ECORD Summer School

Submarine Landslides, Earthquakes and Tsunamis

Introduction Virtual Ship: X-ray Computed Tomography

Michi Strasser, ETH Zürich
X-ray CT Scanner onboard D/V Chikyu

A LightSpeed Ultra 16 (GE Yokogawa Medical Systems, Ltd.),
X-ray CT Scanner onboard D/V Chikyu

Allows scientist to

- Examine 3-D features of deformation structures, bioturbation, ...
- Measure dip angles of structures such as faults, bedding, veins, ....
- Distinguish “natural” fracture/faults and drilling-induced fractures;
- Determine locations for whole-round samples;
  - to identify important structural and sedimentological features to be avoided by WR sampling.
  - identifying intervals with minimal drilling disturbance for WR sampling and for assessing heterogeneity

Creates non-destructive 3D CT images within a few minutes after core on deck
X-ray CT Scanner onboard D/V Chikyu

Core flow
X-ray computed tomography

- Tomography is the study of the reconstruction of two- and three-dimensional objects from one-dimensional slices.

- Tomography is imaging by sections or sectioning. A device used in tomography is called a tomograph, while the image produced is a tomogram.

- The method is used in medicine, biology, material sciences, geology and other sciences.

- It is based on the mathematical procedure called tomographic reconstruction.
The principle of CT is based on the theory that:

“an image on a closed plane can be reconstructed if projections in all directions through any points on the plane are given”
X-ray intensity varies as a function of X-ray path length and the linear attenuation coefficient (LAC) of the target material.

\[ I = I_0 \times e^{-\mu L} \]

- \( I \) = transmitted X-ray intensity,
- \( I_0 \) = initial X-ray intensity,
- \( \mu \) = LAC of the target material
- \( L \) = X-ray path length through the material.
linear attenuation coefficient (LAC) is a physical index which shows how much the X-ray beam reduced when the beam interfere with a material.

It is a function of the material’s physical properties (chemical composition, density and state) and the energy level of the X-ray beam.
X-ray computed tomography

The basic measure of attenuation, or radiodensity, is the CT number given in Hounsfield units (HU) and is defined as

$$CTnumber(HU) = \frac{\mu_t - \mu_w}{\mu_w} \times 1000$$

$\mu_t$ = LAC for the target material, and
$\mu_w$ = LAC for water.
Analytical standards used on Chikyu are:

- air (CT number = $-1000$)
- water (CT number = 0)
- aluminum ($2477 < $ CT number $< 2487$)
The distribution of attenuation values mapped to an individual slice comprises the raw data that are used for subsequent image processing.

Successive 2-D slices yield a representation of attenuation values in 3-D voxels.
X-ray computed tomography

Axial Image
(Z = Zn)

Coronal Image
(Y = 0)

Sagittal Image
(X = 0)

Fig. 6. Types of image plane and the coordinate system

A: Anterior (Working half side)
P: Posterior (Archive half side)
S: Superior
I: Inferior
R: Right
L: Left
Data Format:

Data generated for each core consist of core-axis-normal planes of X-ray attenuation values with dimensions of $512 \times 512$ pixels.

The data is stored and transmitted to shipboard server in DICOM

DICOM (Digital Imaging and Communications in Medicine) is a standard for handling, storing, printing, and transmitting information in medical imaging
X-ray CT onboard D/V Chikyu

Fig. 10. Experimental flow of X-ray CT scanning
Onboard Chikyu

X-CT Image Analysis

OsiriX Imaging Software
Advanced Open-Source PACS Workstation
DICOM Viewer

OsiriX Graphic User Interface
What does an open-source DICOM Viewer look like? Check these screenshots.

Database Window (SQLite)

2D Viewers

Oblique MPR Viewer

http://www.osirix-viewer.com/
During Summer School

X-CT Image Analyis

http://www.3dim-laboratory.cz/en/software/3dimviewer/

Free software for PC to view DICOM data in 3D
X-CT Image Analysis

Free software for PC to analyse DICOM data, and perform measurements (e.g. distance, angle)
This site aims to distribute (1) the science data acquired by IODP expeditions of D/IV CHIKYU as well as (2) the curatorial records associated with DSDP, ODP and IODP sample materials stored in KCC. All the scientific data record in the J-CORES database as well as data files are available for downloading from this site.

Before July 17, 2012, CSF-B values in J-CORES' Bulk Exported file sets were wrong due to a bug of J-CORES Version 1.8.9 and before. These values were corrected by J-CORES Version 1.8.10. Differences of wrong values from correct values were from -0.006 to 0.005 m.

... See full ChangeLog to know how this site has been updated.

Data Access Policy

“Integrated Ocean Drilling Program Sample, Data, and Obligations Policy” outlines the policy for distributing Integrated Ocean Drilling Program (IODP), Ocean Drilling Program (ODP), and Deep Sea Drilling Project (DSDP) samples and data. “The moratorium period is one year long and begins either (1) after the conclusion of an expedition cruise if the majority of the sampling occurred during the cruise or (2) after the conclusion of the expedition onshore sampling party (onshore science party in case of the mission-specific platform).” “During the moratorium period, the only researchers permitted to receive expedition core materials and data are members of the Science Party.” “Expedition data are available online” after the moratorium period.

Chikyu IODP Expeditions Data

314, 315, 316, 319, 322, 326, 331, 332, 333, 343
Hole locations are available in KML (Show it by using Google Maps).

www.sio7.jamstec.go.jp
### IODP X-CT Data access

**NanTroSEIZE Stage 1 Shallow Megasplay and Frontal Thrusts**  
Vessel: Chikyu

<table>
<thead>
<tr>
<th>Hole</th>
<th>LAT/LONG</th>
<th>WD (m)</th>
<th>J-CORES</th>
<th>Whole core XCT</th>
<th>Split core image</th>
<th>Downhole Measurement</th>
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[www.sio7.jamstec.go.jp](http://www.sio7.jamstec.go.jp)
The 3D X-ray CT images for whole-round core sections are the first measurement to be done on board. Whole-core photography and X-ray imaging provide information about surface features and internal structure. The resolution of CT scanning is under 0.35 mm and allows 5 mm depth for beam width. The computed tomography (CT) scan provides 3D evidence of fractures, vugs, fault structure, sedimentary structure and methane hydrates without disturbing the sample. A pure water standard piece and air is used for calibrate giving CT-values. It requires about 5 minutes to scan each 1.5 m section of core.

Image file

Each ZIP file corresponds to a section and the filename of a ZIP file consists of section identifier. A ZIP file contains DICOM files of axial images as well as a reformatted coronal image. Each DICOM file has DICOM header with image data. Pixel data are compressed without any losses by JPEG2000 in the DICOM files (See Section 8.2.4. JPEG 2000 image compression in Digital Imaging and Communications in Medicine (DICOM) Part 5: Data Structures and Encoding distributed in DICOM Homepage).

Software Utilities - They are not support by CDEX. -

"OsiriX is an image processing software dedicated to DICOM images (*.dcm / *.DCM extension) produced by imaging equipment (MRI, CT, PET, PET-CT, SPECT-CT, Ultrasounds, ...)."

"GDCM is an open source DICOM library. It is meant to deal with DICOM files (as specified in part 10 of the DICOM standard)." Command line tool gdc2conv can convert encapsulated DICOM to RAW by issuing a command like gdc2conv --raw compressed.dcm uncompressed.dcm.

lost data

Axial images for some sections were mistaken to archive while they were measured. Empty files whose names end with .lost indicate such sections.

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### IODP X-CT Data access

**Data Index**

See also [data in the J-CORES database for the same hole](http://www.sio7.jamstec.go.jp) to refer related information.

[BETA] [xray-ct 316-C0004C.torrent](http://www.sio7.jamstec.go.jp): BitTorrent metainfo file to download all these files by using BitComet or Vuze.

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<th>Section</th>
<th>Top CSF-A (m)</th>
<th>Bottom CSF-A (m)</th>
<th>Curated Length (m)</th>
<th>Coronal Image</th>
<th>Axial Image</th>
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Tour to the MARUM CT-Scanner

By Holger Kuhlmann