Measurement Catalog

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Introduction

The Integrated Ocean Drilling Program (IODP) is an international science program that explores the Earth's history and structure as recorded in seafloor sediments and rocks, and monitors sub-seafloor environments. This program is lead by Japan and United States, with participation from China and 12 EU nations. The central mission of IODP is listed in the Initial Science Plan, found at http://www.iodp.org/isp/. This service catalog is focused on measurement and equipment in laboratories aboard *Chikyu*. All general boarding information can be found at:
http://www.jamstec.go.jp/*Chikyu*/eng/Expedition/application/exp314-6.html.

Fig. 1 Drilling Vessel *CHIKYU*

Chikyu and its Coring System

"*Chikyu*" (Japanese for Earth) is the largest science-drilling vessel in the world and it is fitted with a technology borrowed from the oil industry that will allow it to bore through 7000 meters of crust below the seabed while floating in 2500 meter of water. It is one of the world's deepest drilling vessels, with a length of 210 m, width of 16 m, and draft of 8.9 m. By comparison, the US deep-sea research ship, *JOIDES Resolution* (*JR*), is able to drill a hole 2111 m deep. At 210 meters and 57,500 metric tons, the *Chikyu* is 45% longer and 2.4 times the weight of JR with 60% more laboratory space. Laboratories, crew accommodations and navigation facilities (with a heliport on the bow) occupy one-third of the vessel. The rest comprise the drilling area and drilling equipment. A total of 150 people, roughly 50 scientists and technicians and 100 crew members are expected to live on *Chikyu* for tours exceeding 30 days. Core preservation is overseen by the curator. Operations continue 24 hours a day during the expeditions and even during port call. All *Chikyu* data can be accessed at http://www.jamstec.go.jp/*Chikyu*/eng/*CHIKYU*/data.html.

The biggest difference between *Chikyu* and *JR* is the drilling system. *Chikyu* is a riser-drilling vessel that uses a Blow-Out Preventer (BOP), which can prevent oil or gas from leaking into the ocean. The advantage of riser drilling is to drill as deep part as targeted continuous core but takes time to drill. For *JR*, the non-riser drilling can operate in shallower waters and is able to drill a number of cores over a wide area. The enclosing pipe of the riser provides a channel for drilling mud-- a viscous slurry of clay, water, and chemicals—which is pumped down through the drill pipe and circulates back up in the space between the drill pipe and the surrounding riser. The dense mud helps prevent the drill hole from collapsing, lubricates the drill bit, and flushes cuttings away, in principle allowing the rig to extend deep beneath the sea floor. The important target for *Chikyu* is to obtain cores from the targeted area and to collect continuous core samples. The core is extracted by using coring tools and the Wireline method. This method has been adapted to a riser drilling ship for the first time. Using this method, a core barrel is placed inside the drill pipe, four types of which are carried aboard *Chikyu*. These systems are used for different geological conditions to allow efficient and uninterrupted core collection. For more details about the core sampling system aboard *Chikyu*, go to: http://www.jamstec.go.jp/*Chikyu*/eng/Science/drilling.html.

Fig. 2 Riser pipes

Table 1. The core sampling system aboard *Chikyu*.

Core Sampling System			
Chikyu	*JR*	Formation	Remarks
Hydraulic Piston Coring System (HPCS)	Advanced Piston Corer (APC)	Soft sediments	Modified
Extended Shoe Coring System (ESCS)	Extended Core Barrel (XCB)	Soft to moderately hard formations	Modified
Standard Rotary Core Barrel (RCB)	Standard Rotary Core Barrel (RCB)	Medium to hard formations	
Small Diameter Standard Rotary Core Barrel (SDRCB)	--	Tool for drilling depth/ Larger diameter than RCB	Newly Developed

Laboratories

The laboratories are spread out over four decks: Lab Roof Deck, Core Processing Deck, Lab Street Deck and Lab Management Deck.

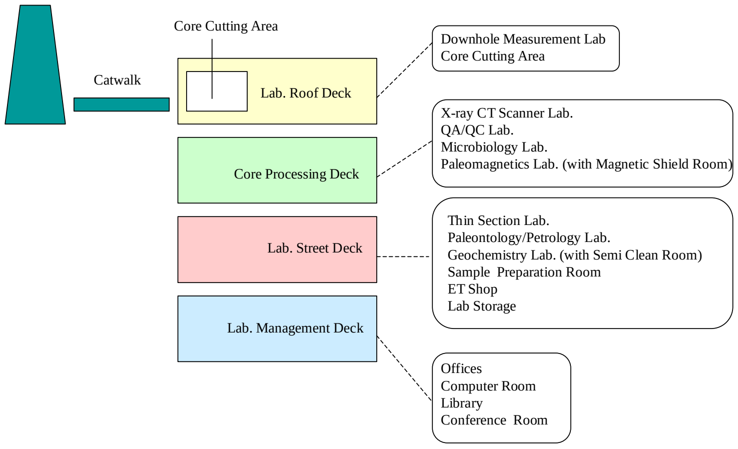


Fig. 3 Lab structure spread over four decks.

Each deck consists of a specialized room for a specific purpose. An elevator connects all levels of the lab floors and is used to transport cores and supplies. Laboratory specialists (lab technicians) will assist in the use of all measurement instruments. Specific instruments for each lab are listed in Table A1 in appendix. The Lab Roof Deck at the top of the vessel is where the core comes in through the cat walk. The Core Processing Deck contains a 3D CT scanner room, physical properties and paleomagnetism laboratories with a magnetically shielded chamber that blocks out 99% of the Earth’s magnetic field. Also, digital photos are taken to record the appearance of each core when it first arrives into the Core Lab. The Lab Street Deck contains the Geochemistry Lab with ICP-MS and ICP-AES and all other instruments for IW analysis, and major and trace elements analysis. The Electric work shop, Gas bottle storage and Chemical storage rooms are also located on this level. Offices, library and computer room, computer center and conference room are located on the Lab Management Deck. More details are available in the table in the appendix.

To operate the core within the laboratory, the facility is used in a variety of research during the operations. The laboratory is available for use by scientists around the world to conduct wide array of studies. The lab facilities aboard *Chikyu* are as well equipped as the land-based laboratories and will help attract visiting scientists and expose all of us to new and innovative science, and promote the exchange of information and ideas of deep earth exploration.


Fig. 4. Core lab on the Core Processing Deck.

IODP Measurements

There are four required IODP measurement data categories which every IO has the responsibility to collect during IODP operations. These are: Minimum measurement, Standard measurement, Supplemental measurements and Safety measurements. The lists of each measurement can be found at http://www.iodp.org/program-policies/5/.

Data Base

All the data taken during the expeditions are stored in the J-CORES database. J-CORES is a scientific data management system built to store and distribute science data taken during *Chikyu* expeditions. Visual core description (VCD) is also taken in J-CORES to edit VCD data in depth. The system is installed aboard *Chikyu* and the onshore CDEX data center. All the applications are available to collect data taken onboard. Data from *Chikyu* are moved to the CDEX data center on a regular basis during the expedition. More details on J-CORES are found at http://sio7.jamstec.go.jp/j-cores/.

Example Core Flow

Here is an example core flow diagram aboard *Chikyu* (Fig. 7.). Sampling and measurement are changeable depending on sample requests given by scientists.

On *Chikyu*, core handling is unique from the ordinary core research vessel. The core is retrieved to the Cutting area (Lab. Roof Deck) from the catwalk using belt conveyor to prevent straining the core. As soon as core is retrieved on cutting area, head space and void gases are measured by using a plug to require high quality gas as an initial assessment. Methane hydrate or any gases need to take out before evaporating long-time exposure in the aerobic environment is allowed to measure if it's necessary in individual cases. They are analyzed immediately for a safety and to prevent deterioration of fresh gases at Geochemistry Lab. The sample in the core catcher at the bottom of the core barrel is used for micropaleontology sampling.

Fig. 5. Core cutting area on the Lab Roof Deck.

Microfossil extraction and age determination are also performed onboard.

As soon as all the gasses are taken at the Core Cutting Area, the 9 meters long core is cut into 7 sections of 1.5 meters in length. Each core section is provided an ID barcode (indicating the expedition number, drill hole number, core number, and section number) by lab technicians. Each 1.5 meter long core is transported to Core Processing Deck, one floor below Lab Roof Deck, by elevator to distracted CT value of whole core and construct inner view of the core are measured with the X-ray CT scanner for its physical property and structure in X-ray CT scan Lab.

Fig. 6. 3D X-ray CT Scanner on the Core processing Deck.

All the nondestructive tests are taken at this point. Interstitial water and microbiology sampling are obtained after the X-ray CT scanner before the core’s condition is affected by exposure to air. After the cores have equilibrated to room temperature, cores are split in half as working and archive halves. The core holder cuts hard cores with diamond blades, while soft cores samples are split with a thin wire.

The working half is distributed to researchers as discrete samples for on-board and onshore analyses. The archive half of the core is stored in a core case for permanent archiving after multi-sensor core logger image (MSCL-I), Visual core description, multi-sensor core logger color (MSCL-C) and Cryogenic Magnetometer (SQUID) are completed. X-ray fluorescence core logger (XRFCL) and multi-sensor core logger split (MSCL-S) are taken as required.

Discrete samples are taking from the working half core to purify each analysis by centrifugal separation and/or filtering. Non-destructive physical property measurements (moisture, density, magnetic susceptibility), X-ray diffraction and geochemical analysis can be measured. Microscopic observations are performed for paleontological and petrological studies such as fossil age determination.

All these data from working and archive cores are stored in the J-CORES database. All data including core analytical results, core images (including X-ray CT scan images), downhole logging data, and mud logging data are stored in the workstation situated in the Data Integration Center where secondary processing, integration, visualization and imaging are done. These data are also accessible while aboard.

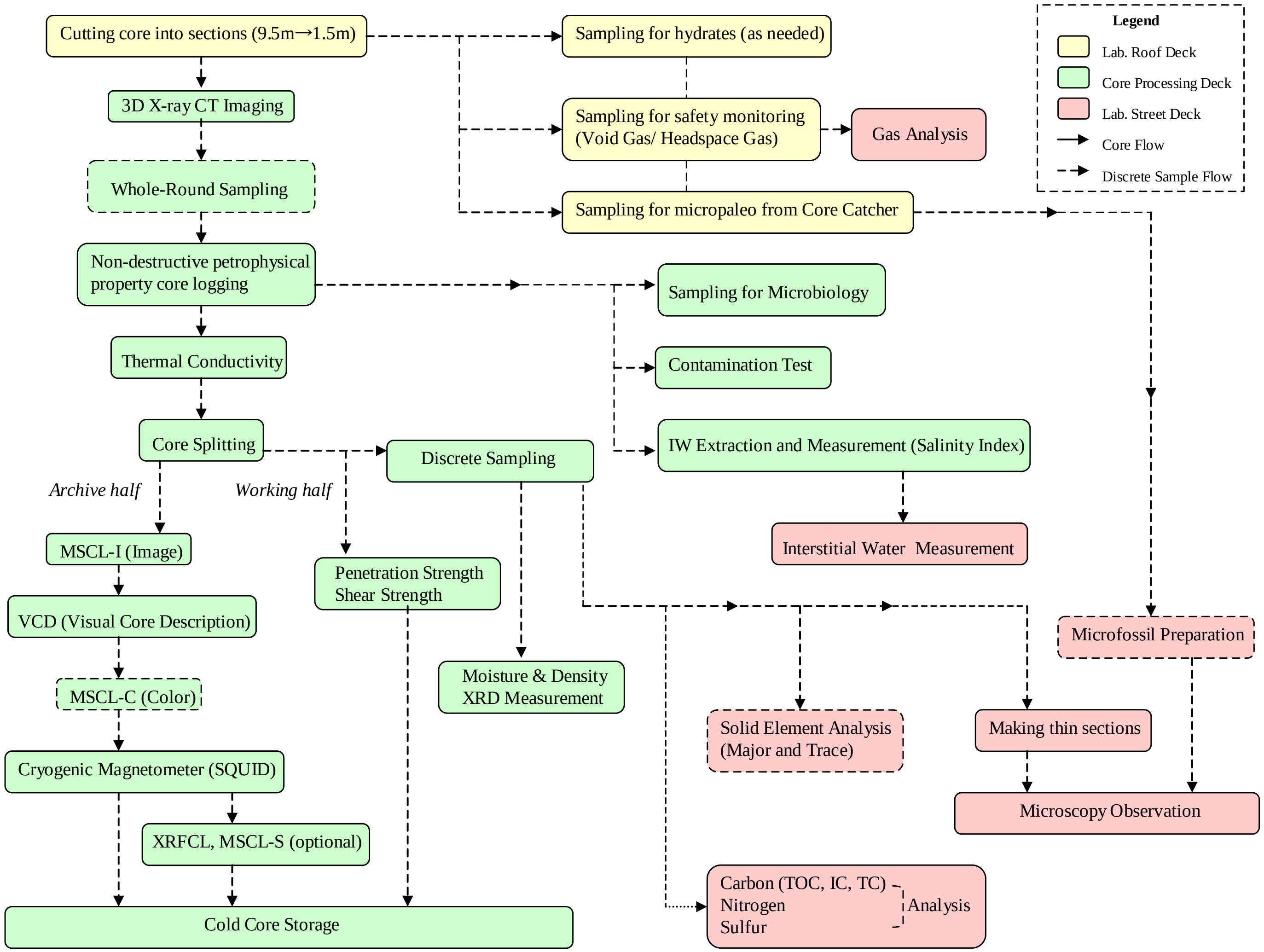


Fig. 7. Example of the core work flow.

Measurement and Existing laboratory equipment

The function of each lab will be to conduct research with the instruments onboard. These major instruments will be used in a variety research and measurement during the expeditions.

3D X-ray CT Scanning

- 3D X-ray CT Scanner
  Model: GE Medical System LightSpeed Ultra 16

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.

Split-core Digital Photography, Core Logging, and Color Reflectance

- Multi sensor core logger (MSCL)
- (MSCL-W (whole), -S (split), -Image, -Color)
  Model: Geotek Ltd.
  Location: Core Lab.

Multi Sensor Core Logger is used for the physical property of core measuring core diameter, P-wave velocity (PWV), Gamma-ray attenuation density (GRA), magnetic susceptibility (MS), non-contact resistivity (NCR) and natural gamma-ray radiation (NGR) sensors. It can handle core section between 50 to 150 mm in diameter and 1.5 m long and can sample at intervals of 1 mm or greater. Unit system has added to MSCL system to shorten the measuring time and to upgrade GEOSCAN III and IV camera unit to save about 2000 scan data. These measurements are required as minimum and standard measurements in IODP. MSCL is also available to obtain color spectrophotometer and digital image of core surface with equipped system. This will help us to constrain the complex mineralogical and fluid systems in rocks and sediments.

X-ray Fluorescence Scanner

- X-ray Fluorescence Core Logger (XRFCL)
  Model: JEOL JSX-3600CA1, TATSCAN-F2
  Location: Core Lab

The water content in fresh core will decrease with time and will affect the values of data measured with XRFCL. To measure under certain condition, core need to be wrapped with thin film with less absorb X-ray to avoid dryness. Sedimentary cores have high moisture content, which may affect the content of elements in total. A thin 4 μm thick ultralene film (CHEMPLEX) or prolene film (SPEX) cover sheet is necessary to cover the core to scan with XRFCL and these covers are highly esteemed by engineers and scientists. For rock cores, cover is not needed due to less moisture. High-resolution measurements using an XRFCL provide major elements from the surface of split core. The high-resolution analysis allows the user to specify time periods, to approach climate change, and to identify small-scale features in the sediments. This instrument allows us to analyze major elements of Na, Mg, Al, Si, P, S, K, Ca, Ti, Mn and Fe.

Moisture and Density

- Penta-pycnometer
  Model: Quantachrome Corp.,
  Location: Core Lab

This remains basically the same as the one on the *JR*. Moisture and density (MAD) is one of the IODP minimum requirement measurements. MAD measurement gives physical properties of bulk density, grain density, wet density, water content, porosity and void ratio on sediment/rock samples. The penta-pycnometer that will be used in the density determination and volume must first be calibrated. Up to five specimens are then analyzed automatically in sequence with no operator involvement. The mass and volume of the evaporated pore-water salts are calculated for a standard seawater salinity (0.035) and seawater density (1.024 g/cm^3). The total mass in wet condition and dry weight as well as dry volume are measured based on the gas pycnometry (method C in ODP tech note No. 26). Unfortunately, this method works only for dry samples due to a large difference in the measurement using the gas pycnometry in wet samples but able to measure with a small portion of sample. Knowing the exact volume of the pycnometer being used, the density of the unknown fluid can now be determined.

- Electric balance
  Model: OHTI (Ocean High Technology Institute)
  Location: Core Lab

This mass balance was made specifically for the lab on *Chikyu*. The high AD exchange conversion technology allows the calculation of mass balances with errors of less than 1% with 0.1 g of sample. Mass is determined with original OHTI electric balance with compensate for the ship's motion. To get all the accuracy electronic balance and/or scale provides, routine calibrations and verifications using precision calibration weights are performed. A set of mass standards ranging from 3 to 20g weights is used for the calibration and on the reference balance during measurements.

Thermal Conductivity

- Thermal conductivity (Whole core and pieces)
  Model: Teka Berlin TK04
  Location: Core Lab

Thermal structure of the Earth is useful to understand activities of earthquake and magma, seismic wave speed in the core and mantle, magnetization and electrical conductivity of rock, and so on. Therefore, thermal conductivity is required for a standard measurement in IODP. Thermal conductivity can be measured on rock samples, i.e. cores or cuttings, or sediment with the probe. Thermal conductivity is measured on the archive half of split core pieces. Sediment cores must be left more than three hours to equilibrate to the room temperature and then a small hole is drilled through the core liner to insert the prove. Rock samples in cores should be selected as large as possible, at least 70 mm in a diameter and 20 mm in thickness, from the split core. Polishing the surface of rocks with a sand paper is recommended to make the surface flat to obtain correct measurement if it’s necessary.

X-ray Diffraction

- X-ray Diffraction
  Model: Spectris, CubiX PRO
  Location: Core Lab

XRD analyses allow the identification of minerals based on their atomic structure. During XRD analysis, X-ray beams reflect off parallel atomic layers within a mineral over a range of diffraction angles. Because the X-ray beam has a specific wavelength, there are only specific angles that the detectors will detect and count the exiting rays. Every substance has a unique diffraction pattern that can be used for identification. With this instrument, scientists can evaluate the mineralogical composition of sediments and the alteration products of ocean crust material. XRD analyses were done on powdered samples. Quantitative analysis of a powdered sample of unknown composition is a difficult problem. An analysis program on the data acquisition computer could be run to analyze the results. After 1991, a freeware program for the Apple Macintosh platform called MacDiff was available to the scientists for a quick qualitative and quantitative analysis of samples. For more through analyses, scientists could take XRD files to their home institution.

Core logging

- Gamma ray attenuation density (GRA)
  Model: Geotek
  Location: Core Lab

Gamma-ray attenuation is used to measure cryogenic mixture density. A 370 MBq Cesium-137 capsule (active element CsCl) 9s is used as the gamma ray source. Cs has a half-life of 30.2 years and emits gamma energy principally at 0.662 MeV. Both the source and detector are mounted diametrically across the core, such that they are as close to the cores as is practical. A narrow beam of gamma ray is emitted from the source and passes across the diameter of the core. At this energy level in most geological materials, the primary mechanism for the attenuation of gamma rays is by Compton scattering. The incident photos are scattered by the electrons with a partial energy loss. The Compton attenuation, therefore, is directly related to the number of electrons in the path of the gamma ray beam.

- Natural Gamma Radiation
  Model: Geotek
  Location:

Since the concentrations of naturally occurring radioelements vary between different rock types, natural gamma radiation provides an important tool for lithologic mapping and stratigraphic correlation.

Core Logging

- Multi-sensor core logger (P-wave velocity)
  Model: Geotek
  Location: Core Lab

The multi-sensor core logging system (MSCL) enables a number of geophysical measurements to be made on unsplit cores encased cylindrical core liners. Core section of up to 1500 mm long and 100 mm in diameter can be used. The system is designed to be operated either manually or under computer control, depending on the requirements and available peripheral equipment. The measurement sensors on the whole core logger are:

1. A pair of compressional (P) wave transducers to measure the velocity of compressional waves (sound) in the sediment.
2. A gamma ray source and detector to measure the attenuation of gamma rays through the sediment, which is used to calculate the density of the sediments.
3. A magnetic susceptibility sensor to determine the amount of magnetic material present in the sediment.

Natural Remanent Magnetization

- Cryogenic magnetometer

Model: 2G enterprises, 760-R Superconducting rock magnetometers
Location: Paelomagnetics Lab

The cryogenic magnetometer is used to understand a geologic history of the drilling site and is the first paleomagnetics analysis on board of *Chikyu*. The 2G 760-R superconducting rock magnetizer is 6m in length and is able to measure 1.5m long split core in X min. The cryogenic magnetometer uses liquid helium to create a very cold superconducting region around the magnetometers sensors. When the magnetized is placed into the sensor area, the sample's magnetic field set up a current in the superconducting coil. This current can then be measure. SQUID (Superconducting Quantum Interface Device) magnetic sensor in the model 760R is very sensitive and is possible to measure even a small magnetism of rock and sediment samples. The cryogenic magnetometer may also be used to measure and demagnetize discrete samples as long core samples up to 7 cm diameter and the access size is 7.6 cm. Measurements on the cryogenic magnetometer are initially made in units of magnetic flux, $\Phi 0$ (phi 0); calibration to magnetic moment ($mA \cdot m^2$) depends on the geometry of the coils. The magnetic field is produced by the degauss coils and IRM solenoid.

ARM & IRM Rock magnetism experiments

- Spinner Magnetometer

Model: Natsuhara Giken Co., Ltd., SMD-88
Location: Core Lab

The spinner magnetometer is used for samples that are strongly magnetized. It rotates the sample rapidly within a coil around an axis. The magnetometer measures the electrical current created in the coil by the spinning sample. The sample is spun in various orientations to determine the intensity and direction of the magnetic vector. Advantages of shielding include greater coupling to the specimen field, reduced stationary field at the specimen, lessened coherent noise from rotor magnetism, and a smaller coil size. Disadvantage of the spinner magnetometer is that it only works with strongly magnetized and highly coherent samples. The detectable moment is between $10E^{-4}$ ~ $10E^{-11}$ Am^2 ($10E^{-1}$ ~ $10E^{-8}$ emu). Specimen shape is either a 1x1 inch cylinder or a 7 cc cube. A series of measurement is made on each sample as it is run through a demagnetization sequence. Six separate spin orientations, 3 spins at least, are required to obtain an accurate measurement. Measurement time is between 5 to 10 minutes per sample depends on magnetic dipole strength.

Contamination Testing

- Gas Chromatograph with electron Capture Detector

  Model: 6890N, Agilent Technologies

  Location: QA/QC Sampling Room

The electron capture detector (ECD) is highly sensitive detector capable of detecting pictogram amounts of specific types of compounds. The high sensitivity if this detector can be a great advantage in certain applications. Compared with the FID, it has much more limited liner response range, generally less than 2 orders of magnitude. The response can also vary significantly with temperature, pressure and flow rate.

Interstitial Water Chemistry and Whole Rock Elements (major and minor)

Salinity

- Refractometer

  Model: Atago, RX5000 α

  Location: Geochemistry Lab

Salinity is one of the important measurements in interstitial water sample and is measured with refractometer. It provides reliable refractive index and salinity of total dissolved solids of aqueous solutions. Temperature is automatically adjusted when temperature of sample varies from 20° C (68° F). IAPSO is applied to use for reference material with a relative standard deviation of 0.003%.

pH and alkalinity

- Titrator

  Model: Metrhom, Titrino 794, Photo D-1

  Location: Geochemistry Lab

The digital titration system is convenient but tends to be less precise and less accurate than the buret system because of mechanical inadequacies. Good technique is necessary to produce acceptable results. Titrino 794 (Metrhom) is used in the laboratory for which the Metrhom Company has provided accuracy and precision data. To minimize errors caused by uncertainty in the volume of titrant dispensed to the sample, titration procedure must account for the accuracy and precision of the titrant-delivery system.

Chloride

- Titrator

  Model: Metrhom, Titrino 794, Photo D-1

  Location: Geochemistry Lab

Chloride is clarified by either Mohr's method or Potentiometric method. Mohr's method determines the chloride ion concentration of a solution by titration with using a silver nitrate. As the silver nitrate solution slowly added, a precipitate of silver chloride forms. The end point of the titration occurs when all the chloride ions are precipitated. To avoid individual errors, the end point of potentiometric titration is calculated by the titration curve automatically and we recommend to use this method rather than Mohr's due to reduce the artificial errors. IAPSO is used for a standard solution with an error range within 0.3 % RSD (1 σ).

Sulfate

- Ion Chromatography

  Model: Dionex, ICSI500

  Location: Geochemistry Lab

The ion chromatography system on board *Chikyu* consists of three instruments: ion chromatograph (ICS1500), autosampler (AS50) and operation PC. Determination of sulfate is carried out by a method of Ion chromatograph, which uses a small portion of sample.

Inductively Couples Plasma (ICP)

Advantages of using an ICP include its ability to identify and quantify all elements with the exception of Argon. The ICP is suitable for all concentrations from ultratrace levels to major components. The largest advantage of employing an ICP when performing quantitative analysis is the fact that multielemental analysis can be accomplished, and quite rapidly. All elements except Argon can be determined using ICP. However, ICP has difficulty handling halogens – special optics for the transmission of the very short wavelengths become necessary.

- Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES)

  Model: Horiba Jobin-Yvon, Ultima 2

  Location: Geochemistry Lab

ICP-AES is to analyze quantitatively the major component (in ppm to wt%) in metal elements contained in the core and interstitial water. Each element emits energy at specific wavelength peculiar to its chemical characters. The intensity of the energy emitted at the chosen wavelength is a proportional to the amount (concentration) of that element in the analyzed sample. Twelve inorganic elements of Al, Ti, Fe, Mg, Ca, Mn, Na, K, Sr and Ba can be measured with ICP-AES. GSJ rock standards JR-3, JG-2, JA-3 and JB-3 are used to calibrate obtained data. For interstitial water sample, eight elements of B, Ca, K, Mg, Na, S, Si and Sr are able to measure. IAPSO (International Association for the Physical Sciences of the Ocean) is used as a master standard from which serial dilutions are prepared for eventual analysis. Reproducibility of this measurement is within 4%.

- Inductive Coupled Plasma Mass Spectroscopy (ICP-MS)

  Model: Agilent Technology, 7500CE

  Location: Geochemistry Lab

The advantages of ICP-MS include multi-element capability, high sensitivity, and the possibility to obtain isotopic information on the elements determined. Disadvantages inherent to ICP-MS system include the isobaric interferences produced by polyatomic species arising from the plasma gas and the atmosphere. The isotopes of argon, oxygen, nitrogen and hydrogen can combine with themselves or with other elements to produce isobaric interferences. ICP-MS is not useful in the detection of nonmetals.

ICP-MS is to quantify the minor elements contained in the core samples and interstitial waters in ppm to ppt order. Only the liquid samples are available to measure onboard. The conventional method of sample introduction for ICP-MS is by aspiration, via nebulizer, into a spray chamber. Aqueous samples are introduced by way of nebulizer, which aspirates the sample with high velocity argon, forming a fine mist. The hot plasma removes any remaining solvent and causes sample atomization followed by ionization. In addition to being ionized, sample atoms are excited in the hot plasma, a phenomenon that is used in ICP-atomic emission spectroscopy. Ionized elements are induced to the mass spectrometer by a high voltage detector applied to detect the ions. At this moment, Cr, Mn, Co, Cu, Zn, Mo, Pb and U in interstitial water are available to measure with a confident value. IAPSO is used for a standard reference to evaluate the interference effects. Rare earth elements (REEs) and rare earth metals in solid samples are also measured in liquid solution with GSJ JA-3, JB-3, JG-2 and JR-3 as evaluation interference. Approximately 1 ml of sample is required per analytical run.

- Spectrophotometer (UV-Vis)
  Model: Shimadzu, UV-2550PC
  Location: Geochemistry Lab

Silicate and ammonium is determined by using the spectrophotometer. Dissolved silicate concentration in interstitial water could highly change due to existence of biological opal, smectite and volcanic ash. Ammonium concentrations dissolved in interstitial water (IW) of ocean sediment generally increase with depth. This trend results from diagenesis of organic matter in the sediment. The analytical method for determination of ammonium concentration using indophenol blue is detected at 640 nm with a light path of 1 cm. Relative standard deviations of the analytical results are within 3%.

CHNS Elemental Analysis

- CHNS/O Analyzer
  Model: ThermoFinigan FlashEA1112
  Location: Geochemistry Lab

CHNS-O analyzer is an elemental analyzer dedicated to the simultaneous determination of the amount of (%) of Carbon, Hydrogen, Nitrogen, Sulfur and Oxygen contained in organic and inorganic samples of core and in substances of solid, liquid and gaseous samples. The method is based on the combustion of the sample in an oxygen atmosphere at 1000º C. In CHN mode, the accuracy of this method is less than 1%, so the sample needs to be pure to pass. The determination of the mass percentage of CHN elements in the sample is based upon the direct weight of the material sample. Samples need to be freeze-dried for over night, crushed and carefully weighed. Samples must be very pure and have the correct chemical structure to pass elemental analysis. If there are any solvents or moisture trapped in the sample, the accuracy of the results will be affected. Some compounds are inherently difficult to combust completely. Incomplete combustion can also cause inaccurate results. In this case, the sample could be re-run under different conditions, with an added oxygen boost, or with the addition of a chemical combustion aid such as vanadium pentoxide.

Carbon Analysis

- Carbonate Analyzer (Coulometer)

  Model: UIC&JANS

  Location: Geochemistry Lab

Total carbon (TC) is determined using a coulometer and is calculated as the difference between TC and IC:

$$TOC\ (wt\%) = TC\ (wt\%) - IC\ (wt\%)$$

Coulometer provides an accurate determination of carbon in a carbon dioxide containing gas stream and can detect carbon in the range of 0.01 g to 100 mg. It is used routinely with the acidification module for the analysis of carbonate in the core samples. Samples taken for carbon analysis are freeze-dried for 24 hours, crushed and carefully weighed. The sample is mixed with acid to convert the carbonate to CO_2 before analysis in the coulometer. All of measurement data are automatically export in the operation PC as a text file to avoid manual entry error.

Head Space Gas Analysis

- Gas Chromatograph (Flame ionization detector)

  Model: Gas Chromatograph (GC)- Agilent Technologies, 6890N
- Flame ionization detector (FID)- Agilent Technologies
- Natural Gas Analysis (NGA)- Wasson-ECE Instrumentation

  Location: Geochemistry Lab

Headspace Gas Analysis refers to the determination of interstitial light hydrocarbon gases including methane, ethane, propylene, propane, butanes, iso-butane and n-butane by Gas Chromatography/ Flame Ionization Detection (GC/FID). The light hydrocarbon gases are not very soluble in water, so they can be extracted from a sediment and water sample into a gas such as nitrogen by partitioning procedure. Sediment samples of ~5 cm^3 are collected immediately from the bottom side of the freshly cut section 1 using a calibrated borer tool after the core retrieval for headspace gas determinations, replaced in 20 ml glass vial, and sealed immediately with a septum and metal crimp cap. When consolidated or lithified samples are encountered, chips or materials are taken in the vial and sealed. If the interstitial water (IW) sample is taken from the core, gas should be collect and separated from the water immediately. The computer software automatically integrates analyte peaks based on their retention times and analysts visually confirm that the software integrates each analyte peak correctly.

Head space and vacutainer gas sample are also analyzed with the natural gas analyzer (NGA) when high concentrations of C^{2+} hydrocarbons and nonhydrocarbons gases such as H2S or CO_2 are anticipated. The NGA is equipped with two detectors; FID and TCD (thermal conductivity detector). The FID measures hydrocarbons from methane to hexane using a capillary column. Thermal conductivity detector measures nonhydrocarbon such as CO_2, H_2S, O_2, N_2 and CO. Prior to the analysis of samples, a calibration curve is established for each analyte to determine the sensitivity and confirm the linear range of the GC/FID and NGA system. A calibrations curve is obtained using 4 different types of gases in disposal cans such as methane (99.9%), ethane (99.5%)

and calibration gas mixture diluted with nitrogen. Gas concentrations are reported as parts per million by volume (ppmv) relative to the standard volume (5 cm^3) of the headspace sample that is injected into the gas chromatograph.

Hydrocarbon Monitoring

- Rock Eval

Model: Vinch Technologies, Rock eval 6 Standard
Location: Geochemistry Lab

Rock eval is used to identify the type and maturity of organic matter and to detect petroleum potential in sediments. Samples chosen to be measured on the Rock eval are also taken for analysis on the TOC, CNS and the oil potential. This method consists of a programmed temperature heating in an inert atmosphere of a small sample to quantitatively and selectively determine the free hydrocarbons contained in the samples, the hydrocarbon- and oxygen- contained compounds (CO_2) that are volatilized during the cracking of the unextractable organic matter in the sample. Need to contact the expedition project manager for a status of use.

Other Equipments

- Magnetic Susceptibility

Model: Bartington Instrument Ltd.
Location: Paleomagnetics Lab

Magnetic susceptibility measurements are non-destructive and cost effective method of determining the presence of iron-bearing minerals within the sediments. The whole core, or individual sediment samples, is exposed to an external magnetic field which causes the sediments to become magnetized according to the amount of Fe-bearing minerals present in the samples. Three types of magnetic susceptibility sensors are available aboard *Chiyku*: MS2C, MS2E and MS2B. MS2C is loop type equipped with MSCL-W (whole round) and used for the magnetic susceptibility measurement of whole core. MS2E is a point type equipped with MSCL-S (split) and C (color reflectance) for split core measurement. MS2B is suitable for discrete sample. Each sensor is connected with MS2 meter and controlled by MSCL software. Need to contact the expedition project manager for a status of use.

- High-performance Liquid Chromatography (HPLC)

Model: Agilent Technology, 1100
Location: Geochemistry Lab

This system is currently not setting as a routine measurement. Request of using the system will be arranged for the target compounds. Need to contact the expedition manager for a status of use.

- Kappabridge

Model: AGICO, KLY-3S
Location: Paleomagnetics Lab

The Kappabridge KLY-3S Magnetic Susceptibility System measures magnetic susceptibility and anisotropy of magnetic susceptibility at sensitivities of minimum to $3x10^{-8}$ SI. The instrument is a semiautomatic inductivity bridge, operated in conjunction with a PC and manufacturer-supplied software. The data sis transferred to storage on a floppy disk, then uploaded to J-CORES using other PC. Details of instrument operation and data analysis are provided in a manual supplied by the lab technicians. This measurement is not included as the IODP measurement plan but is to respond to the scientist party's request. Need to contact the expedition project manager for a status of use.

New Instruments

- Scanning Electron Microscope/ Energy Dispersive Spectroscopy

Model: JEOL JCM-5700LV

The main focus of SEM-EDS is geological research and analysis of the core samples.
In the scanning electron microscope (SEM) a very fine 'probe' of electrons with energies up to 20kv is focused at the surface of the specimen in the microscope and scanned across it in a 'raster' pattern of parallel lines. A number of phenomena occur at the surface under electron impact: most important for scanning microscopy are the emission of secondary electrons with energies of a few tens kv and re-emission or reflection of the high-energy backscattered electrons from the primary beam. The intensity of emission of both secondary and backscattered electrons is very sensitive to the angle at which the electron beam strikes the surface, i.e to topographical features on the specimen. The emitted electron current is collected and amplified; variations in the resulting signal strength as electron probe is scanned across the specimen are used to vary the brightness of the trace of a cathode ray tube being scanned in synchronism with the probe. There is thus a direct positional correspondence between the electron beam scanning across the specimen and the fluorescent image on the cathode ray tube.
Chemical analysis (microanalysis) in the scanning electron microscope (SEM) is performed by measuring the energy or wavelength and intensity distribution of X-ray signal generated by a focused electron beam on the specimen. With the attachment of the energy dispersive spectrometer (EDS), the precise elemental composition of materials can be obtained with high spatial resolution.

- Impedance Analyzer

Model: Agilent, 4292A

It provides accurate and thorough component and material evaluation with various test fixtures. They measure impedance (inductance, capacitance, and resistance) at spot frequencies or across a range of frequencies. Also, the measurement capabilities of transmission parameter and spectrum analysis are available in the combination analyzers. On the other hand, the DC bias and the AC signal level swept measurement functions are available in the impedance analyzer to evaluate the device under actual operating conditions. In addition, some of impedance analyzers offer the temperature characteristic measurement solution in the wide temperature range from -155□ to 155□.

- Multi-Wavelength Particle Analyzer with Micro Volume Module (MVM) System

Model: Beckman Coulter, LS 13 320

It can be ordered in different configurations for Dry, Wet, and combination of dry and wet measurement. The complete processing time from one sample to the next is up to 90 seconds. Single range sample can be measured over the complete range, 0.04μm to 2000μm for both solid and liquid state based on theories of light scattering. For dry sample, powerful circulation system (Tornado dry powder dispersing system) measure and disperse in short time.

- X-ray Fluorescence Spectroscopy (XRF)

Model: Rigaku, Supermini

The XRF spectroscopy is widely used for the qualitative and quantitative elemental analysis of samples. It has the advantage of being non-destructive, multi-elemental, fast and cost-effective. Furthermore, it provides a fairly uniform detection limit across a large portion of the Periodic Table and is applicable to a wide range of concentration, from a 100% to few parts per million (ppm).
XRF Supermini is fully automated, wavelength-dispersive spectrometer using 200W rhodium X-ray tube as the excitation for both major oxides and trace elements.

- Laser Ablation ICP-MS

Model: New Wave, UP-213

The Laser Ablation (LA) ICP-MS facility operates the ICP-MS systems dedicated to Laser Ablation work to perform direct analyses of any metals. The LA-ICP-MS technique is particularly useful for in-situ analyses of trace elements for applications requiring understanding of the spatial variation of elemental content within the sample. The lab currently operates ICP-MS Agilent 7500 and LA UP-213. The high energy Nd:YAG UV (213nm) laser ablation system produces a finer particle distribution. The LA system is fully computer controlled with a real time imaging system capable of reflected and transmitted light (polarized light available) viewing. The system can be programmed to ablate continuous lines, spots or variety of more complex ablation patterns.

- Digital Microscope

Model: Keyence, VHX-900

Digital Microscope provides a depth of field at least 20 times larger than optical microscopes. The VHX-900 can accurately observe a sample that could not be focused on with conventional microscopes. The number of steps required for observation including focus adjustment can be reduced considerably. A sample can be observed with the lens unit held by hand or mounted to the stand in any angle.

- High Pressure P-wave Velocity Measurement

Model: Marui, MIS-235-1-075-055 (customized design)

This is one of original instruments which jointly-developed with Marui Corporation. A system consisting of two rolling transducers, one transmitter and one receiver, is mounted. The active element is a piezoelectric crystal mounted on the central spindle of the rolling transducer, surrounded by caster-oil filled encapsulated in a soft epoxy sheath. This configuration provides a good acoustic coupling between the transducer and the core. A short P-wave pulse is produced at the transmitter at about 230 Kh, that propagates through the cores and is detected by the receiver. The distance traveled is measured as the outside core diameter. A temperature correction is done for the processing of the P-Wave velocities. Using velocity and bulk density it is possible to estimate the acoustic impedance and provide a synthetic seismogram for seismic correlation.

Appendix:

Table A1. Existing instruments onboard *Chikyu*.

Measurement	Instrument	Location	IODP Requirement	Remark
X-ray CT Scanning	3D X-ray CT Scanner	X-ray CT Scanner Room/ Core Processing Deck	Standard	
Split-core Digital Photography, Core Logging and Color Reflectance	Multi sensor core logger (MSCL) (MSCL-W (whole), -S (split), -Image, -Color)	Core Lab/ Core Processing Deck	Standard	
X-ray Fluorescence Scanner	X-ray Fluorescence Core Logger (XRFCL)	Core Lab/ Core Processing Deck	Standard	
Moisture and Density	Penta-pychnometer	Core Lab/ Core Processing Deck	Minimum	
	Electric Balance	Core Lab/ Core Processing Deck	Minimum	
Thermal Conductivity	Thermal Conductivity (Whole core and pieces)	Core Lab/ Core Processing Deck	Standard	
X-ray Diffraction	X-ray Diffraction	Core Viewing Room/ Core Processing Deck	Standard	
Core Logging	Gamma-ray Attenuation Density	Core Lab/ Core Processing Deck	Standard	
	Natural Gamma Radiation	Core Lab/ Core Processing Deck	Standard	
	Multi Sensor Core Logger (MSCL)	Core Lab/ Core Processing Deck	Standard	
Natural Remanent Magnetization	Cryogenic Magentometer System	Paleomagnetics Lab./ Core Processing Deck	Standard	
ARM & IRM Rock Magnetism Experiments	Spinner Magnetometer	Paleomagnetics Lab./ Core Processing Deck	Supplemental	
Contamination Testing	Gas Chromatograph (ECD)	QA/QC Sampling Room/ Core Processing Deck	Standard	
Interstitial Water Chemistry and Whole Rock Elements (major and minor)	Refractometer (Salinity)	Geochemistry Lab/ Lab Street Deck		
	Titrator (pH, alkalinity, Chloride)	Geochemistry Lab/ Lab Street Deck	Standard	
	Ion Chromatography (sulfate, sulfurous, nitrate, nitrite, other halogens)	Geochemistry Lab/ Lab Street Deck	Standard	
	ICP-AES (major cation, silicate, major elements)	Semi-Clean Room/ Lab Street Deck	Standard	
	ICP-MS (trace cation, silicate, trace elements)	Semi-Clean Room/ Lab Street Deck	Standard	
	Spectrophotometer (UV-VIS) (ammonium, silicate)	Geochemistry Lab/ Lab Street Deck	Standard	
Smear Slide/ Thin Section	Cut Off Saw, Thin Section Equipments, Vacuum	Thin Section Room/ Lab Street Deck	Minimum	
	Impregnation, Polishing System, Microscopes	Thin Section Room/ Lab Street Deck	Minimum	

Measurement	Instrument	Location	IODP Requirement	Remark
CHNS Analysis	CNHS/O Analyzer	Geochemistry Lab/ Lab Street Deck	Standard	
Carbonate Analysis	Carbonate Analyzer (coulometer)		Standard	N/A
Head Space Gas Analysis	Gas Chromatograph (NGA)	Geochemistry Lab/ Lab Street Deck	Safety	
	Gas Chromatograph (FID)	Geochemistry Lab/ Lab Street Deck	Safety	
Hydrocarbon Monitoring	Rock Eval	Geochemistry Lab/ Lab Street Deck	Safety	N/A
Other Equipments	Kappabridges	Paleomagnetics Lab./ Core Processing Deck		N/A
	Magnetic Susceptibility (MS2B)	Core Lab/ Core Processing Deck		N/A
	Liquid Chromatograph (HPLC)	Geochemistry Lab/ Lab Street Deck		

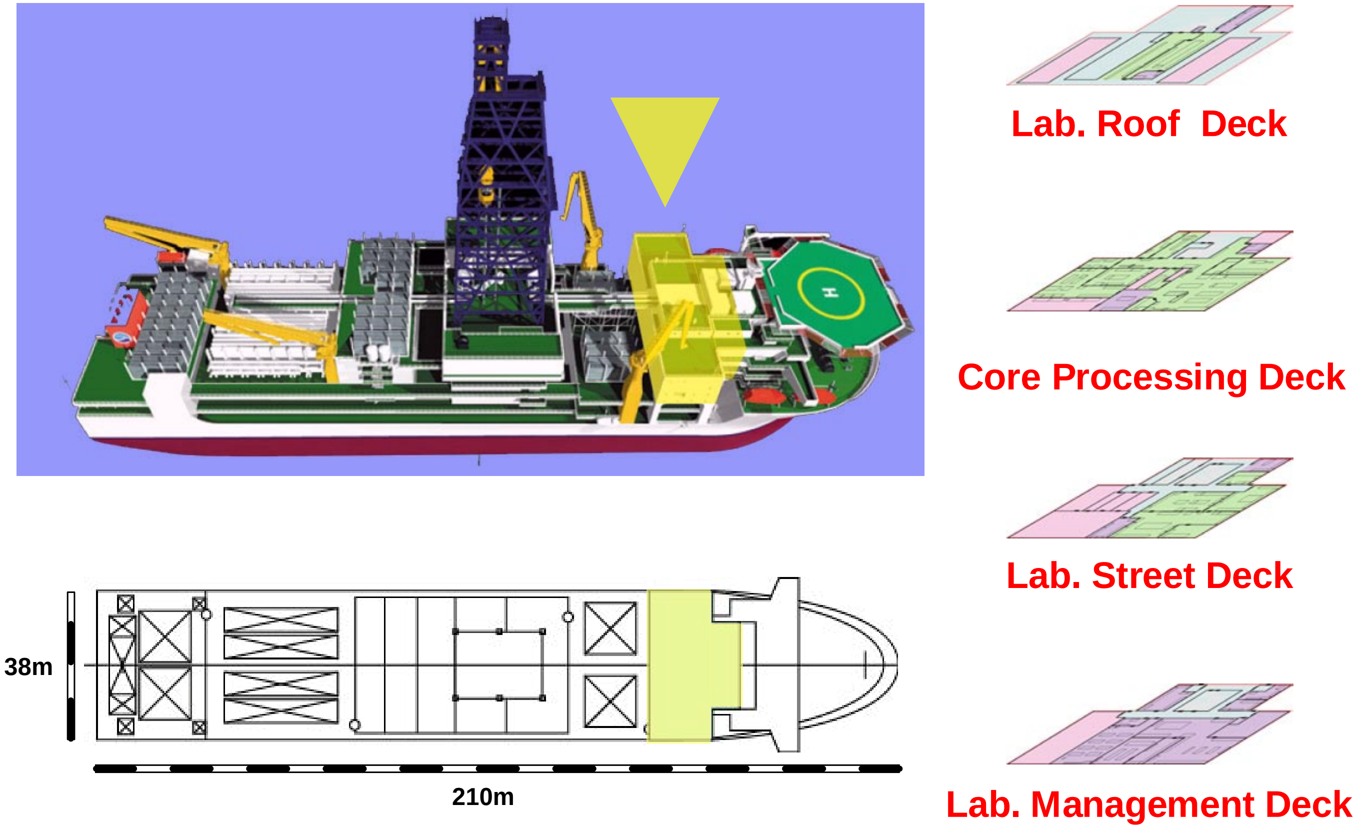
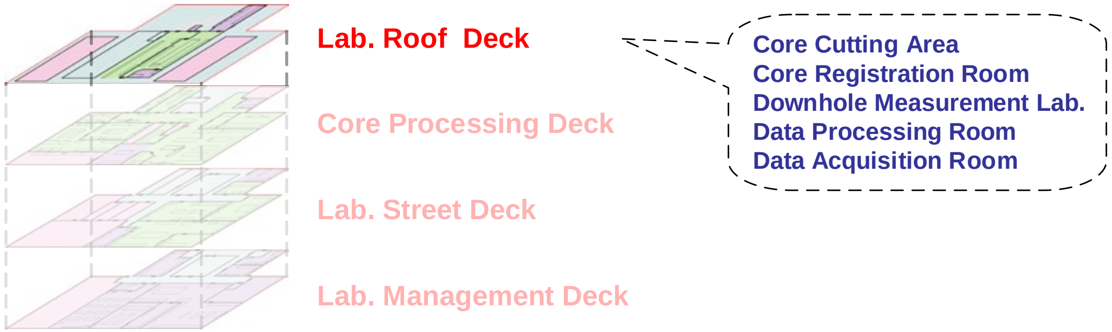


Fig. A1. Location of the four lab facilities decks.



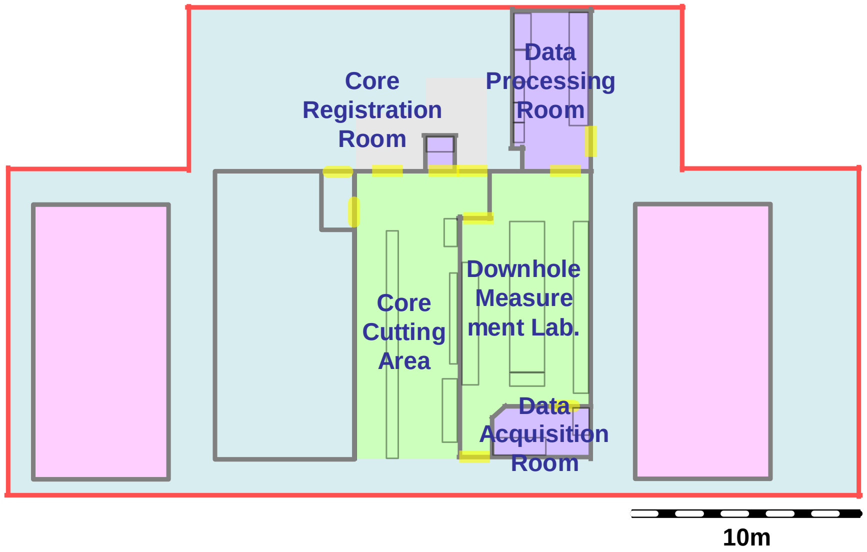


Fig. A2. Layout of the Lab Roof Deck.

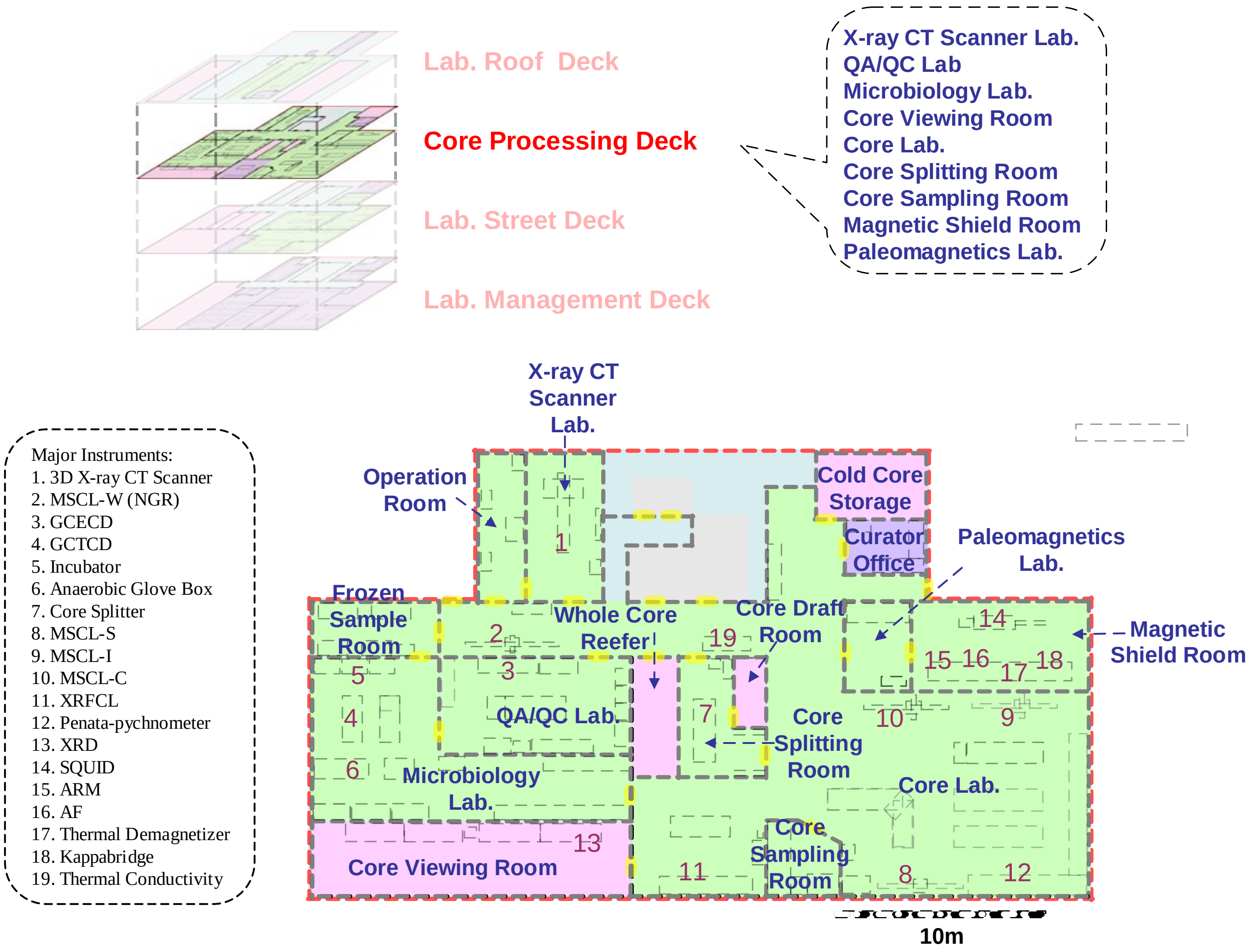


Fig. A3. Layout of the Core Processing Deck.

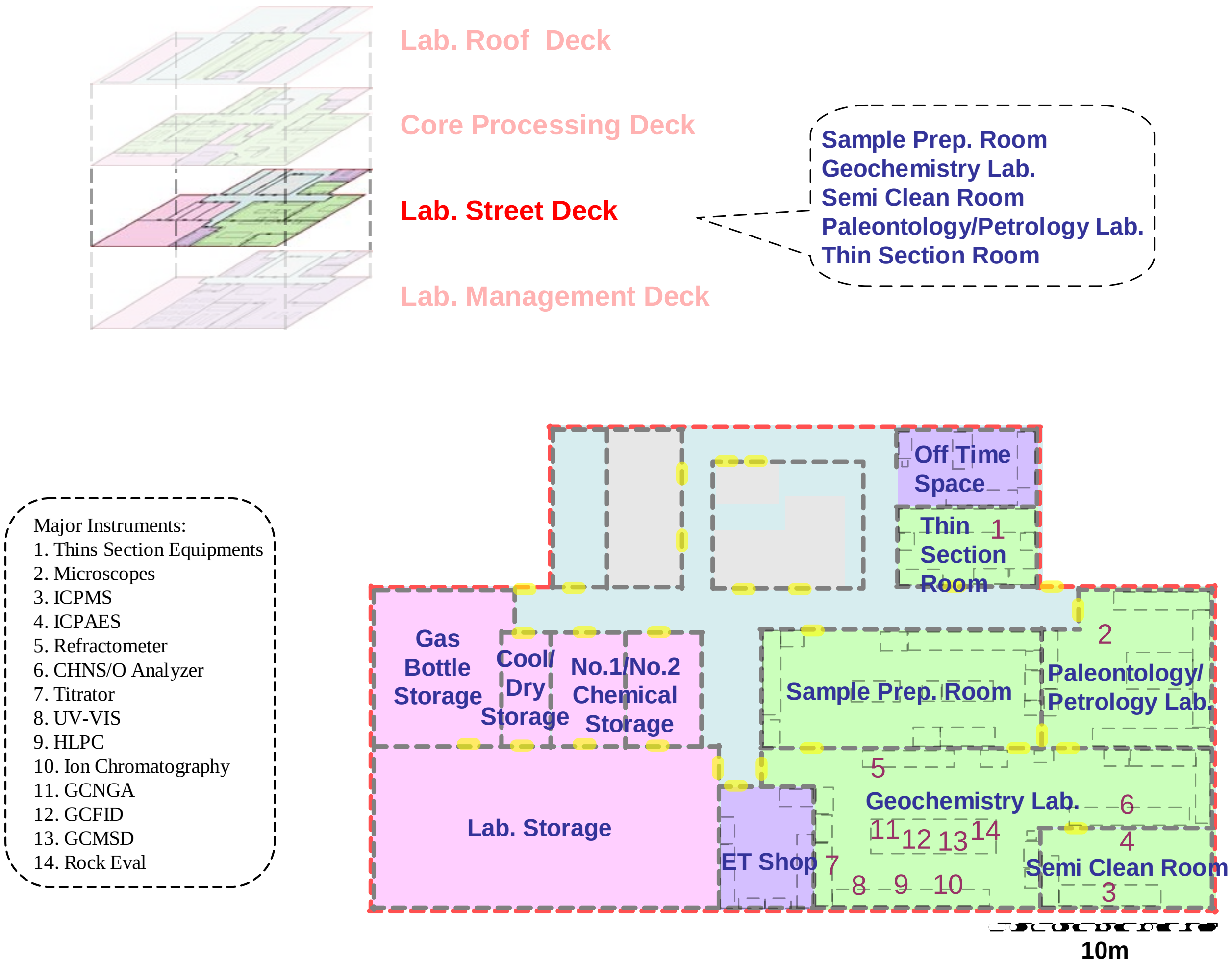


Fig. A4. Layout of the Lab Street Deck.

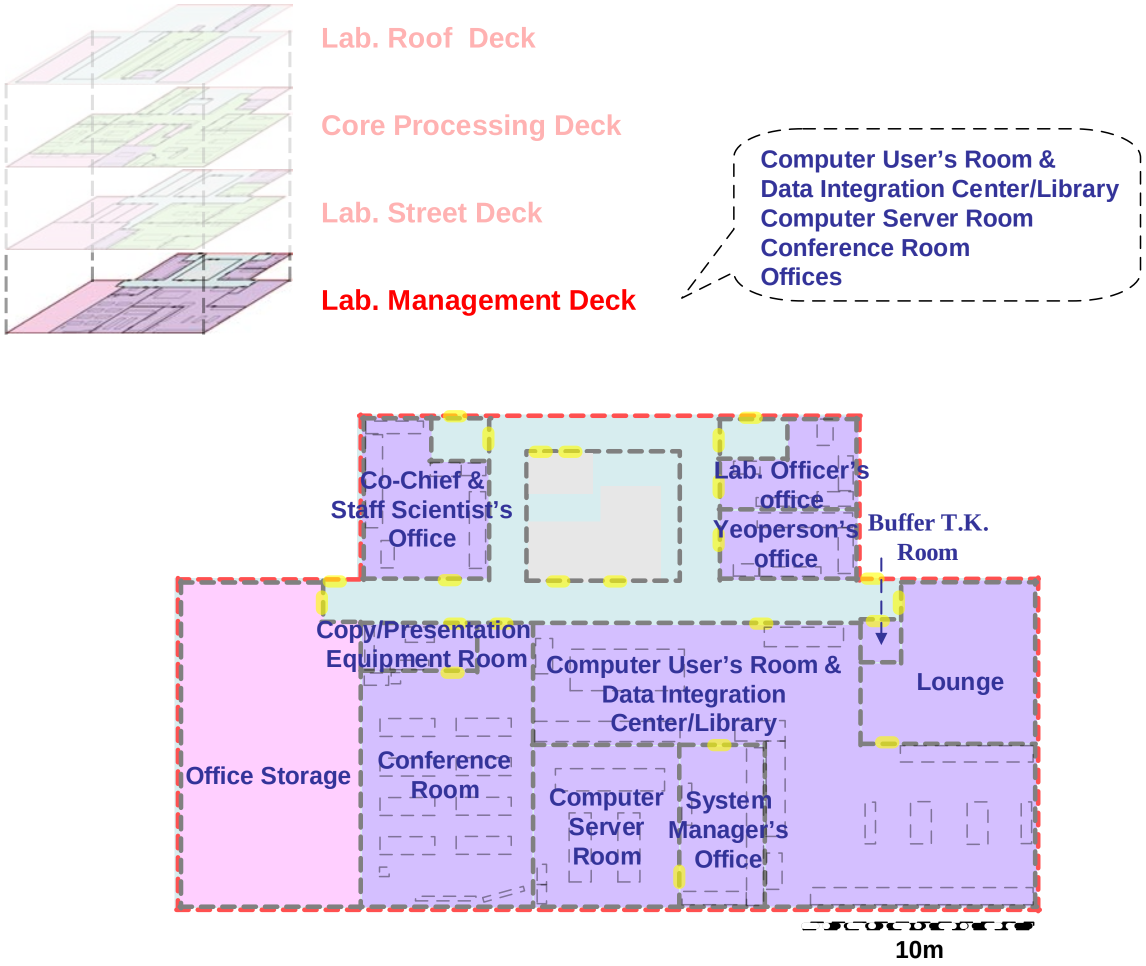


Fig. A5. Layout of the Lab Management Deck.