SCANNING ELECTRON MICROSCOPE/ENERGY DISPERSIVE X-RAY ANALYSIS OF IMPACT RESIDUES IN LDEF TRAY CLAMPS

Ronald P. Bernhard
Lockheed ESC
NASA/JSC
Houston, TX 77058

Christian Durin
CNES - Toulouse FRANCE
Fax n 33.61.27.47.32

Michael E. Zolensky
SN2, NASA Johnson Space Center
Houston, TX 77058

SUMMARY

Detailed optical scanning of tray clamps is being conducted in the Facility for the Optical Inspection of Large Surfaces at the Johnson Space Center to locate and document impacts as small as 40 microns in diameter. Residues from selected impacts are then being characterized by Scanning Electron Microscopy/Energy Dispersive X-ray Analysis at CNES. Results from this analysis will be the initial step to classifying projectile residues into specific sources.

INTRODUCTION

To better understand the nature of particulates in low-Earth orbit (LEO), and their effects on spacecraft hardware, we are analyzing residues found in impact features on Long Duration Exposure Facility (LDEF) tray clamps. Detailed optical scanning of the tray clamps provided to the Meteoroid and Debris Special Investigation Group (M&D SIG) is being conducted in the Facility for the Optical Inspection of Large Surfaces (FOILS) at the Johnson Space Center (JSC) to locate and document impacts as small as 40 microns in diameter, starting with Bay A and working toward Bay H. To date, scanning of the Bay A clamps has been completed.

These impacts are then inspected by Scanning Electron Microscopy/Energy Dispersive X-ray analysis (SEM/EDX) to select those features which contain appreciable impact residue material. Based upon the composition of projectile remnants, and using criteria developed at JSC (ref 1), we have made a preliminary discrimination between micrometeoroid and space debris residue-containing impact features. Based upon these

analyses, we forwarded 13 impact features containing significant amounts of unmelted and semi-melted micrometeoritic residues to Centre National d'Etudes Spatiales (CNES) in France. At the CNES facilities the upgraded impacts were analyzed using a JEOL T330A SEM equipped with a NORAN Instruments, Voyager X-ray Analyzer. Results from these analyses will be the critical step in classifying projectile residues into specific source groups. This information is critical to construction of flux models for natural vs. man-made particulates in LEO.

LDEF TRAY CLAMPS

LDEF experiment trays were held in place by a series of chromic-anodized aluminum (6061-T6) clamps; eight clamps were used to attach the experiment trays on each of the 12 sides of LDEF, while experiment trays on the Earth and space ends were held in place by 12 clamps. Each clamp was fastened to the spacecraft frame using three stainless steel hex bolts. Clamps exposed an area of approximately 58cm^2 each (4.8cm X 12.7cm X .45cm, minus the bolt coverage). All 774 clamps were surveyed for impacts greater than 0.5 mm during spacecraft deintegration at the Kennedy Space Center. Some 337 out of 774 LDEF tray clamps have been archived by the M&D SIG in the Curatorial Facility at JSC and are available for scientific examination through the Meteoroid & Debris Special Investigation Group (M&D SIG).

A numbering scheme was devised by the M&D SIG for the clamps which would provide hardware location information with respect to its position within a particular bay (Fig. 1). From the labeling scheme, it can be seen that a clamp occupying position 1 of Bay A02 would be identified by the label A02C01, with A02 indicating the experiment location of Bay "A" and Row "02", and C01 interpreted as "C" for clamp and "01" being the clamp number. Each clamp uses a Cartesian coordinate system to reference impact locations on exposed surfaces. The X and Y coordinates were measured in millimeters in a grid system (positive or negative) from a standard origin assigned by the M&D SIG at the lower-left corner (fig. 1).

RESULTS

Table 1 lists preliminary results for our clamp analyses. For each entry clamp number, impact feature numbers and SEM/EDX determined impact residue constituents are listed.

Table 1 Results of Clamp Analyses

CLAMP NUMBER	IMPACT NUMBER	IMPACT DIAMETER	RESIDUE COMPONENTS
A01 CO1	001	200	Mg, Si, Ca Fe
A01 CO1	002	100	Trace
A01 CO1	003	100	Unknown
A01 CO3	001	120	Contamination
A01 CO3	002	230	Mg, Si, Ca Fe
A01 CO4	001	100	Paint Patch
A01 CO4	002	180	Trace
A01 CO8	001	370	Unknown
A03 CO1	001	150	Mg, Si, Ca Fe
A03 CO3	001	220	Unknown
A04 CO3	001	260	Unknown
A04 CO5	001	210	Contamination
A04 CO5	002	120	Fe, Ni, Cr
A04 CO8	001	160	Unknown
A04 CO8	002	400	Unknown
A05 CO3	001	180	Unknown
A05 CO6	001	250	Si, Ca S, K, Fe
A05 CO6	002	70	Unknown
A05 CO6	003	140	Trace
A05 CO6	004	50	Unknown
A05 CO6	005	90	Unknown
A05 CO7	001	400	Unknown
A05 CO7	002	100	Unknown
A05 CO8	001	180	Contamination
A06 CO6	001	320	Unknown
A07 CO1	001	210	Unknown
A07 CO1	002	120	Si, Ca, Fe
A07 CO1	003	110	Si, Ca, S, Fe
A07 CO1	004	210	Unknown
A07 CO1	005	130	Trace
A07 CO3	001	380	Unknown
A07 CO3	002	260	Contamination
A07 CO3	003	N/A	No Impact
A07 CO3	004	40	Unknown
A07 CO3	005	180	Paint
A07 CO3	006	400	Unknown
A07 CO3	007	40	Contamination
A07 CO6	001	100	Unknown
A07 CO6	002	220	Unknown
A07 CO6	003	200	Si, Ca, Na, Mg, Fe
A07 CO6	004	240	Unknown
A07 CO6	005	100	Fe, Ni, Cr
A07 CO6	006	150	Unknown
A07 CO6	007	300	Trace

CLAMP NUMBER	IMPACT NUMBER	IMPACT DIAMETER	RESIDUE COMPONENTS
A07 CO6	008	150	Unknown
A07 CO8	001	200	Unknown
A07 CO8	002	220	Trace
A07 CO8	003	300	Unknown
A07 CO8	005	260	Si, Ca, K, Fe, S, Mg
A07 CO8	006	140	Si, Mg, Ca, Fe
A08 CO1	001	900	Unknown
A08 CO1	002	130	Si, Mg, Ca, Fe
A08 CO1	003	250	Trace ?
A08 CO1	004	140	Unknown
A08 CO1	005	200	Si, Mg, K
A08 CO1	006	80	Si, Mg, Fe, Ca
A08 CO1	007	100	Unknown
A08 CO1	008	110	Unknown
A08 CO3	001	400	Unknown
A08 CO3	002	140	Paint
A08 CO3	003	80	Unknown
A08 CO3	004	200	Unknown
A08 CO3	005	160	Unknown
A08 CO3	006	150	Unknown
A08 CO3	007	380	Unknown
A08 CO7	001	360	Paint Patch
A08 CO7	002	350	Unknown
A08 CO7	003	270	Paint
A08 CO7	004	470	Unknown
A08 CO7	005	130	Si, Mg, Ca, Fe
A08 CO7	006	60	Unknown
A08 CO7	007	160	Contamination
A08 CO7	008	60	Paint Patch
A08 CO7	009	130	Unknown
A08 CO7	010	170	Unknown
A08 CO7	011	140	Paint Patch
A08 CO7	012	230	Paint Patch
A08 CO7	013	40	Paint Patch
A08 CO7	014	100	Paint Patch
A08 CO8	001	700	Unknown
A08 CO8	002	500	Unknown
A08 CO8	003	500	Trace ?
A08 CO8	004	150	Unknown
A08 CO8	005	200	Unknown
A08 CO8	006	120	Si, Mg, Ca, Fe
A08 CO8	007	190	Unknown
A08 CO8	008	90	Unknown
A08 CO8	009	110	Unknown
A08 CO8	010	100	Paint
A08 CO8	011	400	Unknown
A08 CO8	012	350	Unknown

CLAMP NUMBER	IMPACT NUMBER	IMPACT DIAMETER	RESIDUE COMPONENTS
A08 CO8	013	120	Si, Mg, Ca
A08 C10	001	250	Unknown
A08 C10	002	100	Unknown
A08 C10	003	120	Unknown
E09 C05	001	180	Trace
E09 C05	002	250	Unknown
E09 C05	003	160	Unknown
E09 C05	004	170	Paint
E09 C05	005	280	Unknown
E09 C05	006	330	Unknown
E09 C05	007	240	Unknown
E09 C07	001	75	Fe
E09 C07	002	150	Unknown
E09 C07	003	200	Unknown
E09 C07	004	140	Fe, Ni, Cr, Mn
E09 C07	005	160	Unknown
E09 C07	006	300	Unknown
E09 C07	007	130	Si, Mg, K, Fe S
E09 C07	008	220	Si, Mg, Fe
E09 C07	009	150	Unknown
E10 C01	001	1200	Si, Mg, Fe
E10 C01	002	120	Unknown
E10 C01	003	180	Trace
E10 C01	004	120	Trace ?
E10 C01	005	180	Unknown
F09 C05	001	120	Unknown
F09 C05	002	270	Unknown
F09 C05	003	70	Paint
F09 C05	004	380	Unknown
F09 C05	005	240	Unknown
F09 C05	006	190	Unknown
F09 C07	001	280	Unknown
F09 C07	002	280	Unknown
F09 C07	003	200	Unknown
F09 C07	004	150	Trace
F09 C07	005	100	Unknown
F09 C07	006	70	Unknown
F09 C07	007	210	Contamination
F09 C07	008	120	Unknown
F10 C05	001	100	Unknown
F10 C05	002	140	Paint
F10 C05	003	270	Unknown
F10 C05	004	90	Unknown
F10 C05	005	460	Unknown
F10 C05	006	100	Unknown
F10 C05	007	90	Unknown
F10 C05	008	100	Unknown

C-4

Because the initial intent of this survey was to identify only those impacts which contained large amounts of micrometeoritic residue, a minimal amount of time was spent analyzing for small or not obvious projectile remnants. The spectra are qualitative and can establish a basic classification of either "natural" or "man-made", although many of the impacts are classified as having no detected origin. We believe that further, more detailed, analyses would undoubtedly uncover evidence of impactor residues in many of the latter craters. A factor hindering our analyses is the fact that the clamps have all been anodized, which deposited a surface layer of Si, Mg, and S, all of which are important elements. This contamination has been properly considered as background, but in many instances its presence makes characterization of the residues extremely difficult. A breakdown of analyzed clamp-impact residues into categories of "natural", "man made", "unknown" and "contaminated" is illustrated in Fig.2. These data are only preliminary, and await confirmation by the more detailed EDX analyses being performed at CNES; these latter results will be reported at a later date.

Documentation of these clamps will be presented in catalog form at a later date. In these catalogs each clamp impact feature will be documented with scanning electron micrographs and EDX spectra, as shown in Figs. 3-6.

REFERENCE

1 Zolensky M.E., Zook H., Atkinson D., Coombs C., Dardano C., See T., Simon C. and Kinard W. (1992) Interim report of the Meteoroid and Debris Special Investigation Group. This volume.

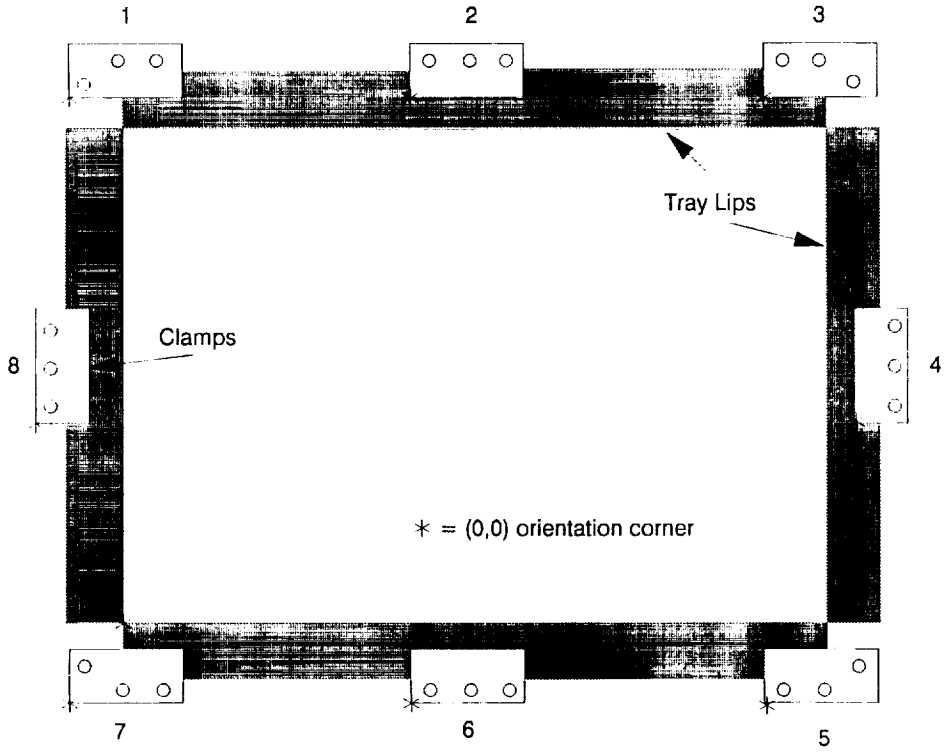

Figure 1. Disposition of tray clamps around experiment trays in Bays A-F. Circles indicate bolt holes; asterisks indicate the registration origin point for each clamp.

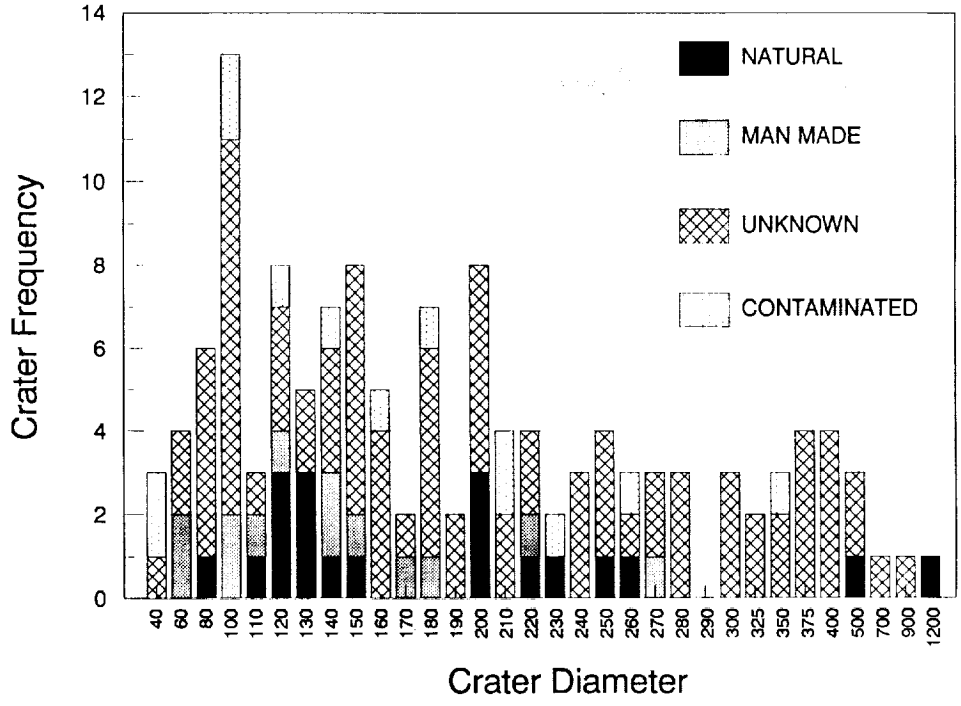

Figure 2. A breakdown of analyzed clamp-impact residues into categories of "natural," "man made," "unknown" and "contaminated."

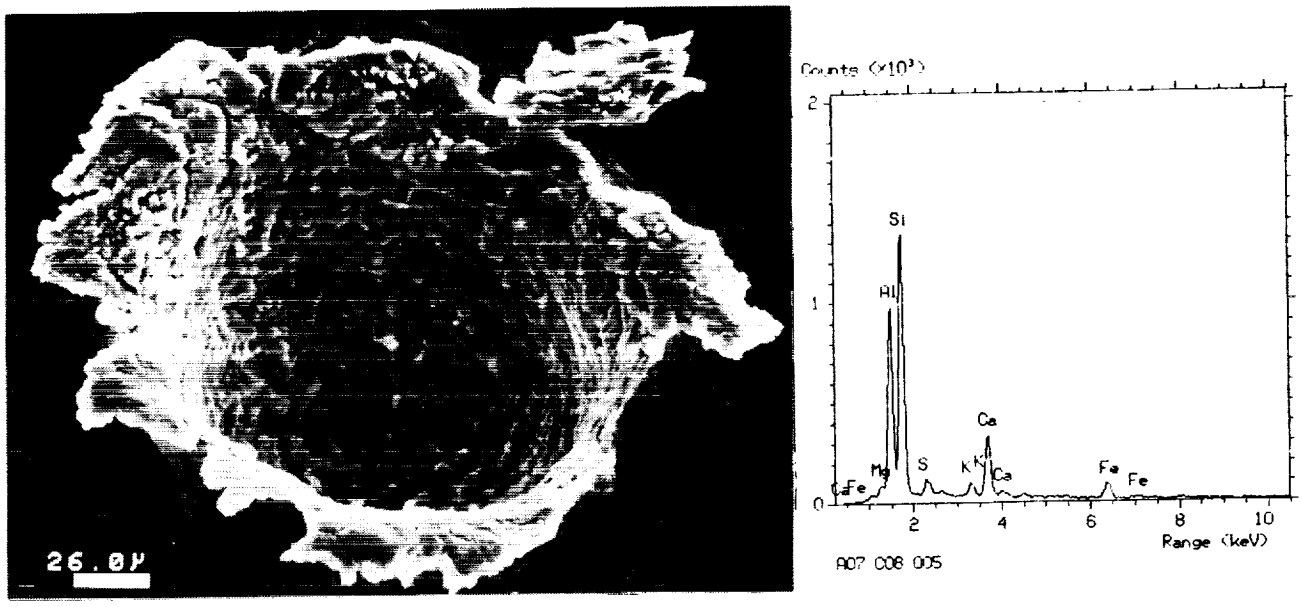

Figure 3. Impact crater into clamp number eight of Bay A07. The large amounts of micrometeoritic residue in the bottom and on the walls of the crater are rare for most features found on LDEF surfaces. The X-ray spectra displays a micrometeoritic composition associated with this projectile residue.

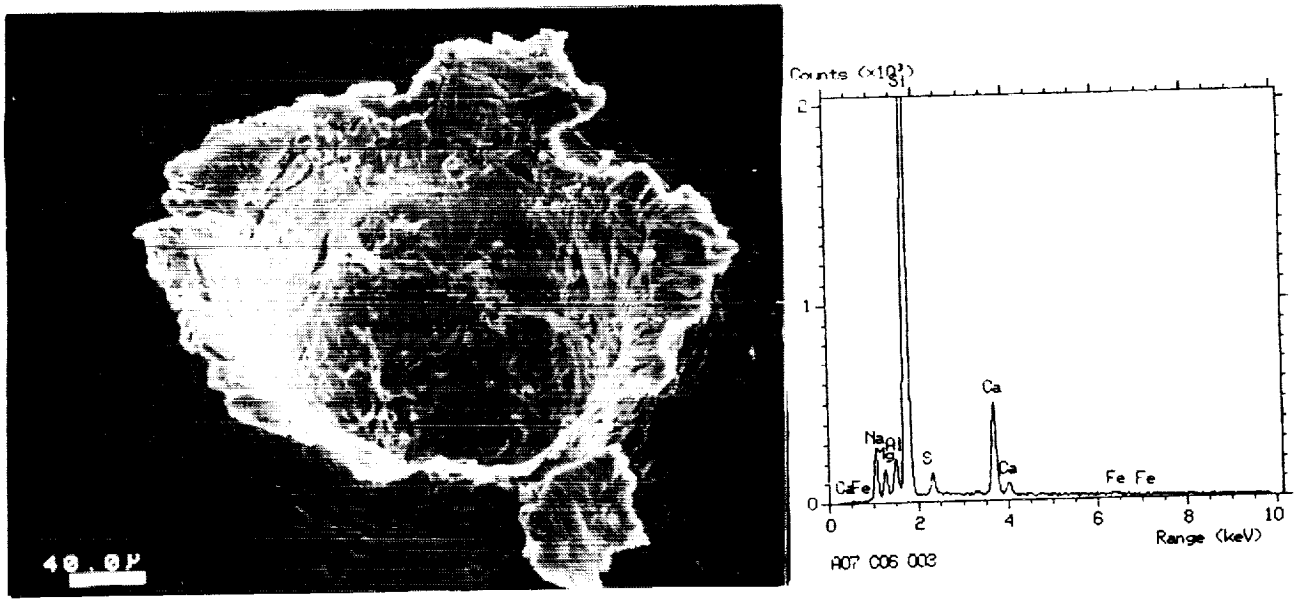

Figure 4. The morphology of the interior of this impact shows a lining of projectile residues present. Although the crater has typical depth to diameter ratios the amount of projectile preserved after shock is relatively high. A general X-ray spectra taken from a small grain within the crater illustrates the components which exist.

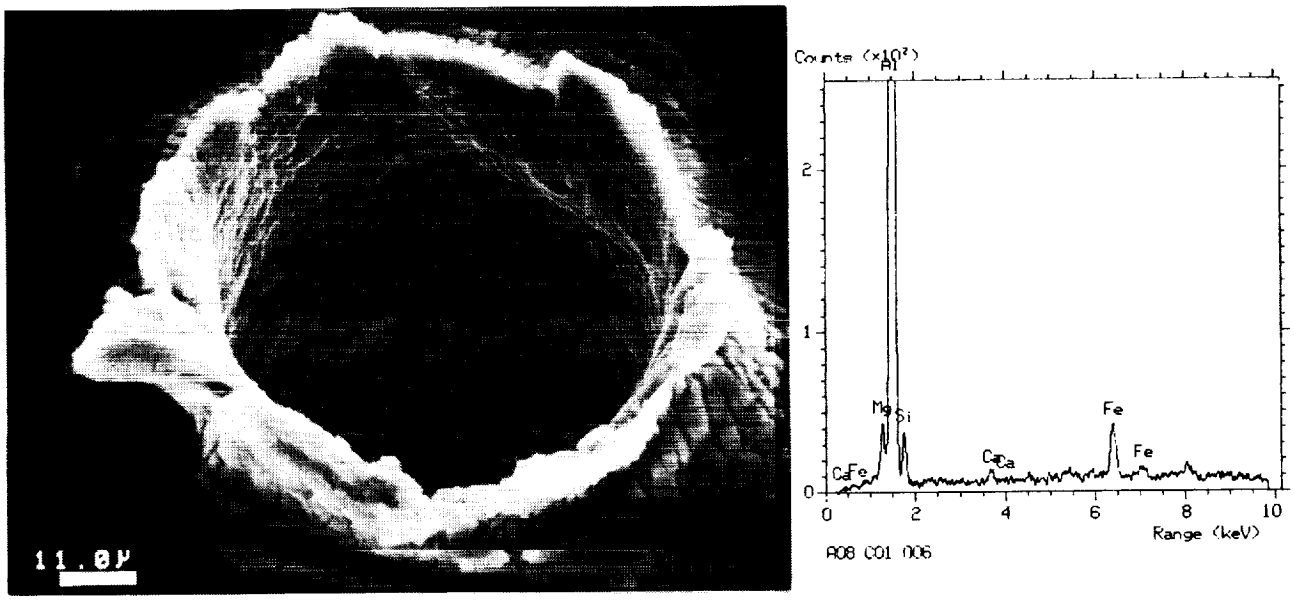

Figure 5. Closer to the leading edge of LDEF, clamp number one of tray A08 has an unusually deep morphology as seen in this oblique view. The walls and bottom to the impact feature are completely coated with micrometeoritic residues. The X-ray spectra retains large amounts of the clamp target material. The anodized layer of the aluminum clamp is very evident when shown as radial cracking around the parameter of the crater.

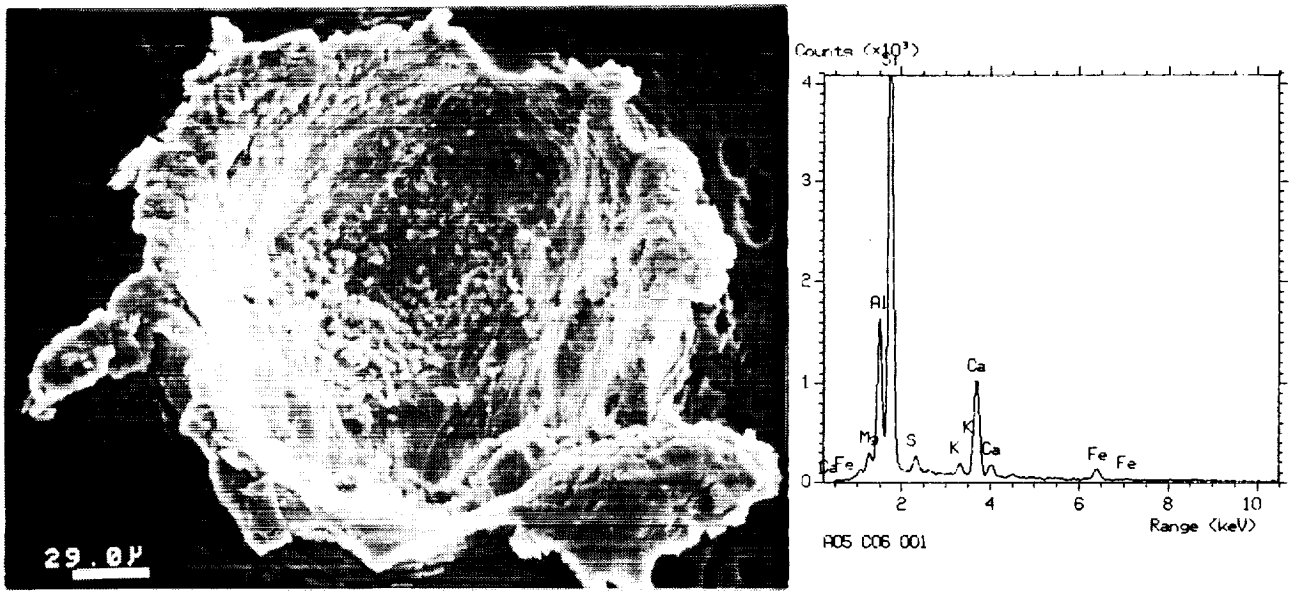

Figure 6. In some cases the projectile collides with the exposed surface at large oblique angles or the projectile contains large voids of porosity, in these cases the impact crater may be asymmetrical. Impact feature number 001, on clamp six, from tray A05 contains grains which appear to be relatively unaffected by collision. Energy dispersive X-ray analysis reveals a typical micrometeoritic spectra.