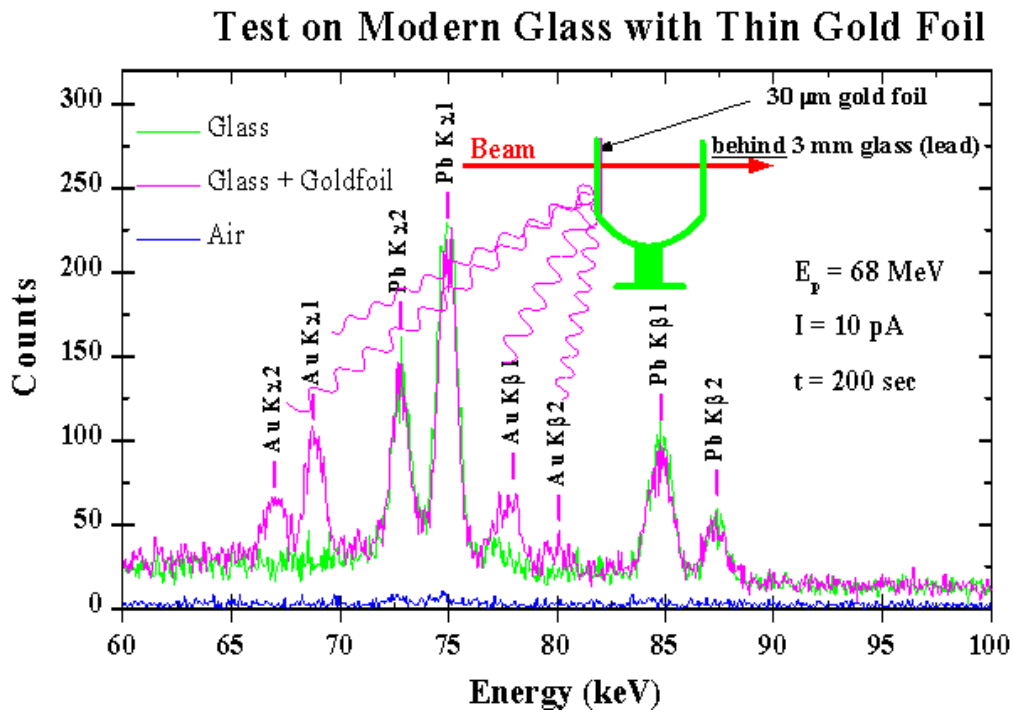
Each of the Mars Exploration Rovers which attracted worldwide attention for their exploits in 2004/5 carries an Alpha-particle X-Ray Spectrometer (APXS). GUPIX subroutines are being used to analyze the data.

http://pixe.physics.uoguelph.ca/home/

JINA

Material Study with PIXE

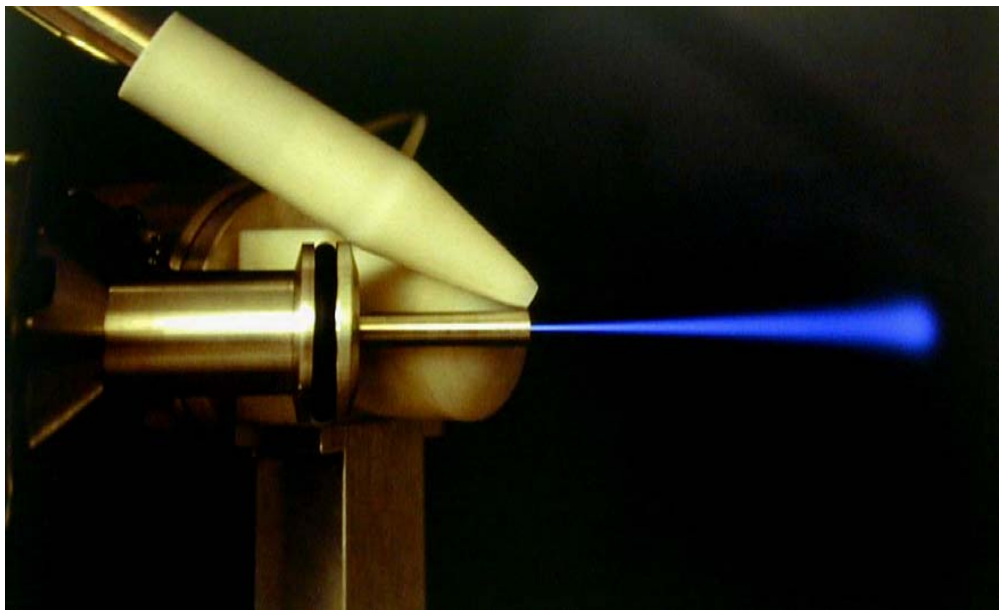
Some facilities use very high energy beams to allow them to probe materials to greater depths. Care must be taken with such measurements to prevent damage to the sample and to protect against beam induced radiation.



http://www.hmi.de/isl/ana/pixe2_en.html

External Beam PIXE

Here is a view of the proton beam emerging into the air in the target room. The blue light is from the interaction of the proton beam with the atoms and molecules in the air.

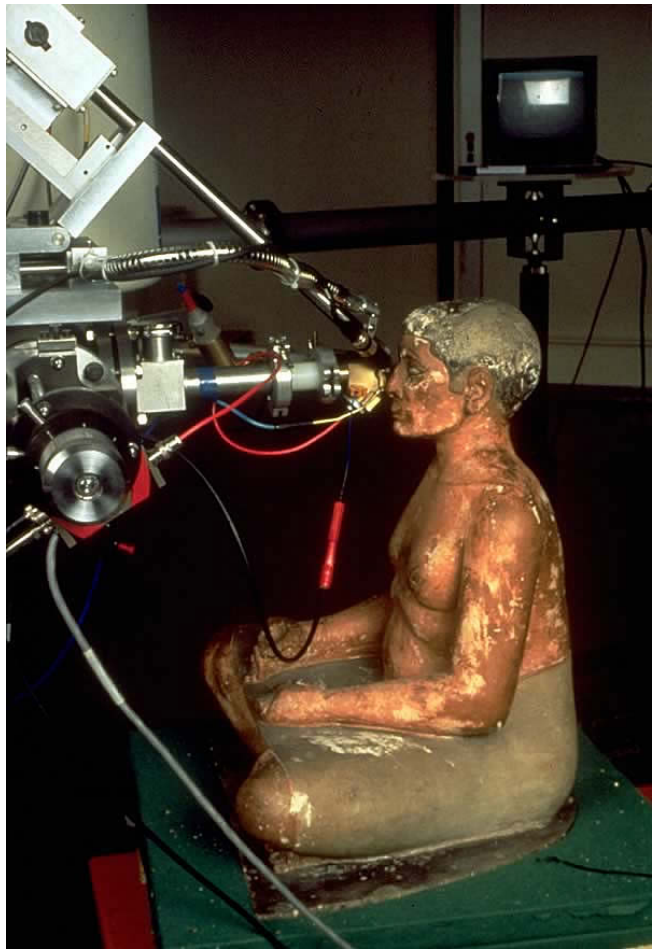


This allows us to examine materials which could not be explored in vacuum, as would be required with some other ion beam analysis techniques.

From Pier Andrea Mandò, Dipartimento di Fisica and Sezione INFN, Florence, Italy

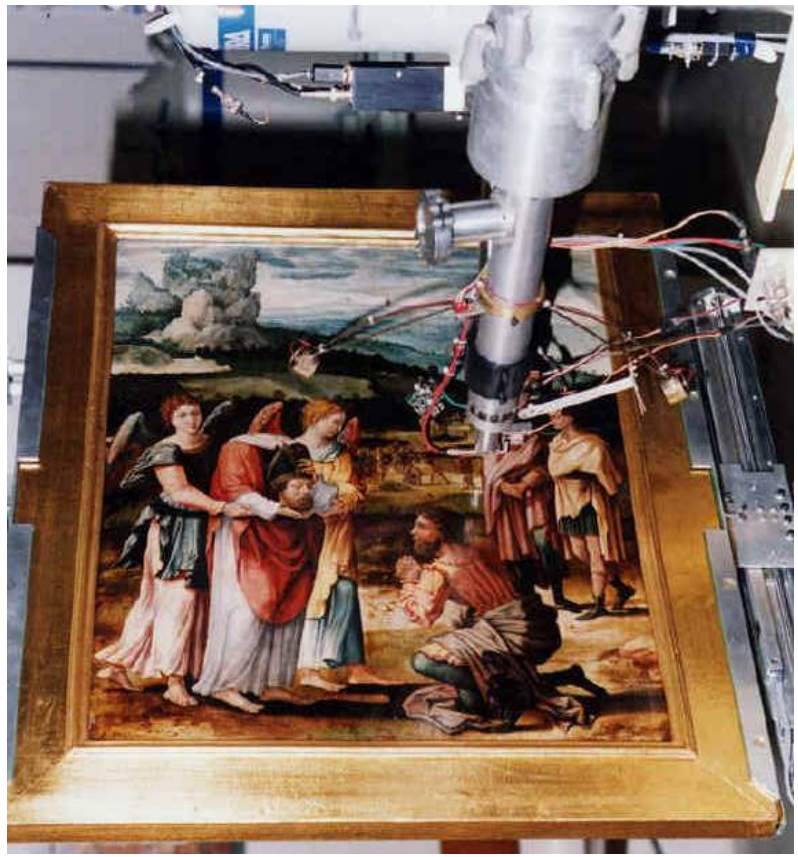
Artwork Analysis

PIXE can be used to examine sculptures, looking at the pigments in paint. We have already examined some Meso-American figurines and used PIXE to help understand the nature of the paints used to decorate the figurines.



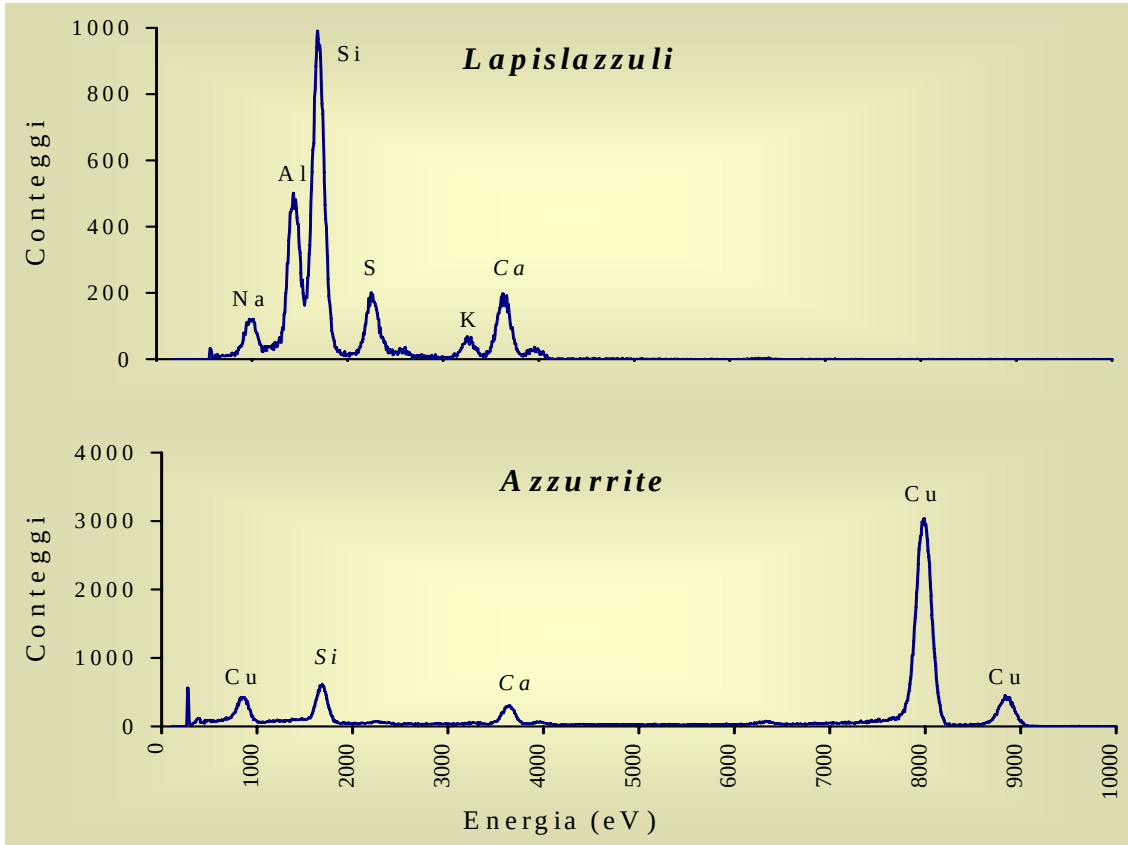
Artwork Analysis

PIXE is often used to examine artwork. Provenance can often be established by examining the pigments used in the paints. Forgeries can easily be distinguished by the modern components in the pigments.



Pigment Analysis

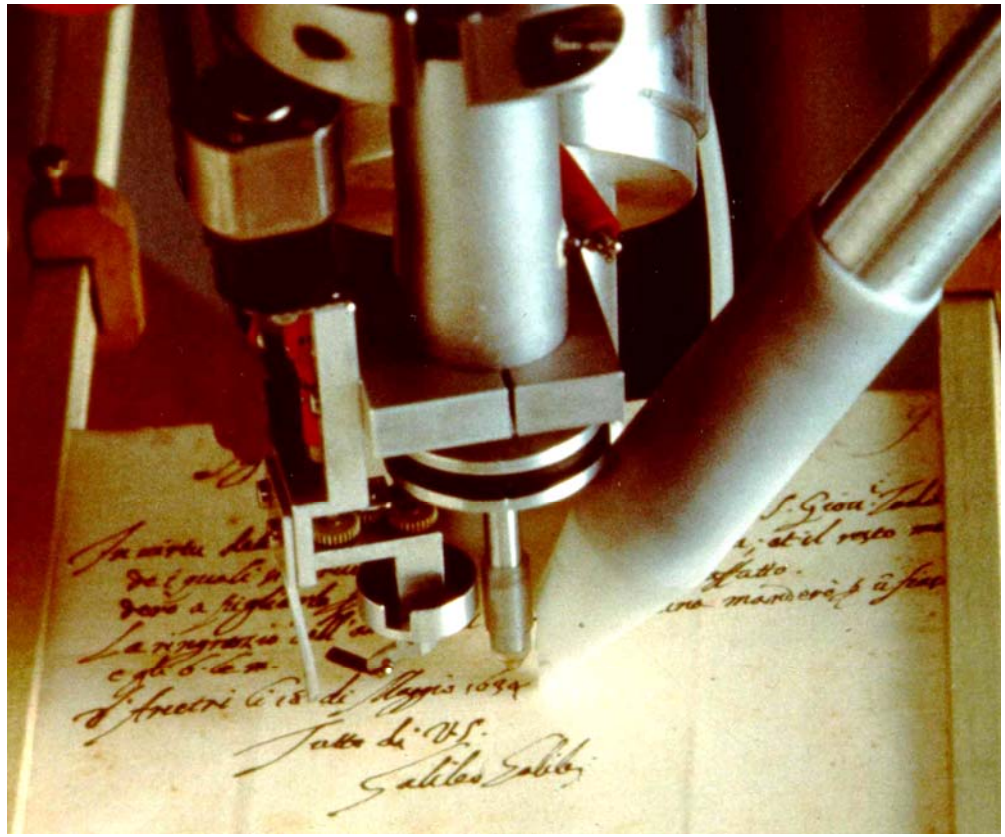
Here are PIXE spectra comparing two different blue pigments, showing how easily they can be distinguished.



From Pier Andrea Mandò, Dipartimento di Fisica and Sezione INFN, Florence, Italy

Historic Document Analysis

PIXE analysis of the inks used in Galileo's documents can be used to establish a chronology of historic events.



From Pier Andrea Mandò, Dipartimento di Fisica and Sezione INFN, Florence, Italy

More Applications?

Applications for PIXE as a tool to analyze materials are probably only limited by our imaginations.

We hope to develop PIXE here as a teaching tool, and perhaps, to provide some limited materials analysis services to outside entities.

But, we would also like to try .....

Chicxulub Meteor Impact

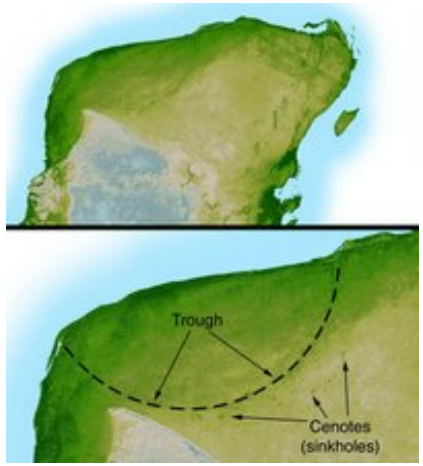
Chicxulub Meteor Impact

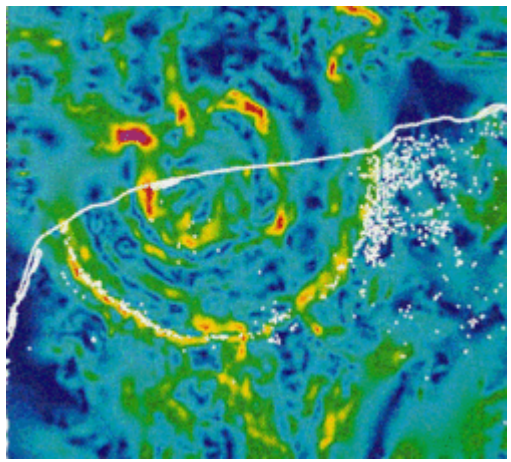
JINA

The Joint Institute for Nuclear Astrophysics
www.JINAweb.org

Chicxulub Meteor Impact

- Radar topography reveals the 180 kilometer (112 mile) wide ring of the crater.
- Gravity map of the Chicxulub Crater.

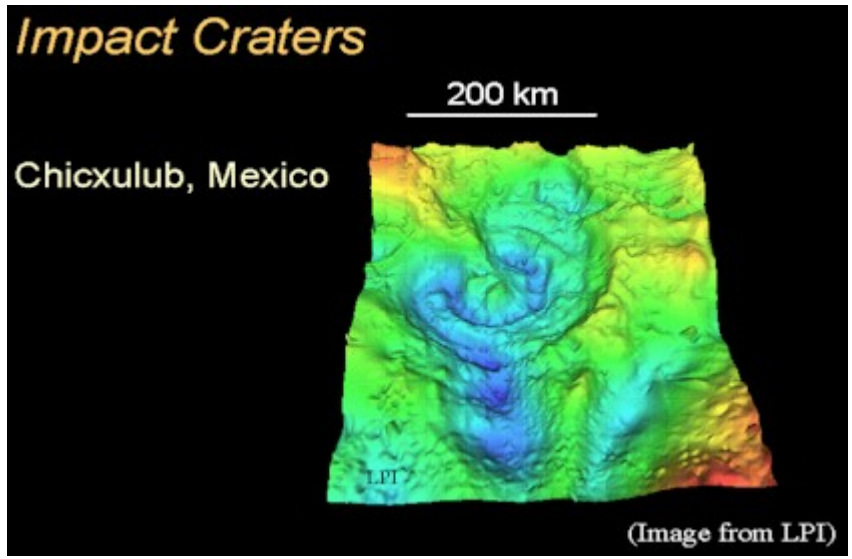




images from NASA/JPL-Caltech

Chicxulub Meteor Impact

- The crater was formed 65 million years ago, the result of an impact with an asteroid. The impact that formed this crater is also believed to have caused the mass extinction noted at the K/T (i.e. Cretacous Tertiary) boundary, when the dinosaurs disappeared.



The K-T Boundary

EONS	ERAS (ANIMALS)		PERIODS	ERAS (PLANTS)
PHANEROZOIC	CENOZOIC	65	Quaternary Tertiary	CENOPHYTIC (Age of Angiosperms)
	MESOZOIC	245	Cretaceous Jurassic Triassic	MESOPHYTIC (Age of Gymnosperms)
	PALEOZOIC	570	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian	PALEOPHYTIC (Colonization of Lands)
PROTEROZOIC	LATE	700 900	Ediacaran	PROTEROPHYTIC (Origin Eukaryotes)
	MIDDLE	1600		
	EARLY	2500		
ARCHEAN	LATE	3000		ARCHEOPHYTIC (Origin Prokaryotes)
	MIDDLE	3400		
	EARLY	3960		
HADEAN		4600		

- The emission of dust and particles caused environmental changes very similar to a nuclear winter. Physicist Luis Alvarez, and his son Walter, a geologist, studied the layer of clay seen around the world at the K-T boundary. They postulated that the extinction of the dinosaurs, roughly contemporaneous with the K-T boundary, could have been caused by the impact of just such a large meteorite.

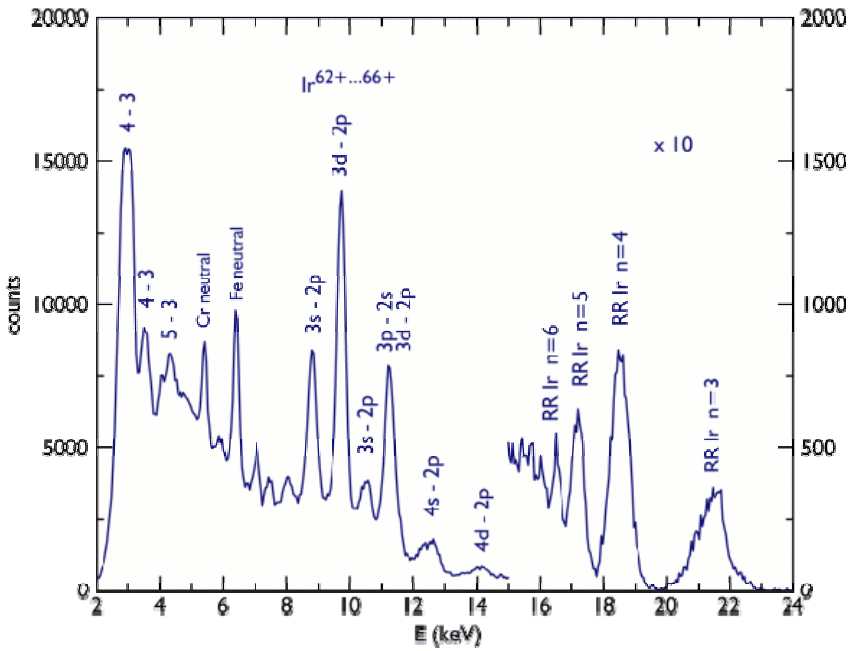
The K-T Boundary

- The main evidence is a widespread, thin layer of iridium present in this geological boundary across the world. Iridium is a rare metal on Earth, but abundant in meteorites.

Drumheller, Alberta

The Iridium Anomaly

- The Iridium in a sample from the K-T boundary would be relatively easy to detect using standard laboratory techniques, such as PIXE.

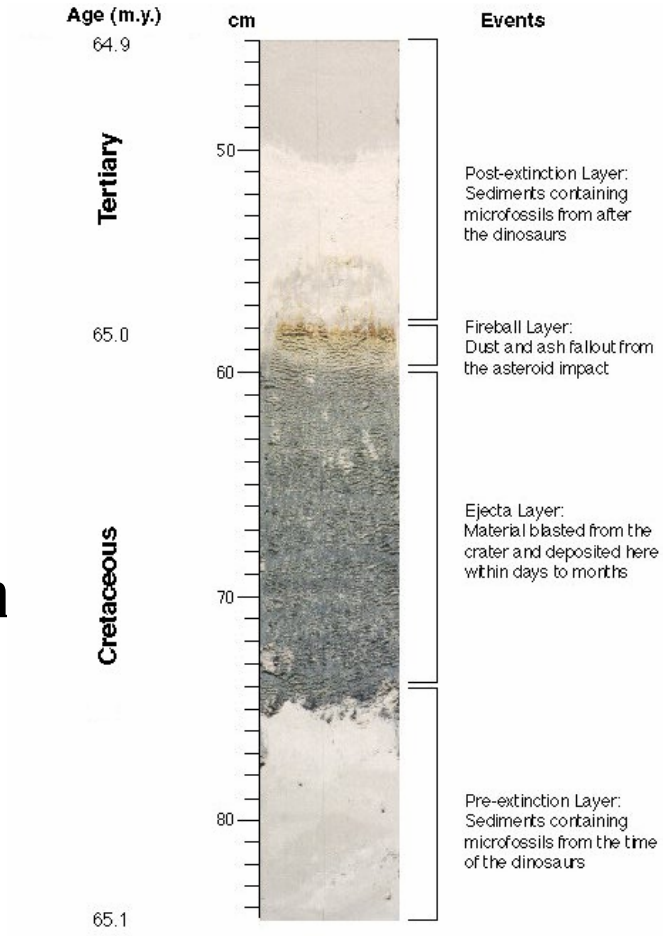


Examining Core Samples

- Core samples already exist from all over the world in huge numbers, having been collected for a variety of reasons. Many are stored in governmental archives, and are available to researchers to study.

Examining Core Samples

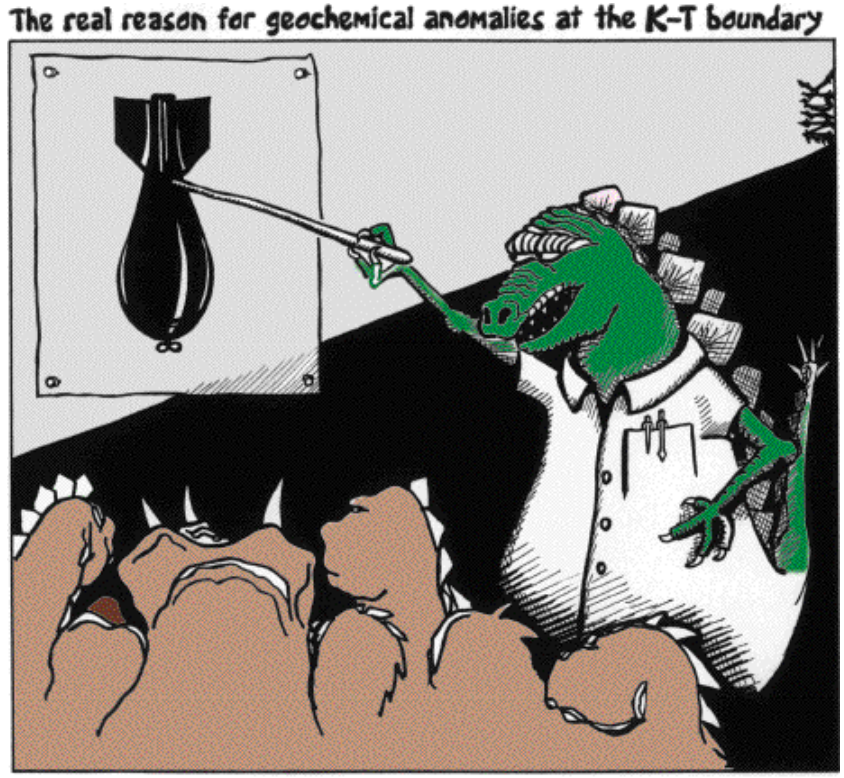
- We want to use PIXE here in our lab to examine existing core samples for the K-T boundary layer by measuring the Iridium concentrations. Initially, this would be an outreach program to educate students about the application of techniques from nuclear physics.



JINA

What will we find?

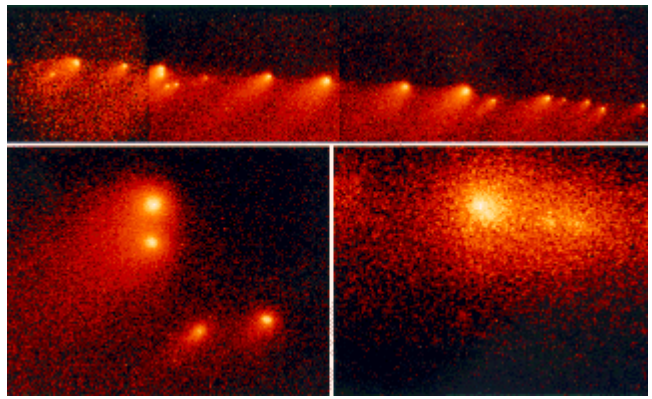
- We can certainly locate the K-T boundary, but this is already known. However, we will teach students in the process, in a fundamental, "hands-on" way.
- We can search core samples for other impact events, such as the Chesapeake meteor impact, which are relatively un-studied.



JINA

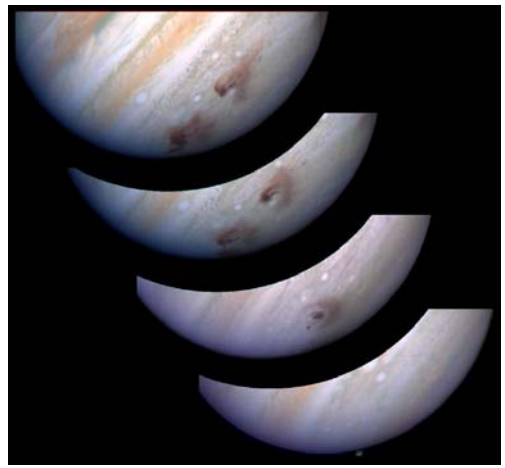
What will we find?

- Perhaps there are other meteor impact sites from the same event, such as with comet Shoemaker-Levy 9 that broke apart before striking Jupiter.

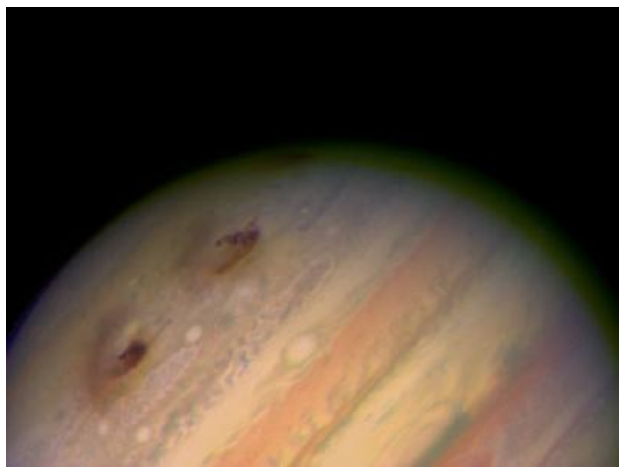


Our analysis could definitely determine if other sites were from the same event as the Chicxulub impact.

Can you imagine?



- If it could be shown that there were multiple impacts associated with the K-T boundary event, the implications for the mass extinction theory would be enormous.



Comet
Shoemaker-Levy 9
Collision with Jupiter

July 1994