

IODP Depth Scales Terminology

IODP-MI
April 2011
Version 2.0

Versions

Date (YYYY-MM-DD)	Version	Modifications	Author
2007-06-14	1.0	Original version	Depth Scale meeting participants
2009-07-07	1.1	Updated mud depth scale	CDEX/IODP-MI
2011-04-21	2.0	Version 2.0	IODP Depth Scale Task Force

Table of Content

Introduction 1
Definitions 2
Depth Scale Method Descriptions 4
Driller's Depth Scales 4
Seismic depth 9
Guidelines for usage of IODP Depth Scale Terminology……10

List of Tables and Figures

Figure 1: Relationships between IODP depth scales ……..1
Table 1: IODP depth scales summary ……..…….3
Figure 2: IODP depth scales illustration ……..12
Figure 3: CSF-A ……..13
Figure 4: CSF-A and CSF-B ……..14
Figure 5: Core length changes over time ……...……..15
Image 1: Core expansion ……15
Image 2: Voids in core recovery ….……15
Figure 6: CCSF …...……..16
Figure 7: Default depth scale in IODP publications and reports…….....17
Figure 8: Non-default depth scale in IODP publications and reports…….……...…18
Figure 9: Multiple depth scales in IODP publications and reports…….……...…19

Introduction

The measurement of depth is a central concept for IODP activities. Use of the units meters below sea floor (mbsf) and meters below rig floor (mbrf) in ODP/IODP is inadequate because innovations in the methods by which depth is measured or calculated have progressed. Whereas the traditional units are still allowed in IODP publications, sufficient documentation is needed to explain the differences in meaning and relationship between depth scales.

The reason for documenting the IODP depth scales is to provide scientists data and sample materials with documented units and methods for capturing depth information, so that hey will be able to perform shipboard duties, write reports and understand IODP literature. Use of these depth scales should also support the use of IODP data in depth mappings, analytical software tools, core visualization software and applications.

The issue of depth in IODP(or any other drilling program) is complex. Depth is measured and used in many different ways. Increased documentation of the differences in the relative scales by which we report depth allows cross-correlation and integration (e.g., core, log and seismic correlation) between different data sets that allow greater understanding of the subseafloor. This document addresses the relationships between the different IODP depth scales and their relationship to the legacy system (Figure 1).

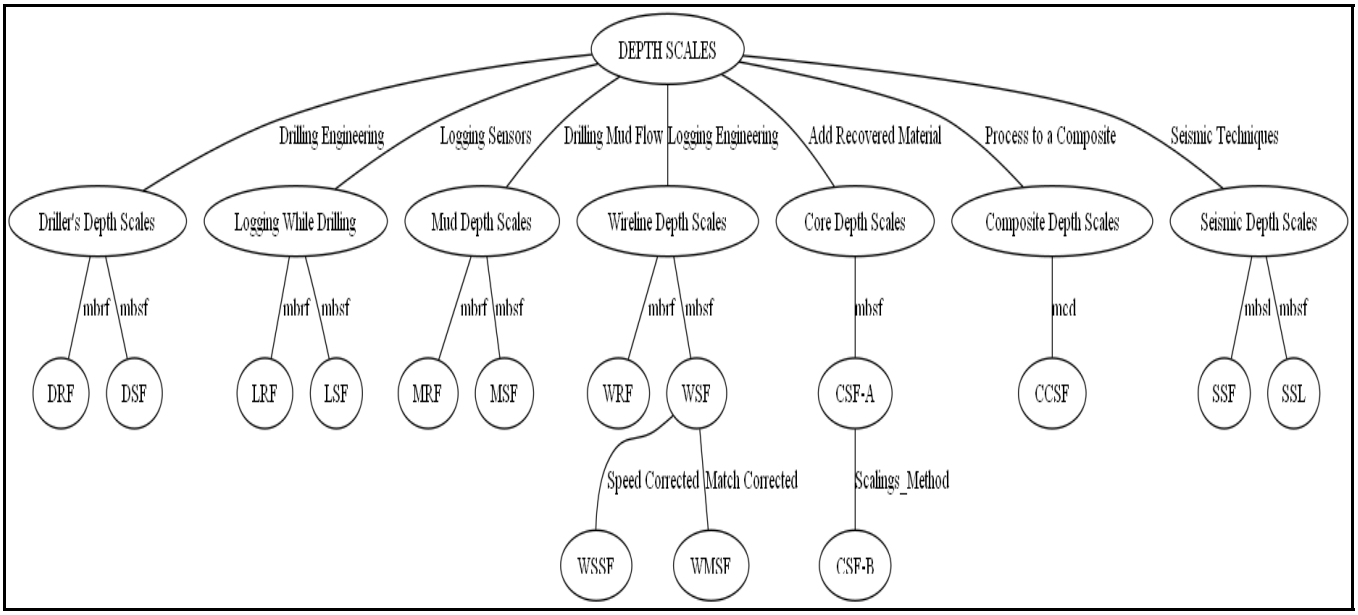


Figure 1: Summary of IODP Depth Scales showing their sources and relationships.

This document presents the sources and magnitudes of errors associated with the different depth scales, the methods by which distances are measured and/or derived, the datum to which the depth is relative, the units in which the distance is measured, and the relationship between the different depth scales.

A all depth scales used in Expeditions must be described in the methods section of each Expedition Report. A Guideline for use of IODP Depth Scale Terminology is available here: http://campanian.iodp.org//Depth_Scale/Guidelines_for_use_of_IODP_Depth_Scale_Terminology.pdf

The depth scales are summarized in Table 1 and Figure 2.

Definitions

Depth: A distance measured on a depth scale, and represented by a numeric value with units specified in its definition. Positive is vertically downward.

Depth scale: is a linear scale defined by the following parameters:

- Datum
- Path (The path for depth scales in this document is "Measured Depth", “Processed Depth”, and “Composite Depth”.)
- Unit of length (The unit of length for all distances in this document is SI units)
- Method/tool by which the scale was created.

Depth map: relates two depth scales to each other, by utilizing a series of paired control points, each pair represents depth values from the FROM scale and the TO scale. Depth values from the FROM depth scale are interpolated between the control points on the TO depth scale. A depth map has the following information associated with it:

- TO scale name (the scale to be used for rendering the data)
- FROM scale name (the scale mapped to the TO scale)
- Method used for associating control points
- Date
- Author(s)

An example of a depth map is meters equivalent logging depth (meld). This depth map is constructed by correlating equivalent physical measurements (e.g., bulk density or natural gamma ray radioactivity) made on cores and in downhole logs.

	Depth Scale Name	Acronym	Datum	Description	Previous Unit	Type
Driller's Depth Scales	Drilling depth below rig floor	**DRF**	Rig floor	The sum of lengths of all drill string components deployed beneath the rig floor. Includes length of all components and the portions thereof below rig floor.	mbrf	Measured depth
	Drilling depth below sea floor	**DSF**	Sea floor	The length of all drill string components between sea floor and target.	mbsf	Processed depth
LWD & Measurements While Drilling (MWD) Depth Scales	LWD depth below rig floor	**LRF**	Rig floor	The sum of lengths of all drill string components deployed beneath the rig floor reference.	mbrf	Measured depth
	LWD depth below sea floor	**LSF**	Sea floor	The length of all drill string components between sea floor and target.	mbsf	Processed depth
Mud Depth Scales	Mud depth below rig floor	**MRF**	Rig floor	The length of all drill string components between where cuttings and gas originate and the rig floor based on lag time of arrival at rig floor and mud pump rate.	N/A	Processed depth
	Mud depth below sea floor	**MSF**	Sea floor	MRF with sea floor depth below rig floor subtracted.	N/A	Processed depth
Wireline Depth Scales	Wireline log depth below rig floor	**WRF**	Rig floor	Length of wireline and sensor offset between the rig floor and the target.	mbrf	Measured depth
	Wireline log depth below sea floor	**WSF**	Sea floor	WRF with sea floor depth below rig floor subtracted.	mbsf	Processed depth
	Wireline log speed-corrected depth below sea floor	**WSSF**	Sea floor	WSF corrected with accelerometer data.	mbsf	Processed depth
	Wireline log matched depth below sea floor	**WMSF**	Sea floor	Depth derived by correlation between reference run and another run to make a set of WSF runs internally consistent.	mbsf	Processed depth
Core Depth Scales	Core depth below sea floor	**CSF-A**	Sea floor	Distance from sea floor to target within Recovered Core. Combines DSF to top of Cored Interval with Curated Section length to target within cored material. This method allows overlap at Cored Interval and Section boundaries.	mbsf	Processed depth
	Core depth below sea floor	**CSF-B**	Sea floor	Distance from sea floor to target within recovered core. Combines DSF to top of cored interval with curated length to target within cored material. This method applies compression algorithm (i.e., scaling) if recovery is above 100%.		Processed depth
Composite Depth Scales	Core composite depth below sea floor	**CCSF**	Sea floor	Distance from sea floor to target within recovered core using a scale of adjusted depths constructed to resolve gaps in the core recovery and depth inconsistencies.	mcd	Composite depth

Seismic Depth Scales	Seismic Depth Below Sea Floor	**SSF**	Sea floor	Distance below sea floor and target derived from seismic travel time, velocity, and water depth.	m	Processed depth
	Seismic Depth Below Sea Level	**SSL**	Sea level	Distance below sea level derived from seismic travel time and velocity.	m	Processed

Table 1: IODP depth scales summary table.

Depth Scale Method Descriptions

Driller's Depth Scales

This method is based on the driller's determination of length of all drill string components lowered below the rig floor.

Drilling depth below Rig Floor (DRF)

Example: Pipe tally and visual estimate of length of portion of pipe below rig floor.

Sources of Error: Driller's estimate; pipe and bottom hole assembly (BHA) stretch (elastic stretch, temperature, weight on bit, pump-off, differential pressure, hydrostatic, annulus viscous drag, nozzle thrust, torque) and compression; deviation from vertical; tides and uncompensated heave.

Methods of Correction: ROV to correct for pipe catenary; future correction methods could include pressure transducer on mudline core barrel.

Magnitude of Uncertainty: Meters

Drilling depth below Sea Floor (DSF)

Based on subtraction of sea floor depth from DRF. The sea floor depth is determined by one of the methods below:

- Tag sea floor: contact of drill string with sea floor as determined by increase in weight on bit (WOB);
- Mudline core: length of recovered mudline piston core is subtracted from rig floor measurement by DRF;
- Visual control: visual observation of tag sea floor with camera or ROV;
- Inherited depth: assume seafloor depth from previous nearby hole.

Sources of Error: Same as DRF; stiffness of seafloor material, recovery or loss of material; condition of seafloor and ROV/camera depth; accuracy of inherited depth.

Methods of Correction: Same as DRF

Magnitude of Uncertainty: Meters

Logging While Drilling (LWD) and Measurements While Drilling (MWD) Depth Scales

These methods measure *in situ* formation properties with instruments that are located in the drill collars immediately above the drill bit. Measurements are made shortly after the hole is cut and before it is adversely affected by continued drilling or coring operations.

LWD and MWD depth below Rig Floor (LRF)

Example: draw work encoder measures location of traveling block which is combined with pipe tally and sensor offsets

Sources of Error: Same as DRF

Methods of Correction: Same as DRF

Magnitude of Uncertainty: Decimeters internal to the data set; meters absolute relative to sea floor.

LWD and MWD depth below Sea Floor (LSF)

Based on subtraction of sea floor depth from DRF. The sea floor depth is determined by one of the methods described in DSF or by using a reference logging measurement (e.g., the step change in natural gamma ray radioactivity at the seafloor).

Sources of Error: Same as LRF and magnitude of sea floor depth uncertainty.

Methods of Correction: Same as DSF; comparison of multiple sea floor depth measurements.

Magnitude of Uncertainty: Decimeters internal to the data set; meters absolute relative to sea floor.

Mud Depth Scales

Mud logging is the process of collecting, analyzing and recording the cuttings, fluids, and gasses brought to the surface by the drilling fluid (mud).

Mud depth below Rig Floor (MRF)

Derived from estimating lag time between generation of cuttings/fluids/gases at the bit and their arrival on rig floor, and associating the lag time with the drill bit depth (lag depth).

Sources of Error: Same as DRF; borehole condition; engineering uncertainties.

Methods of Correction: Same as DRF; the travel time from drill bit to rig floor can be calibrated by the use of tracers.

Magnitude of Uncertainty: Meters

Mud depth below Sea Floor (MSF)

Similar to the conversion from DRF to DSF, subtract the distance between rig floor and sea level from an estimate of sea floor depth at the Mud depth below rig floor scale using one of the techniques described in DSF.

Sources of Error: Same as DSF and MRF and magnitude of sea floor depth uncertainty.

Methods of Correction: Same as DSF and MRF; the travel time from drill bit to rig floor can be calibrated by the use of tracers.

Magnitude of Uncertainty: Meters

Wireline Depth Scales

This method is based on the wire length between downhole sensor and rig floor.

Wireline log depth below Rig Floor (WRF)

Example: Length of wireline from rig floor to top of tool plus distance from top of tool to sensor.

Sources of Error: Sea state; uncompensated heave; wireline stretch; downhole tool motion (e.g. stick and slip).

Methods of Correction: Use of wireline heave compensator; correction for computed stretch of cable (already applied in Schlumberger software I think, but would be worth checking); depth matching to a reference run;

tool speed corrections.

Magnitude of Uncertainty: Meters

Wireline log depth below Sea Floor (WSF)
Example: Length of wireline from sea floor to top of tool plus distance from top of tool to sensor. Sea floor can be determined from the step in wireline natural gamma radiation signal at the sea bed, from step in the logs at the bottom of casing, or, where a log determination is unavailable, from using techniques under DSF.

Sources of Error: Same as WRF; plus magnitude of sea floor depth uncertainty.

Methods of Correction: Wireline speed corrections, when applied this becomes **WSSF**Same as WRF; comparison of multiple sea floor depth measurements.

Magnitude of Uncertainty: Meters

Wireline log Speed-corrected depth below Sea Floor (WSSF)
This is WSF with wireline speed corrections applied. Used for high-resolution logs such as microresistivity (FMS).

Sources of Error: Same as WSF; correction errors.

Methods of Correction: Correction for irregular motion of the tool during logging using accelerometer data; used for high-resolution logs such as microresistivity (FMS).

Magnitude of Uncertainty: Typically tens of centimeters internal to the data set; meters absolute relative to sea floor

Wireline log Matched depth below Sea Floor (WMSF)
This is a depth scale derived using a reference data set (typically the logging pass with the longest depth extent or most reliable sea-floor) to match depths from other data sets from the same or related holes.

Sources of Error: Same as WSF; reference log errors; number or type of tie points used for correlation.

Methods of Correction: Depth matching of common log features between a specific set of logging data and the reference set.

Magnitude of Uncertainty: Tens of centimeters internal to the data set; meters absolute relative to sea floor

Core Depth Scales

These methods are based on the curated lengths of Core recovered and drilling depth (DSF).
The standard practice is to place the top of the recovered core at the top depth of the Cored Interval and place all recovered material below that top (including the core catcher), so that the non-recovered interval is placed at the bottom of the cored interval.

Definitions:
Cored Interval: The advance made by the drill string components in the attempt to drill a Core.

Recovered Core: The length of recovered material measured before sectioning.

Section length: The length of each subdivision of recovered core, made on catwalk. Generally 1.5m.

Curated Section length: Includes core expansion and re-spacing of rock pieces in cores. May be more than 1.5m.

Core depth below Sea Floor-A (CSF-A)

Distance from sea floor to target within Recovered Core. Combines DSF to top of Cored Interval with Curated Section length to target within cored material. This method allows overlap relative to Cored Interval and Section boundaries. See Figure 3.

Sources of Error: Same as DSF; incomplete recovery; core expansion/contraction as a result of elastic rebound and gas expansion (see Figure 4); core explosion; curatorial processing effects; engineering errors; drilling disturbance. See Figure 4.

Methods of Correction: Same as DSF. Comparisons with other data sets.

Magnitude of Uncertainty: Centimeters to meters.

Core depth below Sea Floor-B (CSF-B)

Distance from sea floor to target within Recovered Core. Combines DSF to top of Cored Interval with Curated Section length to target within Recovered Core. This method applies a compression algorithm (i.e., scaling) if recovery >100%. This method does not allow overlap of Recovered Core with adjacent Cored Intervals. See Figure 5.

Sources of Error: Same as CSF-A; scaling errors. See Figure 4 and Images 1 and 2.

Methods of Correction: Same as CSF-A.

Magnitude of Uncertainty: Centimeters to meters.

Core Composite Depth Scale

Distance from sea floor to target within Recovered Core using a scale of adjusted depths constructed to resolve gaps in the core recovery and depth inconsistencies. This method is based on the curated lengths of Core recovered Sections and drilling depth (DSF). Composite Core Depth Scales must include reference to author and date of creation. See Figure 6.

This method typically uses CSF-A as a baseline depth scale. Typical shipboard construction of a composite scale consists of shifting cores based on correlation of high-resolution core logging data from multiple, adjacent holes (Figure 6). Other sub-methods may be used such as scaling or appending cored intervals, or correlation of core data to equivalent downhole logging data. The process of composite scale construction is to some degree subjective and these scales must therefore include reference to author and date of creation.

Core Composite depth below Sea Floor (CCSF)
Examples: Append if long; scale by factor; correlate features; splice.

Sources of Error: Same as CSF-A and/or CSF-B; errors in transformation choices; interpretation errors; correlation errors.

Methods of Correction: Create new CCSF based on more correlation points, correlation to downhole logs. Revised Matched Composite Depth.

Magnitude of Uncertainty: Centimeters to meters.

Seismic depth

This method is based on the time traveled by seismic waves, converted to a depth based on velocity. Seismic depth scales must include reference to author and date of creation.

Seismic depth below Sea Level (SSL)
Distance below sea level derived from seismic travel time and velocity.

Sources of Error: Algorithm errors; velocity uncertainty; sampling frequency; wave frequency.

Methods of Correction: Core log (and core data) and core log seismic integration for seismic modeling (synthetic seismogram); check shot for interval velocity.

Magnitude of Uncertainty: Meters to hundreds of meters

Seismic depth below Sea Floor (SSF)
Distance below sea floor and target derived from seismic travel time, velocity, and water depth.

Sources of Error: Same as SSL; sea floor reflection picking.

Methods of Correction: Same as SSL; borehole data referenced to depth.

Magnitude of Uncertainty: Meters to hundreds of meters

Guidelines for usage of IODP Depth Scale Terminology in Integrated Ocean Drilling Program Reports and Publications

This section of the provides guidelines for Implementing Organizations and Science Party members on the use of IODP Depth Scale Terminology in scientific reports and publication series to be produced by the Integrated Ocean Drilling Program (IODP). Description of IODP scientific reports and publication series can be found in the Statement of IODP Publications and Reports (http://www.iodp.org/index.php?option=com_docman&task=doc_download&gid=583).

The following guidelines apply to use of the IODP Depth Scale Terminology available at the IODP Program Policies, Procedures and Guidelines web page (http://www.iodp.org/program-policies/2/).

The intent of these guidelines is to contribute accurate descriptions of the methods by which depths are determined for IODP Expeditions while maintaining an intuitively understandable terminology within IODP publications. The IODP Depth Scale Terminology document explains the methods by which depth is measured or calculated, the differences in meaning and relationship between depth scales, the units in which depths are recorded, and the abbreviation of units used in IODP databases, depth mappings, analytical software tools, and visualization software.

The following guidelines apply to all IODP publications and reports:

1) A detailed description of the depth scales used during operations and data collection must be presented in the Methods section of reports and publications. The description in the Methods section should include designation of default depth terminology for use in the publication or report, to be used in all cases where depth was determined using the specified method.

2) The terms “meters below seafloor” or “meters below rig floor” and abbreviations “mbsf” and “mbrf” should be used throughout the report or publication in both text and figures where the depth being referenced was determined using the depth scale specified as the default depth scale for that report or publication in the Methods section.

3) If depth being referenced was not determined using the depth scale specified as the default depth scale for that report or publication, the abbreviation of the actual method should be used in both text (e.g., 12.34 m CCSF) and figure labels (e.g., Depth CCSF (m)).

4) The relationship between the default depth scale and the depth scale used in more specific investigations should, where possible, be clearly documented in the Methods section (e.g., the relationship between “mbsf” and “CCSF” as used in 3) above). If it is not possible to establish such a relationship, this should be stated in the Methods section.

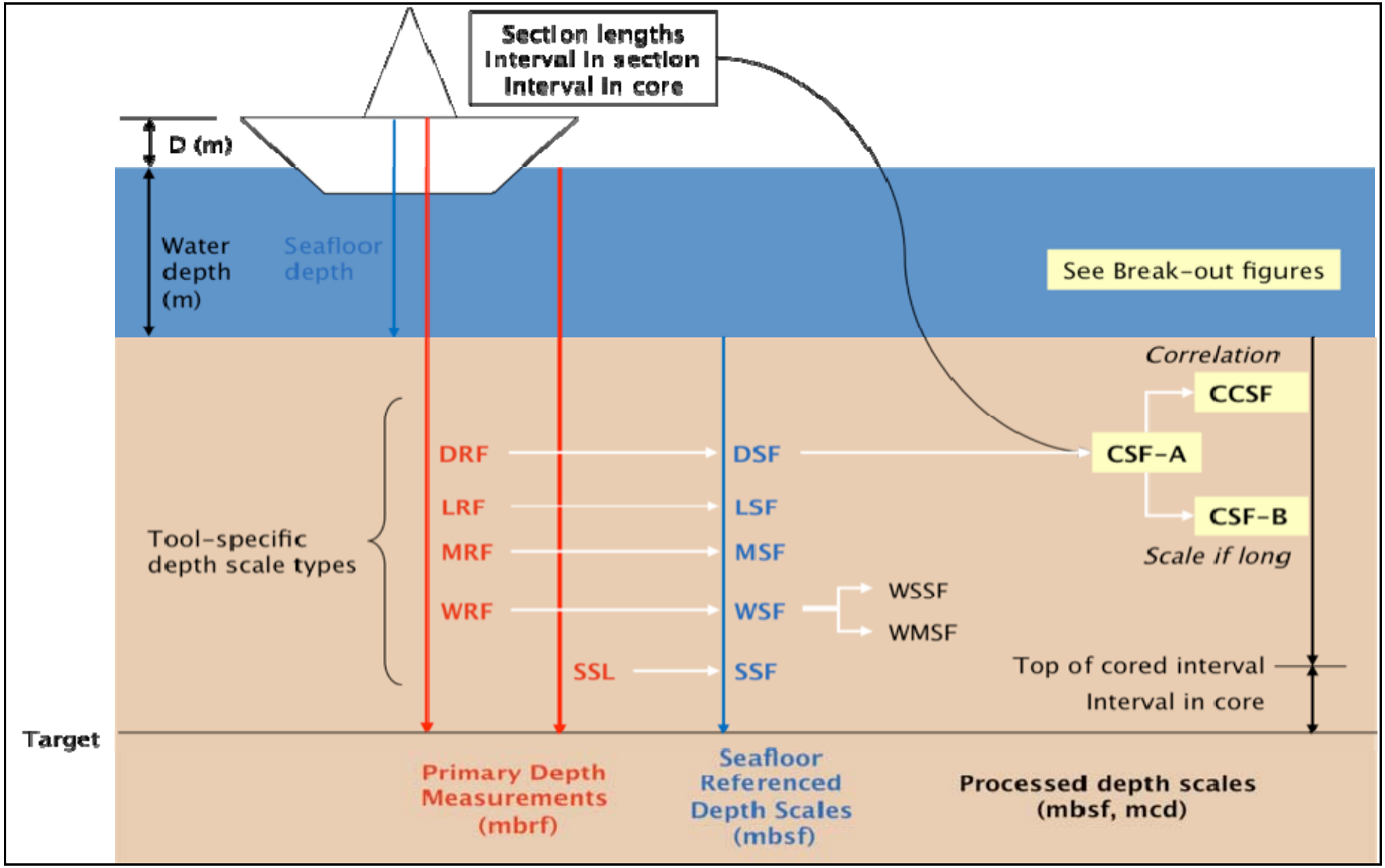


Figure 2: IODP Depth Scales illustrated schematic

(DRF=Drilling depth below rig floor; LRF=LWD depth below rig floor; MRF=Mud depth below rig floor; WRF= Wireline log depth below rig floor; DSF=Drilling depth below sea floor; LSF=LWD depth below sea floor; MSF=Mud depth below sea floor; WSF=Wireline log depth below seafloor; WSSF=Wireline log speed corrected depth below sea floor; WMSF=Wireline log matched depth below sea floor; SSL=Seismic depth below sea level; SSF=Seismic depth below sea floor; CSF-A= Core depth below sea floor-A; CCSF=Core composite depth below sea floor; CSF-B=Core depth below sea floor-B.

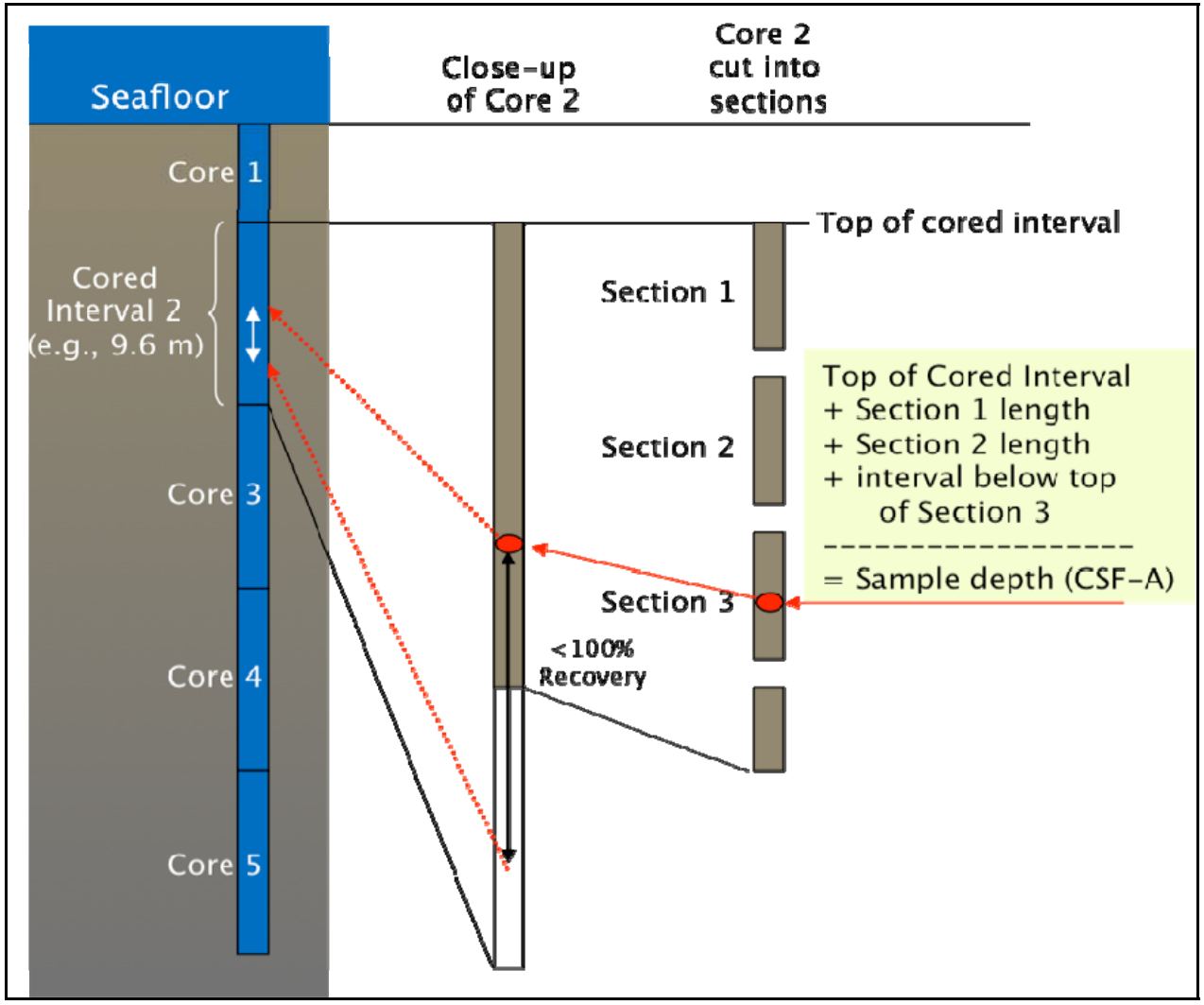


Figure 3: Core depth below Sea Floor-A (CSF-A) is the standard practice for calculating sample depth.. The red dot represents a sample taken from a core section. Vertical arrows indicate sample depth error component based on incomplete recovery. A. Subseafloor section with cored intervals from which recovered cores were removed. B. Recovered core from cored interval 2, with incomplete recovery. By convention, the top of recovered core is placed at top of cored interval (curated depth). C. Sections cut from the core and used for further sub-sampling, with the computation for sample depth.

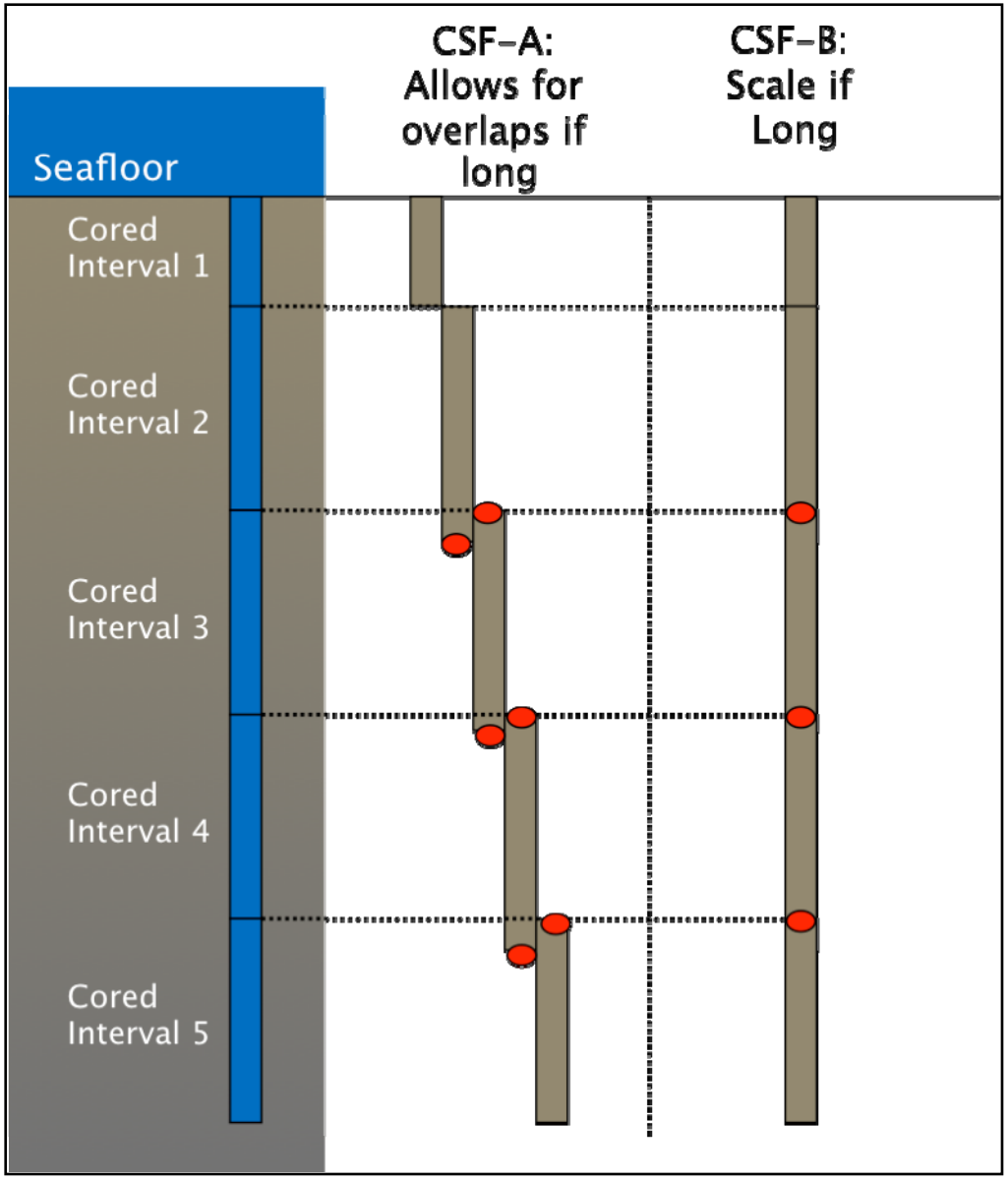


Figure 4: The Core depth below Sea Floor-B (CSF-B.) scale presents a solution for situations where recovered cores overlap at the CSF-A scale. With the APC, it is common to achieve a nominal recovery of >100% as a result of core expansion due to elastic rebound and gas expansion. This expansion creates apparent overlaps and stratigraphic reversals when data are plotted at the CSF-A scale, as illustrated with red dots. CSF-B scales the core lengths if nominal recovery >100%. CSF-B is mainly useful for data presentation purposes.

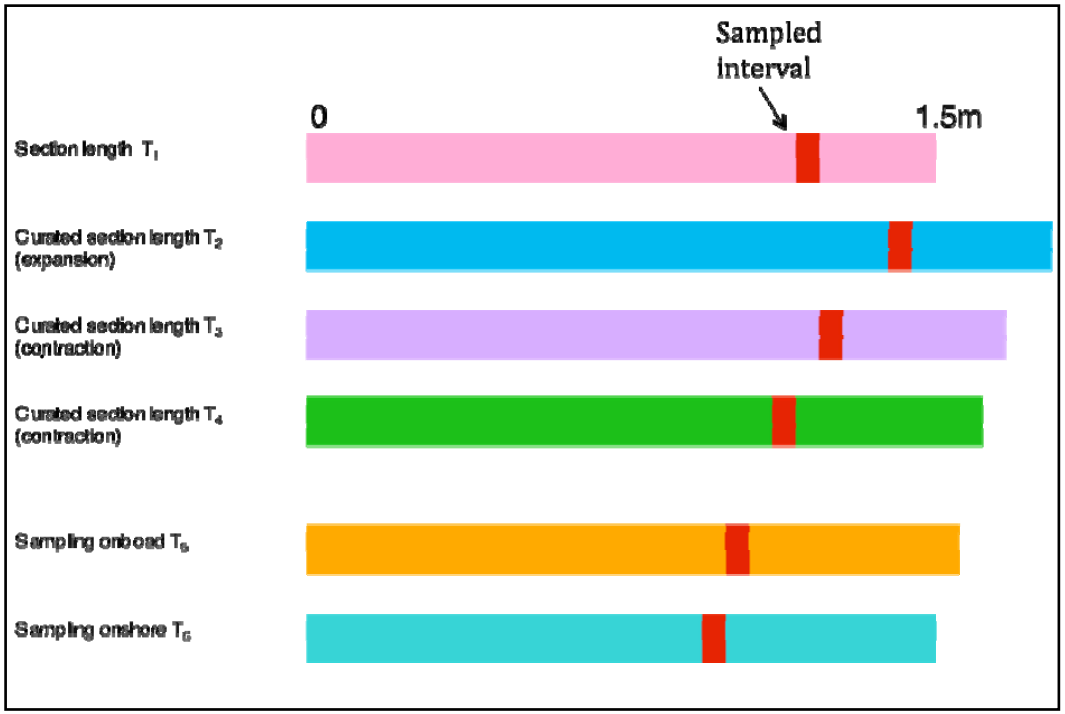


Figure 5: Schematic representation of section length changes over time and the relative position of a sampled interval as a result of the changes. The change in depth as a result of this material expansion is not being compensated or corrected for, it is part of the overall depth error.



Image 1: Core expansion.

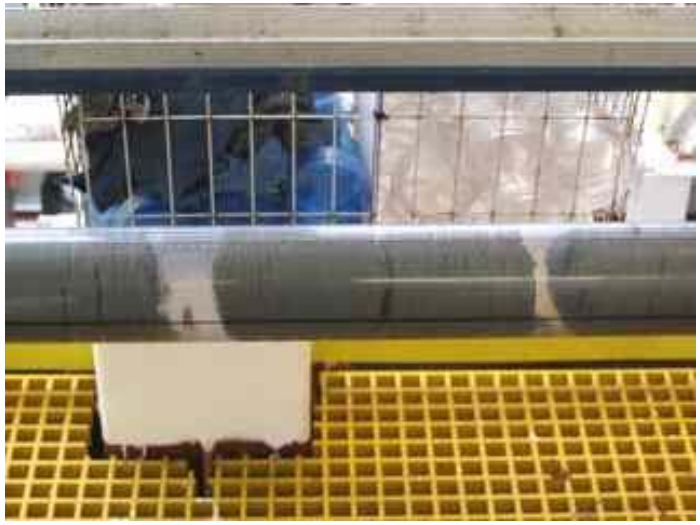


Image 2: Voids in core recovery.

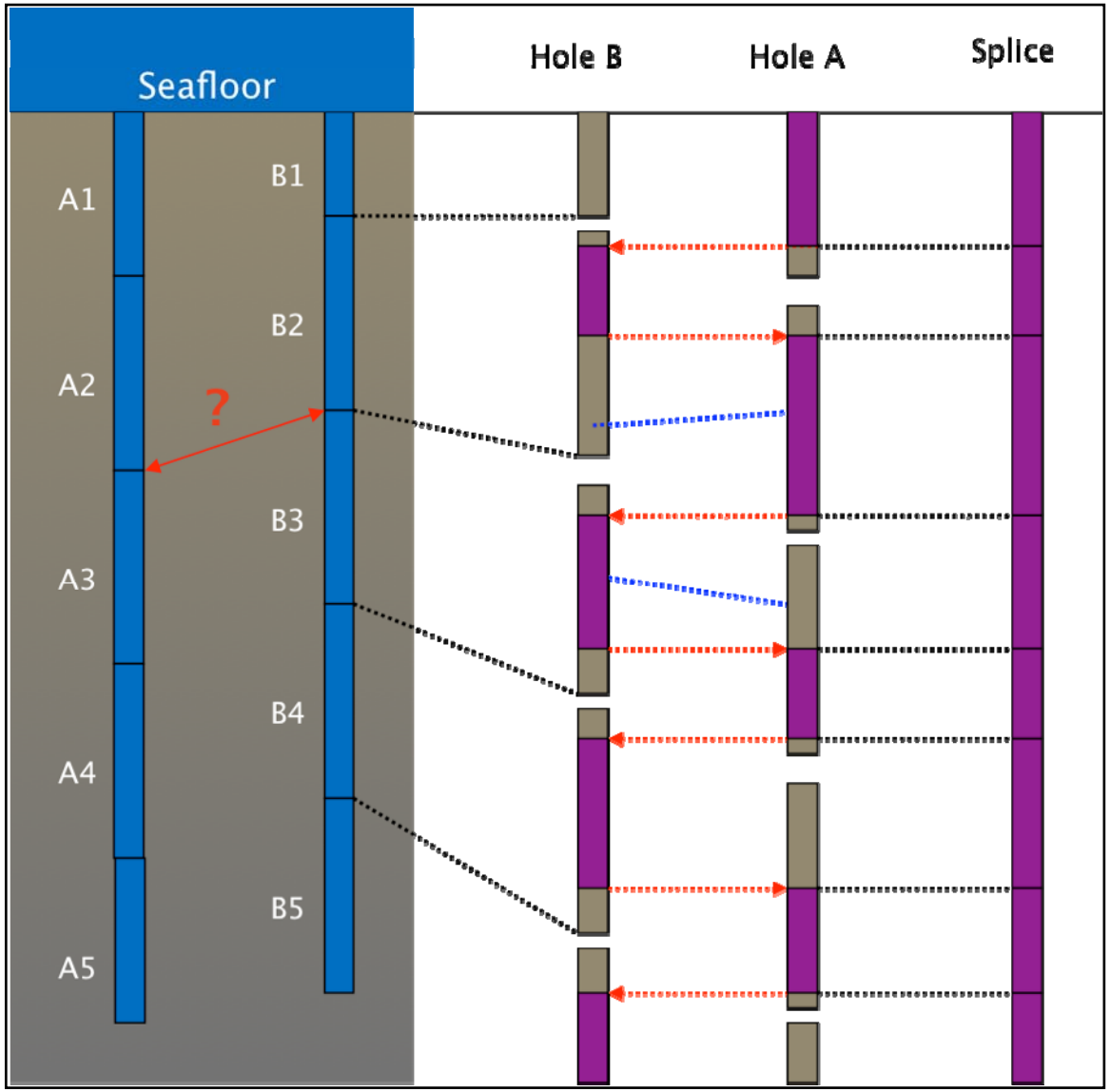


Figure 6: Core composite depth below sea floor (CCSF) scales are constructed based on correlation of data associated with recovered cores from multiple holes from a given site (for example Holes A and B with cored intervals 1-5). Brown and purple intervals represent recovered core. Purple intervals from Holes A and B are selected by the correlator to form a spliced complete stratigraphic section. Red dashed lines indicate tie points between two cores allowed in the standard shipboard procedure. Blue dashed lines indicate stratigraphic features that do not align due to differential stretching and squeezing of core material.

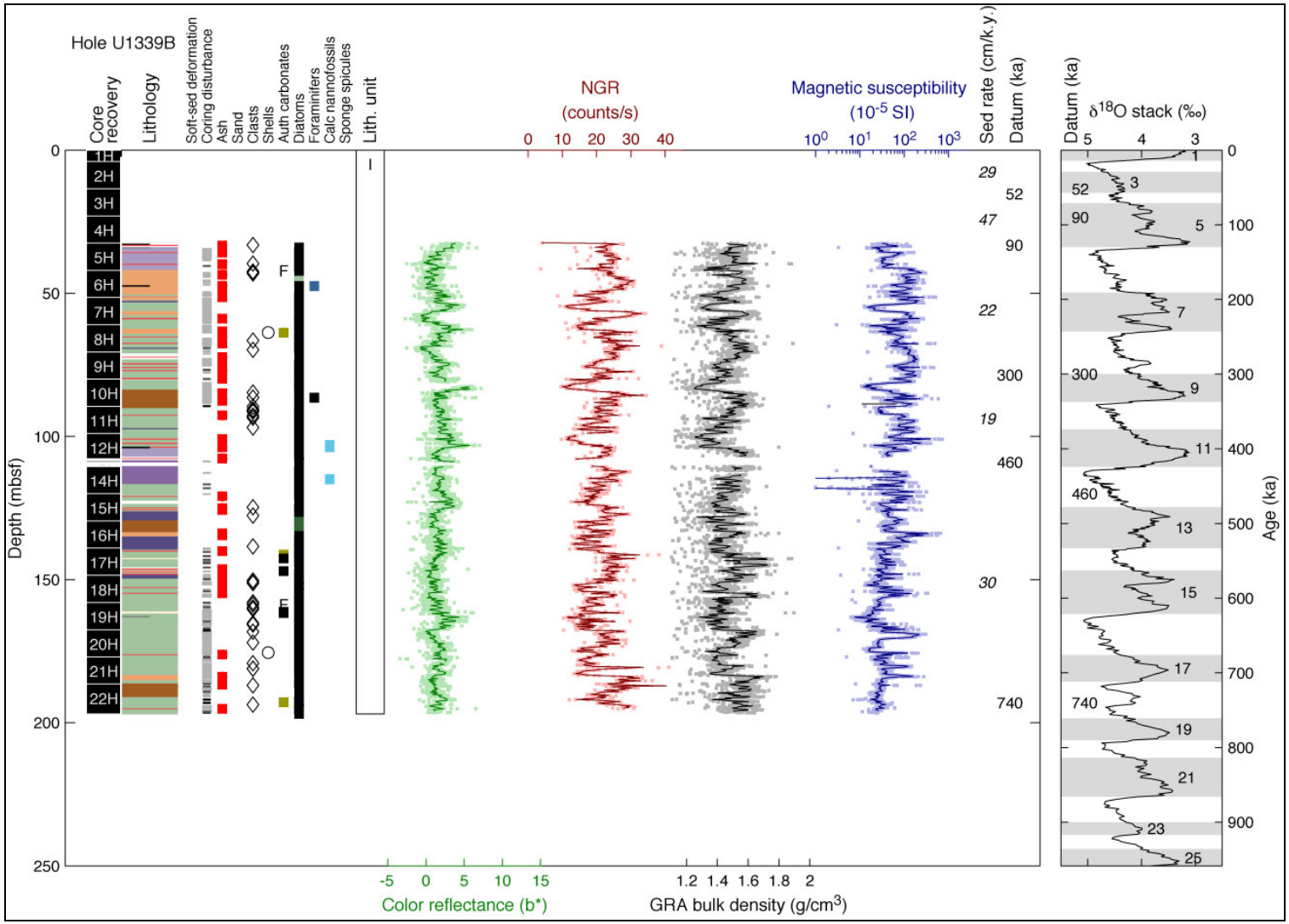


Figure 7: Figure from IODP Publication illustrating use of default depth scale labeled as mbsf in IODP publications and reports.

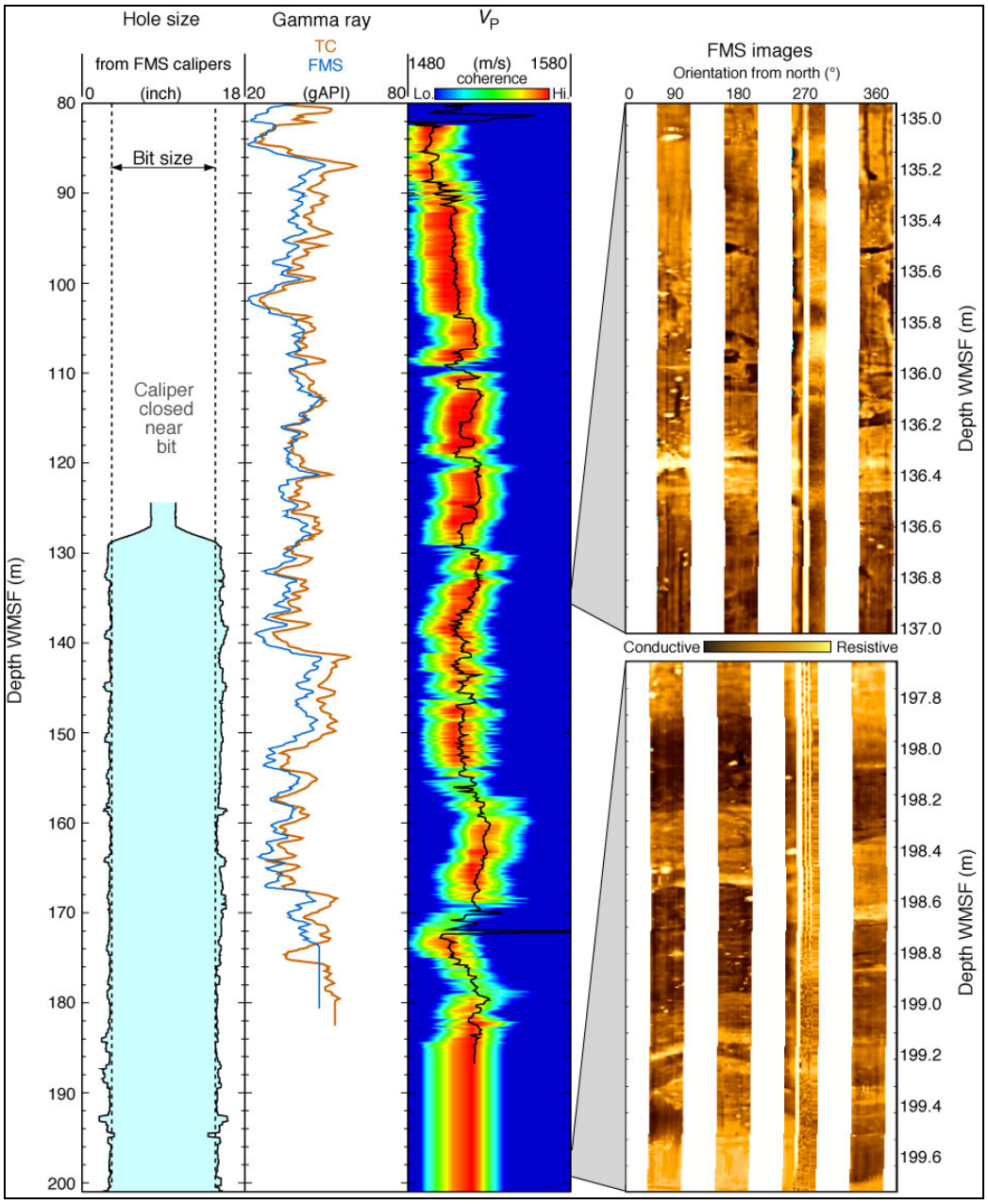


Figure 8: Figure from IODP Publication illustrating use of non-default depth scale, Wireline Log Matched Depth below Sea Floor (WMSF), in IODP publications and reports.

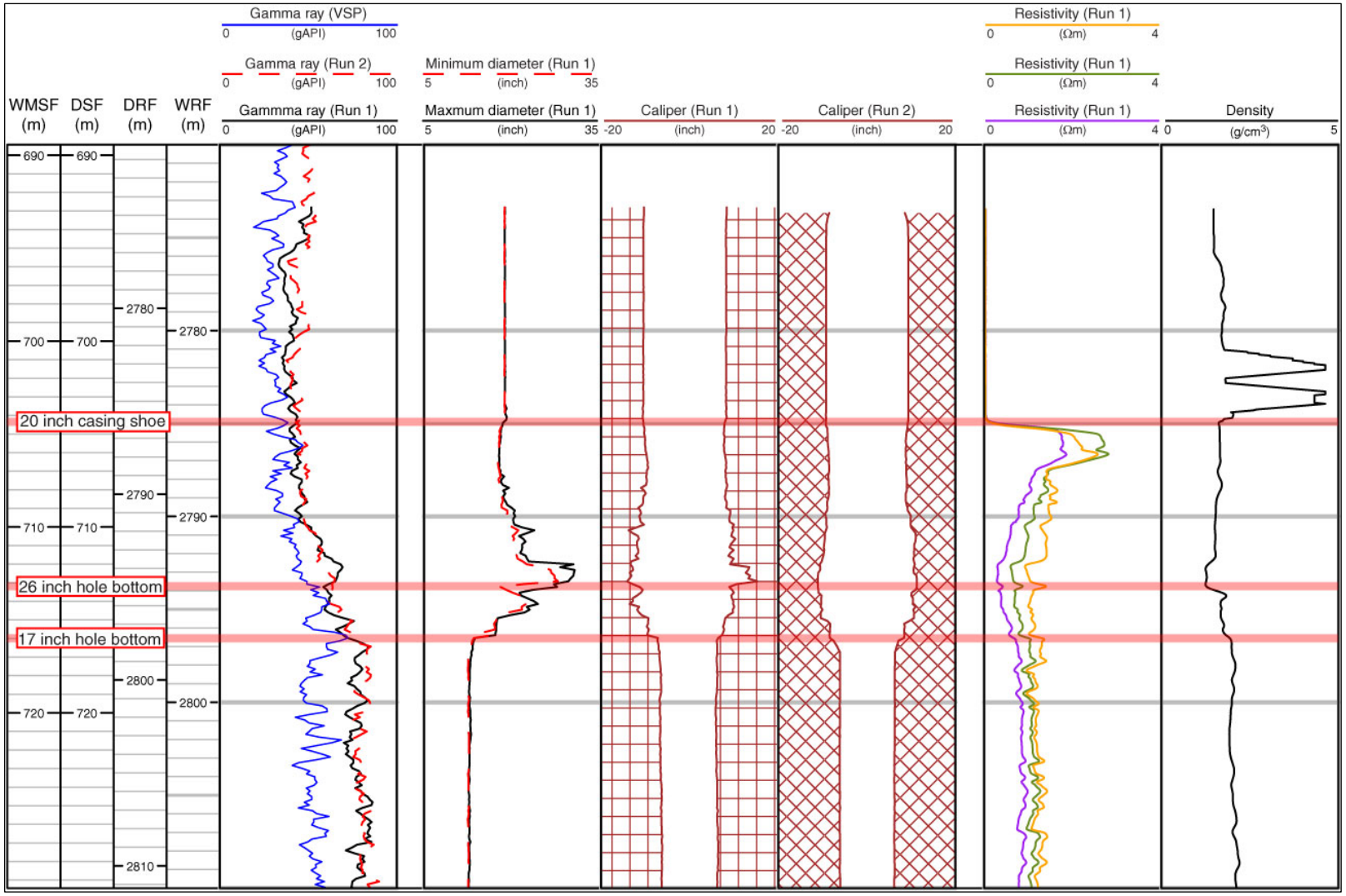


Figure 9: Figure from IODP Publication illustrating use of multiple depth scales in IODP publications and reports.

References

IODP-MI, 2007. IODP Depth Scale Terminology version 1.1.
http://campanian.iodp.org//Depth_Scale/IODP_Depth_Scale_Terminology_1.1.pdf

IODP-MI, 2011. Guidelines for use of IODP Depth Scale Terminology in IODP Publications.
http://campanian.iodp.org//Depth_Scale/Guidelines_for_use_of_IODP_Depth_Scale_Terminology.pdf

Blum, Peter, 2003. Depth Types and Depth Units in the IODP, An ODP Legacy Memo.
http://campanian.iodp.org/Depth_Scale/USIO_iodp_depth_types.pdf