COMPUTED MICROTOMOGRAPHY (CMT) OF EXTRATERRESTRIAL OBJECTS USING A LINEAR PHOTODIODE ARRAY DETECTOR
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Introduction: Computed microtomography (CMT) is a useful technique for imaging the internal structures of objects with high spatial resolution. The principal value in planetary sciences is the ability to “see” the internal structures of extraterrestrial objects, such as rare Antarctic meteorites, prior to developing sampling strategies and allocation plans. In particular, the locations of clasts are determined, allowing planes with maximum number of clast intersections (potential cut planes) to be visualized. In addition, physical characteristics of the object can potentially be quantified such as size distributions, fracture abundance, clast elongation, and preferred grain orientation.

Computed Microtomography at NSLS: CMT techniques using bending magnet and wiggler synchrotron radiation at the National Synchrotron Light Source (NSLS; Brookhaven National Laboratory, NY) have been under development [1-3]. A bending magnet delivers high flux up to about 30 keV and is sufficiently energetic for millimeter-sized samples. However, more energetic x-ray sources are required to penetrate a typical cm-sized, silicate-bearing object. The superconducting wiggler (SCW) at NSLS (beamline X17) has a gain at 60 keV of about 1000 over the flux from the bending magnet and is well-suited to this purpose. Spatial resolutions down to 1 micrometer have been achieved. Our previous work has used primarily a transmission approach with a scintillation detector and a 2-dimensional CMT image was made on a fragment of the Allende carbonaceous chondrite with this apparatus on the wiggler source [4]. These initial results demonstrated the applicability of the technique but were limited by the slowness of data acquisition and processing. In particular, a pencil x-ray beam was used in conjunction with intensity monitors before (ionization chamber) and after (scintillation counter) the specimen. This setup required each horizontal 2D image to be obtained by translating the entire sample through the beam, rotating a small angle around the vertical axis, repeating the translation, and continuing this process until 180 degrees were traversed. Total acquisition time for a single slice was typically 1 hour.

New Results using a Linear Array Detector: We report here our first attempts to use a linear array detector to improve the acquisition speed. In this approach, a slit source (horizontally larger than the object but vertically narrow) irradiated an entire plane in the object simultaneously alleviating the need for the translation procedure. A linear position-sensitive array detector was then used to simultaneously measure the integrated absorption along many parallel beam paths through the sample. The particular array used in this work was a 1024-element photodiode array with a total width of 25 mm (each element = 25 micrometers) and covered by a thin, Gd2O2S phosphor. Optical blooming by the phosphor limited the effective spatial resolution of the device to about 100 micrometers. In this application, the irradiated object is continuously rotated and the readout and resetting of the detector is timed to obtain measurements with high angular accuracy and resolution. Total acquisition time for a single slice using this method was typically 10 seconds, an improvement in speed of about a factor of 200. By vertically translating the sample and repeating the 2D process, a 3D image can be obtained.

A three-dimensional CMT image was made of Allende (carbonaceous chondrite), the same 1 cm, freestanding intact fragment previously studied. Forty (40) horizontal slices within the Allende fragment were imaged in only 30 minutes. Each slice was separated vertically by 100 micrometers. The resulting reconstructed tomogram shows the positions of chondrules,
inclusions and fractures with a spatial resolution of about 100 micrometers.

**Radiation Effects:** These demonstration experiments show that CMT is presently capable of providing detailed structural images of earth and planetary materials. Future technical improvements in CMT are expected from developments in synchrotron source brightness (e.g., Advanced Photon Source, Argonne National Laboratory), detector spatial resolution, detector speed and computational speed. Nonetheless, potential detrimental consequences of the CMT irradiation must be studied before the method can be considered for routine use on rare extraterrestrial objects as part of the preliminary examination activities of the Curator. That is, it is important to ensure that applications of radiation-sensitive analytical techniques (e.g., thermoluminescence) are not compromised by the CMT imaging.

Although systematic tests of radiation effects on meteorite analogs remain to be done, there is good reason to believe that these effects are small. These CMT techniques are being developed primarily for imaging of live biological specimens. Obviously, minimization of radiation effects is a foremost goal of this research. Radiation doses delivered by the SCW synchrotron beam are calculated theoretically in this biomedical work and experimental verification of the computational methods has been obtained in some cases using various dosimeters (TLD, calibrated radiation sensitive films). These calculations suggest a dose rate under the CMT conditions (1.5 mm Ta filter on incident beam) of 10-100 rads/sec or a total dose per CMT slice (10 sec exposure) of about 100-1000 rads. This dose is relatively low when compared with the typical cosmic radiation exposure (> 10^6 rads) and the equivalent dose of meteorite thermoluminescence (10^4-10^5 rads; e.g., [5,6]). The use of monochromatic radiation rather than filtered white radiation is expected to reduce the required radiation dose by about an order of magnitude.

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