Using Combined XRD-XRF Analysis to Identify Meteorite Ablation Debris

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Fifth IEEE International Conference on Emerging Technologies (ICET),
October 19-20, 2009, Islamabad, Pakistan

Nature Precedings : doi:10.1038/npre.2010.4866.1 : Posted 8 Sep 2010

Combined XRD-XRF Analysis

- XRF spectrometer is used to determine the individual component wavelengths of the fluorescent emissions produced when any material sample is exposed to X-rays.

- X-ray diffraction (XRD) is the technique of choice these days for determination of mineralogical make up of a variety of materials especially geological samples.

- The complimentary nature of XRD and XRF methods makes them invaluable for quantitative phase and elemental composition analysis.

Background Information

- Location: Pind (33°09'47"N and 73°34'09"E) approximately half a kilometer northeast of village Lehri (33°09'09"N and 73°33'35"E) in district Jhelum, Pakistan.

- For analysis purposes, representative samples were collected from different sites on the location using magnetic prospecting.

- These sites lie within a narrow patch of land approximately 100 m across and 250 m in length, extending north to south on both sides of the road that leads from village Lehri to a nearby village Rawatra, further up in the northeast direction.

Elevation: 1650 ft
Eye Altitude: 3148 ft

Image Date: November 4, 2006
Source: DigitalGlobe/Google Earth

Sample Appearance and Properties

- Strongly magnetic
- Fairly distinguishable from rest of the soil
- Rough and pitted surfaces
- Depressions and shrinkage cracks
- Black in color with metallic luster
- Variable thickness (0.5 to 3 cm)
- Few are covered with a dull bronze colored layer (indicative of rusting attributable to weathering effects)

Sample 1: Tested at Geoscience Advance Research Laboratories, Islamabad using XRD and WD-XRF Analysis

Sample 2: Tested at National Physical and Standards Laboratory, Islamabad using Standard Chemical Analysis

Likely Origins

- Taking into account the physical characteristics, appearance, weight to size ratio and the very way in which this suspected stone variety is scattered over a limited area, three origins may be considered:

    1. Volcanic (volcanic rock)
    2. Industrial (waste/by product of some industrial process)
    3. Extraterrestrial (meteorite ablation debris)

Test Results

- The XRD analysis detected wüstite ($Fe_{1-x}O$) and magnetite (Fe_3O_4) as predominant mineralogical phases in the outer crust of the tested sample stone.

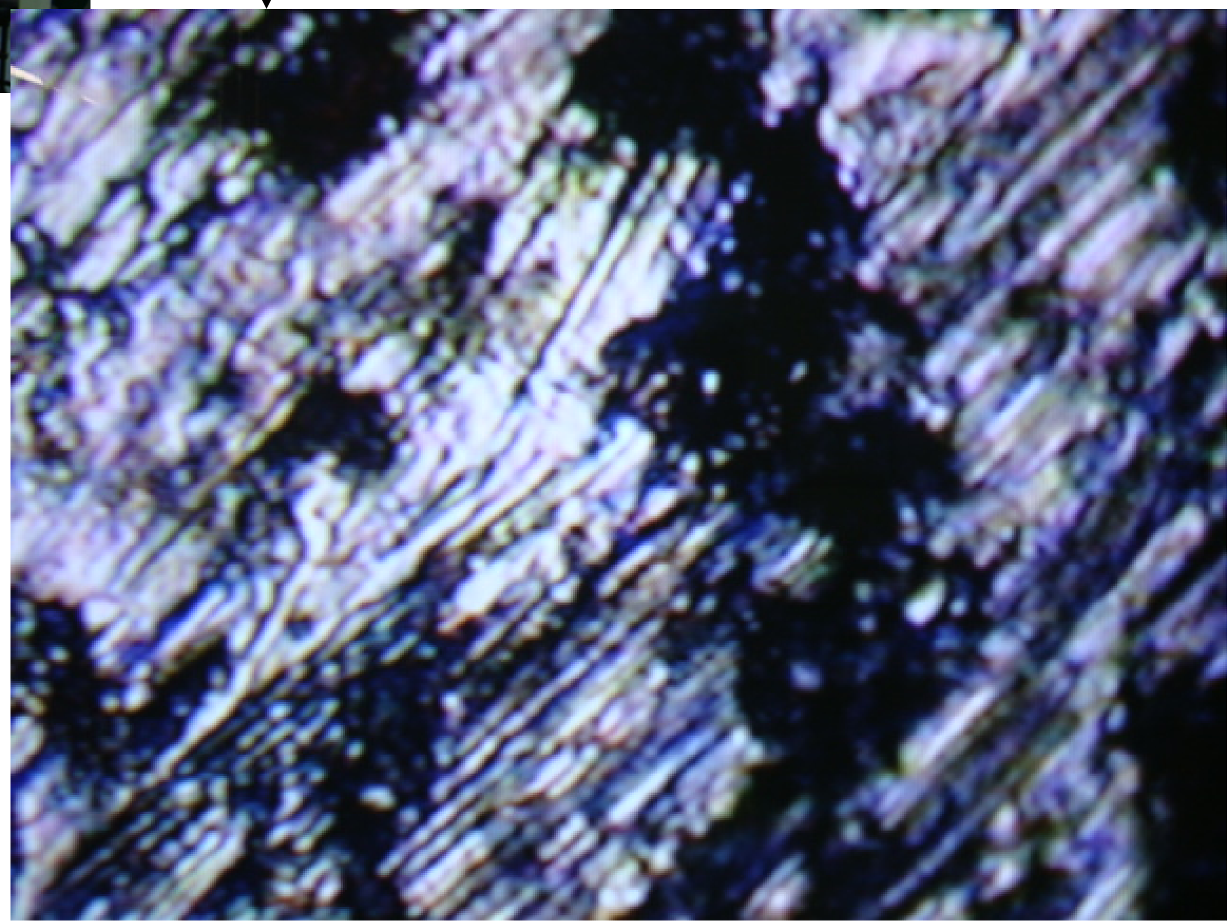
- Elemental composition determined through XRF spectrometry analysis is included in the next slide.

- Presence of metallic phase in the interior structure of a polished surface of the tested sample stone is illustrated using photomicrographs taken with reflected light at 20× and 100× magnification.

Element	Composition (wt%)
Si	3.93
Ti	0.508
Al	0.95
Fe	56.28
Mn	0.066
Mg	0.342
Ca	2.69
Na	0.114
K	0.146
P	0.228
V	0.07
Cr	0.324
Ni	0.00786
Sr	0.0093
Ba	0.367
W	0.024
Cl	0.046
Cu	0.0015

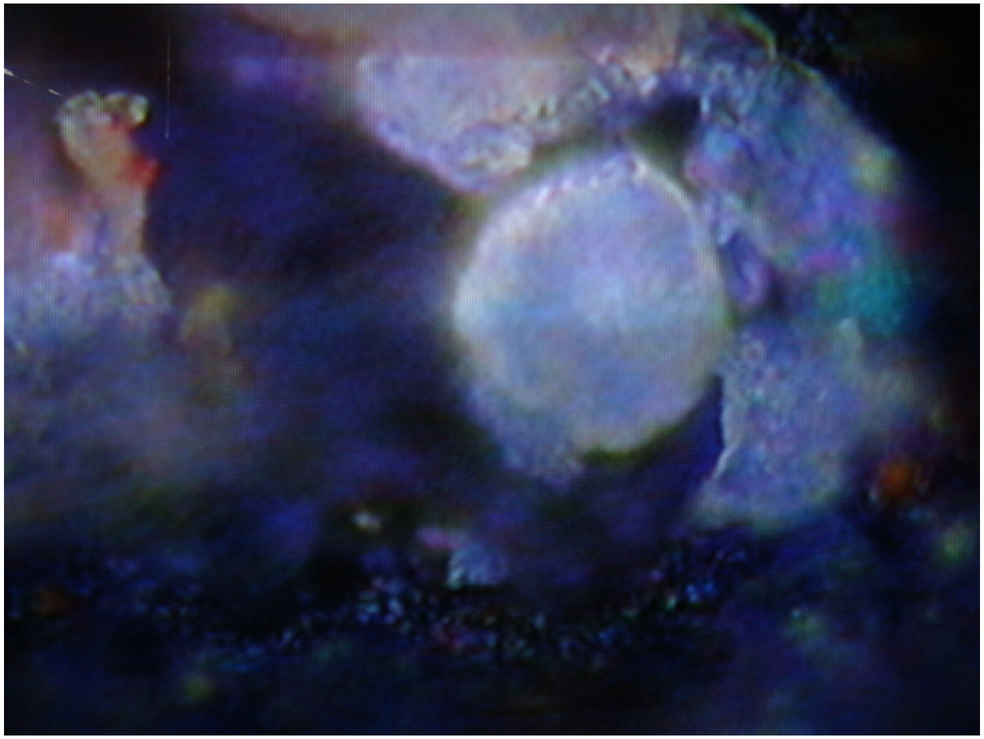
Elemental Composition (wt%) of the Sample Stone Determined through WD-XRF Spectrometry Analysis.

Sample Stone Microstructure Analysis using Optical Microscope.



Photomicrograph Section Showing Metallic Phase (Silver-Gray) on a Polished Surface of the Sample Stone at 20× Magnification.

Metallic phase (white) observed at 100× magnification on a polished surface of the tested sample stone. Note almost round in shape single grain of metal phase with relatively well-defined boundary in the center of the photomicrograph section.



Analysis

Volcanic

(No)

- Presence of wüstite (shows existence of a highly reducing environment where as magmas offer high oxygen fugacities or increased possibility of oxidation than reduction).
- Volcanic magnetite contains TiO_2 in the range of 4-30 wt% whereas in this case there is a very low abundance of TiO_2 (0.848 wt%) detected.

Industrial

(No)

- No industry associated setups in recent times or in past years have existed in or around the site.

Meteorite Debris

(Yes)

- Increased relative abundance of Fe.
- Low abundance of cosmically abundant elements (Mn, Cr, Ti etc.).
- Presence of wüstite (a rare Fe mineralogical phase mostly observed with meteorites undergoing ablation effects while passing through earth's atmosphere).
- Low Ni Content

Meteorite Type: Initial Hypothesis

- Based on available physical, chemical and mineralogical data, the meteorite is classified as a chondrite. (Further testing through combustion analysis will be carried out to determine total carbon content, which in turn will be used to fix nature and origins of the meteorite debris.)

Meteorite Age: A Comment

- Carbon dating can be used to ascertain the point in time when the meteorite entered earth's atmosphere and crashed on the site identified.
- Radiometric analysis can only be used to determine time periods in tens of thousands or in certain cases hundreds of thousands of years. i.e. Carbon dating ~ 60, 000 years.
- As meteorites are the oldest specimens of matter in space, they tend to be as old as earth itself (~ 4.55 billion years) and were created as an outcome of very first geological processes in the primitive, slowly evolving solar system.

Thank You