

# 7. REFLECTANCE SPECTROPHOTOMETRY AND COLORIMETRY

## 7.1. Principles

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### PHYSICAL BACKGROUND

Color is the human eye's perception of reflected radiation in the visible region of the electromagnetic spectrum (400–700 nm). It originates from electromagnetic energy changes in electron orbitals, caused by the absorption of photons, in the transition elements contained in the crystal structure of minerals (e.g., Burns, 1970).

One of the most objective ways to measure color is to use diffuse-reflected spectrophotometry. Light reflected from the material is collected in an integration sphere, normalized to the source light of the reflectance, and calibrated with the measurement of a pure white standard (100% reflection) and a black box (zero reflection) over the entire wavelength spectrum of visible light. For material studies, near-ultraviolet (250–400 nm) and near-infrared (700–850 nm) have been shown to be useful.

Reflectance spectra are related to color using established international conventions. According to the Commission Internationale d'Eclairage (CIE) (1986) method, tristimulus values are derived from the color reflectance spectra as follows:

For 2° standard observer (CIE, 1931) and  $400 \leq \lambda \leq 700$  (nm): (1)

$$X = K \sum S(\lambda) x(\lambda) R(\lambda), \quad (2)$$

$$Y = K \sum S(\lambda) y(\lambda) R(\lambda), \quad (3)$$

$$Z = K \sum S(\lambda) z(\lambda) R(\lambda), \quad (4)$$

$$K = 100 / \sum S(\lambda) y(\lambda). \quad (5)$$

For 10° standard observer (CIE 1964) and  $400 \leq \lambda \leq 700$  (nm): (6)

$$X_{10} = K \sum S(\lambda) x_{10}(\lambda) R(\lambda), \quad (7)$$

$$Y_{10} = K \sum S(\lambda) y_{10}(\lambda) R(\lambda), \quad (8)$$

$$Z_{10} = K \sum S(\lambda) z_{10}(\lambda) R(\lambda), \quad (9)$$

$$K = 100 / \sum S(\lambda) y_{10}(\lambda), \quad (10)$$

where  $\lambda$  is the wavelength at a 10-nm pitch;  $S(\lambda)$  is the relative spectral power distribution of the illuminant;  $x(\lambda)$ ,  $x_{10}(\lambda)$ ,  $y(\lambda)$ ,  $y_{10}(\lambda)$ ,  $z(\lambda)$ , and  $z_{10}(\lambda)$  are color-matching functions; and  $R(\lambda)$  is the spectral reflectance of the specimen.

Several color spaces have been defined based on the tristimulus values X, Y, Z, such as the Yxy, L\*a\*b\* and its derivative L\*C\*H°, Lab, and L\*u\*v\* systems. The L\*a\*b\* system is presented here in more detail, and its use is recommended for sediment and rock color analyses. It is far superior to and therefore supersedes the Munsell color system traditionally used in earth science.

### The L\*a\*b\* Color System

The L\*a\*b\* system is also referred to as the CIELAB system. It can be visualized as a cylindrical coordinate system in which the axis of the cylinder is the lightness variable  $L^*$ , ranging from 0% to 100%, and the radii are the chromaticity variables  $a^*$  and  $b^*$ . Variable  $a^*$  is the green (negative) to red (positive) axis, and variable  $b^*$  is the blue (negative) to yellow (positive) axis.

The variables are defined as follows (CIE, 1986; related references: ASTM, 1985a; ASTM, 1985b; ISO, 1984; DIN, 1980):

- If  $(X/X_n), (Y/Y_n), (Z/Z_n) > 0.008856$ :
 
$$L^* = 116(Y/Y_n)^{1/3} - 16, \quad (11)$$

$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}], \quad (12)$$

$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]. \quad (13)$$

- If  $(X/X_n), (Y/Y_n), (Z/Z_n) < 0.008856$ :
 
$$L^* = 903.29(Y/Y_n), \quad (14)$$

$$a^* = 500\{7.787[(X/X_n) + 16/116] - 7.787[(Y/Y_n) + 16/116]\}, \quad (15)$$

$$b^* = 200\{7.787[(Y/Y_n) + 16/116] - 7.787[(Z/Z_n) + 16/116]\}, \quad (16)$$

where X, Y, and Z are tristimulus values for the 2° or 10° observer of the specimen, and  $X_n, Y_n,$  and  $Z_n$  are tristimulus values for the 2° or 10° observer of a perfect reflecting diffuser.

### Derived Parameters

Various standard parameters can be calculated from the L\*a\*b\* system variables.

If  $L^*, a^*, b^*$  are the specimen data, and  $L^*_t, a^*_t, b^*_t$  are the target color data, differences are defined as:

$$\Delta L^* = L^* - L^*_t, \quad (17)$$

$$\Delta a^* = a^* - a^*_t, \quad (18)$$

$$\Delta b^* = b^* - b^*_t, \quad (19)$$

and the color difference between two points is

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}. \quad (20)$$

In the L\*C\*H° system, the metric chroma parameter,  $C^*$ , and the metric hue-angle,  $H^\circ$ , are defined as:

$$C^* = [(a^*)^2 + (b^*)^2]^{1/2} \quad (21)$$

$$H^\circ = \tan^{-1}(b^*/a^*) \text{ (degrees)}, 0^\circ \leq H^\circ \leq 360^\circ. \quad (22)$$

Differences between specimen and target color are

$$\Delta L^* = L^* - L^*_t \quad (23)$$

$$\Delta C^* = C^* - C^*_t = [(\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} - [(\Delta a^*_t)^2 + (\Delta b^*_t)^2]^{1/2}, \quad (24)$$

and the metric hue difference,  $\Delta H^*$ , between two points is defined as

$$\Delta H^* = [(\Delta E^*_{ab})^2 - (\Delta L^*)^2 + (\Delta C^*)^2]^{1/2} = [(\Delta a^*)^2 - (\Delta b^*)^2 + (\Delta C^*)^2]^{1/2} \quad (25)$$

## *Munsell Colors*

There is no international standard for converting tristimulus values to Munsell HVC (hue, value, and chroma) notation. Tables have been established to relate Munsell colors to  $Yxy$  data, and the  $L^*C^*H^\circ$  parameters can be related to Munsell colors using such tables. Interpolation is used if necessary to approximate values not available in the tables. The use of Munsell colors has many disadvantages: different conditions of illumination and viewing angle and variability in human eye's response and sensitivity. It is a procedure that is neither highly objective nor can the data be analyzed quantitatively. Munsell color classification should therefore not be used.

## **ENVIRONMENTAL EFFECTS**

### *Measuring Color of Split-Core Surfaces*

Measuring split-core surfaces poses some potential problems affecting the measurement:

- moisture, or uncontrolled drying of the material,
- surface roughness,
- particle size,
- oxidation, and
- use of protective plastic wrap.

Cores are split with a wire if they are soft enough, and with a saw once wire cutting is no longer effective. The problem is that wire cuts of very soft sediment and quite stiff sediment from farther downhole may create different surface roughnesses. This can affect color reflectance significantly. The problem is mostly solved by "cleaning" the core surface with a sharp edge such as a knife blade or glass slide. The process is tedious and time-consuming, however.

Moisture content affects color reflectance significantly. Automated shipboard measurements at very small sampling intervals require that the material is measured at whatever moisture content is present. Both uncontrolled drying and oxidation that begin as soon as the core is split "lighten" material characterized by organic matter or iron compounds. The oxidation of iron compounds also tends to increase reflectance, particularly at the red end of the spectrum. Unfortunately, it cannot be assumed that the changes caused by drying or oxidation are uniform over the entire spectrum of visible light. Absolute spectral characteristics for sediment and rock colors must therefore be established with dry powders. There is no practical solution to the discrepancy between dry and wet material measurement, and it must be accepted as the inherent analytical error. To keep the variation as systematic as possible, it is a good practice to take color measurements at constant periods after the core has been split, such as about 1 hr.

Nagao and Nakashima (1991) examined the difference between wet and dry measurements of marine cores in  $L^*a^*b^*$  color space. They found that for typical pelagic sediment of the uppermost meter below seafloor,  $L^*$  is up to 20% higher in dried specimens and  $a^*$  and  $b^*$  are higher by approximately 1. Fortunately, however, color parameter profiles, such as  $L^*a^*b^*$ , do not change their character as a function of moisture content (Nagao and Nakashima, 1992). These authors also examined and discussed the effects of grain size, addition of water to dried samples, and oxidation. They concluded that  $L^*$  values are controlled mainly by

water content with a small grain-size and homogenization effect;  $a^*$  and  $b^*$  values are controlled by water content, oxidation of greenish materials, and grain size. Pore-water composition may have an effect, as shown by the difference in measurements of samples remolded with pure water from original values.

Balsam et al. (1997) performed factor analyses on spectral data from Leg 155 cores obtained with the shipboard Minolta CM-2002 on wet split cores and with a Perkin-Elmer Lambda 6 on corresponding dried and powdered samples. Shipboard data yield a four-factor solution to explain 99% of the cumulative variance, whereas shore-based data produced at least seven interpretable factors to explain 99% of the cumulative variance. The four factors identified in the ship data are also present in the shore data. This and other statistics indicate that measurements from dried sediments are significantly more sensitive to subtle variations in the data set than measurements on wet cores, which appear to contain less information. However, differences in instrumentation and the fact that wet cores were measured through a film of Saran Wrap may also have affected the sensitivity of these measurements.

## USE OF COLOR DATA

The two most common uses of color reflectance data are (1) color parameters such as  $L^*a^*b^*$  provide detailed time series of relative changes in the composition of the bulk material and are frequently used to correlate sections from core to core or hole to hole and to analyze the cyclicity of lithologic changes; and (2) spectral data can be used to estimate the abundance of certain compounds. The first type of investigation, referred to as colorimetry, is simple and straightforward. Spectral analysis of visual light spectra (VIS) provides semiquantitative estimates of hematite and goethite with a sensitivity that is at least 1 order of magnitude better than from XRD analysis (Deaton and Balsam, 1991). Carbonate, opal, organic matter, chlorite, and some combinations of clay minerals can also be detected, although near-ultraviolet (NUV) and near-infrared (NIR) data (which cannot be obtained with the Minolta CM-2002) should or must be included for at least some of these analysis (Balsam and Deaton, 1991, 1996; Nakashima et al., 1992; Balsam and Wolhart, 1993; Balsam and Otto-Bliesner, 1995).

The spectra of marine sediments are typically smooth and show small peaks and valleys. A common statistical method to enhance relative changes is to use the first derivative of the measurement intervals. This “boundary hunting” method reveals the maximum rate of change in the original spectrum or the shoulders of the original absorption peaks, which occur at characteristic wavelengths. The added advantage of using first derivatives is that problems inherent in core surface measurement (moisture, oxidation, use of plastic wrap, surface texture and grain size, etc.) or the difference between measurements using different instruments (Balsam et al., 1997) are minimized. Yet, several effects must be considered when using first derivatives for quantitative estimation: matrix composition has a severe effect on peak height and the exact wavelength of a peak depends on the concentration of a component (Deaton and Balsam, 1991; Balsam and Wolhart, 1993) and the grain size of a component may influence the reflectivity and absolute band intensity (Gaffey, 1986).

Results from many ODP legs have shown that the correlation between  $L^*$  and carbonate content is usually the best and most obvious one and also is similar at many sites. Parameters  $a^*$  and  $b^*$  do not seem to yield much characteristic information or cyclic variations. They are, however, sensitive to clay mineralogy, nannofossil content, etc. Ratios such as  $a^*/b^*$ , or parameters of the  $L^*C^*H^*$  system, may distinguish these variations better than  $a^*$  and  $b^*$ .

## 7.2. Minolta CM-2002 System

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### EQUIPMENT

The Minolta Photospectrometer CM-2002 is a compact, hand-held instrument for measuring the spectral reflectance of surfaces with a diameter of more than 8 mm. The instrument combines measurement, data processing, and display functions in a single unit. Ultracompact spectral sensors developed by Minolta, hybrid IC analog circuitry, and a 32-bit, 16-MHz microcomputer provide high-speed, high-accuracy measurements of spectral reflectance from 400 to 700 nm. To ensure accuracy, the CM-2002 uses a double-beam feedback system, monitoring the illumination on the specimen at the time of measurement and automatically compensating for any changes in the intensity or spectral distribution of the light.

Objects are illuminated diffusely with a pulsed xenon arc light and viewed at an  $8^\circ$  angle to the normal to the object's surface (standard observer, Commission Internationale d'Eclairage, CIE). The width of the viewing beam is  $7.4^\circ$ . This geometry meets the specification for diffuse illumination and  $0^\circ$  viewing angle (CIE, 1986) as well as the specification for diffuse illumination and  $8^\circ$  viewing angle (ISO, 1984; DIN, 1980). In addition, the instrument's geometry and design allow for the specular component to be included (SCI setting) or to be excluded (SCE setting). The SCE setting is the recommended mode of operation for sediments in which the light reflected at a certain angle (angle of specular reflection) is trapped and absorbed at the light trap position on the integration sphere. Specular reflectance is perfect reflectance, or glare, and including it provides a better estimate of color as seen by the human eye. However, glare does not contribute to the spectrum, and Minolta recommends the SCE setting for general purposes (the SCI setting is useful for color mixing or computer color matching). Also, the SCE setting is favored for comparison with laboratory data based only on diffuse light (Balsam et al., 1997).

Light reflected from the surface of the specimen at an angle of  $8^\circ$  to the normal enters the optical fiber cable and is transmitted to spectral sensor 1. At the same time, the light inside the integration sphere illuminating the specimen is transmitted to spectral sensor 2. The light from each optical fiber cable is divided by wavelength at a 10-nm pitch (400–700 nm) before striking the segments of the silicon photodiode array of the spectral sensors. The sensors convert the light into electrical currents proportional to the intensity of the light. The currents are then passed to the analog control circuits and converted into digital signals.

Measurements can be calculated based on either the 2° or 10° standard observer and any of 11 illuminants (CIE standard illuminants A, C, D<sub>50</sub>, and D<sub>65</sub> and fluorescent illuminants F2, F6, F7, F8, F10, F11, and F12). Measurement results can then be displayed in a variety of ways: graphically as spectral reflectance or color difference, or as numerical absolute and/or difference values for XYZ, Yxy, L\*a\*b\*, L\*C\*H°, Hunter Lab, or L\*u\*v\* color spaces; metamerism index, Munsell notation; CMC (2:1) or (1:1); FMC-2; whiteness index (ASTM E 313 or CIE); or yellowness index (ASTM D 1925 or ASTM E 313). The standard output for the ODP database includes the full, 31-channel spectra, X, Y, Z; L\*a\*b\* parameters; and Munsell notation.

Do not expose this instrument to heat > 55°C (e.g., lights, direct sunlight) or magnetic fields (e.g., speakers).

## CALIBRATION

### *Loading Calibration Data*

A white ceramic attachment (cap) is supplied with the Minolta CM-2002 as a standard accessory. The cap is a transfer calibration standard that was factory-calibrated over 31 intervals of 10-nm length between 400 and 700 nm against the primary standard consisting of pressed BaSO<sub>4</sub> (ISO 7724/2) at the National Physical Laboratory in the United Kingdom. The calibration coefficients from this primary calibration are supplied with the Minolta CM-2002 memory card. When a new camera or standard is purchased, the calibration data must be loaded by installing the new memory card. The data remain in memory until they are changed.

The life time of the lithium battery on the memory card is approximately 2 years.

### *Zero Calibration*

Zero calibration is performed to compensate for the effects of stray light owing to the flare characteristics of the optical system. Flare characteristics may change over time because of dust, stains, etc., in the optical system. In addition, zero calibration may also eliminate variations resulting from changes in ambient or internal temperature. At the time of shipment, zero calibration data measured by Minolta are stored in an EEPROM in the CM-2002. These data should be updated routinely.

The calibration is performed by removing the protective cap or any other attachment from the aperture and aiming the aperture into the air so that no objects are within 1 m and no light source is aimed at. A zero-calibration box can also be used, but it is not available on the ship.

Zero calibration must be performed under the same conditions as the measurements are taken (SCE setting, ambient temperature, etc.). Zero-calibration data will remain in memory even if the power is switched off. If a zero calibration is performed it must be followed immediately by a white calibration.

### *White Calibration*

The white calibration sets the maximum reflectance to 100%. Each time the camera is switched on, or after a zero calibration has been performed, white calibration must be performed before measurements are taken. In addition, changes in ambient or internal temperature may affect the accuracy of the

measurement. The white calibration should therefore be performed regularly, meaning every few hours if the instrument is used around the clock.

White calibration must be performed under the same conditions as the measurements are taken (SCE setting, ambient temperature, etc.). The calibration data for the cap have been obtained at temperatures of  $23^{\circ} \pm 1^{\circ}\text{C}$ . For highest accuracy, the instrument should always be operated at this temperature.

Do not apply plastic wrap to the standard. Although this may make relative sense on the ship, such a calibration would not allow comparison with corresponding data obtained in other laboratories. Always cover the standard with a protective cap when not in use because the color may change, even in normal room light.

The calibration standard can be cleaned with lens-cleaning fluid. Wipe the surface clean with a soft cloth moistened with water and let dry before use. If the white calibration cap becomes scratched or stained, a new standard must be purchased. In this case, the new calibration data must be loaded (refer to the preceding "Loading Calibration Data" section, and the manufacturer's manual).

### *Calibration Procedure*

Before measuring a new core:

1. Switch the instrument off and on. This brings you automatically to the calibration mode.
2. Remove any attachment from the aperture. Aim the aperture away from any light sources and at least 1 m away from any object (zero-calibration box should be available in the future).
3. Press ZERO CALIB. Wait until three measurements have been taken (three light flashes, ~10 s). The CM-2002 automatically returns to calibration mode.
4. Attach the white calibration cap. Do not cover the white calibration pad with the plastic wrap because this reduces its validity as a factory-calibrated transfer standard.
5. Press MEAS WHITE CALIB. Wait until three measurements have been taken (three light flashes, ~10 s). The CM-2002 automatically returns to MENU mode.
6. Select DATA OUT mode from the menu. This sets up the system for measurements controlled by the external computer.
7. It is recommended that a control measurement be taken with the white calibration cap on.
8. Remove the calibration cap and start core measurement.

Automation of color measurements in the near future may allow semiautomatic calibration at the beginning of each core, and automatic control measurements would monitor drift at the beginning and the end of each section scan.

## **PERFORMANCE**

### *Precision (repeatability)*

Spectral reflectance: standard deviation within 0.1%.

Chromaticity value:  $\check{y}E^*_{ab}$  within 0.03.

Accuracy depends strongly on the calibration routine. The error should be less than 1% if calibration is performed regularly. The calibration data for the white calibration cap were obtained at a temperature of  $23^{\circ} \pm 1^{\circ}\text{C}$ . For the highest accuracy, the instrument should always be operated at this temperature.

## MEASUREMENT

At present, the Minolta CM-2002 is operated manually, using an external data-capture program. Thus, data quality depends largely on the operator.

1. Perform a zero calibration followed by a white calibration before measuring a new core (see procedure in “Calibration” section). Perform zero and white calibrations at least once per shift (every 12 hr; see “Calibration” section).
2. Use a consistent time lag after core splitting for the color measurements; about 1 hr is standard. Surface moisture variations from splitting and subsequent exposure of the split surface are largest during the first half hour to hour.
3. Cover the split-core with GLAD Cling Wrap crystal clear polyethylene, which transmits light uniformly over the spectrum of visible light and has minimal effect on the spectra (Balsam et al., 1997).
4. Do not use the optional granular-materials cover (part CM-A40).
5. Exclude the specular component (SCE setting). Although the specular component, which is essentially glare, provides a better estimate of color as seen by the human eye, it does not contribute to the spectrum reflected from sediment. Using the SCE setting should reduce the effect of varying moisture on the core surface.
6. Set the number of measurements per position. One measurement per position is sufficiently precise, but three measurements are better. Dense sampling should not be compromised for multiple measurements.
7. Set the appropriate core identifier and sampling interval on the external computer program.
8. Take a control measurement using the white calibration attachment. The current program expects you to take a control measurement at the beginning and the end of a core, which are written to the data file. (The future program will write these measurements to a separate file.)
9. Set the photospectrometer gently on the split-core surface, and hold it orthogonal to the core surface.
10. Avoid measuring cracks because the measurement result will be useless and will degrade the value of the color profile.
11. Press the measurement button and wait until a flash occurs.
12. Set the instrument at the next interval; the program increments the pre-specified interval automatically.
13. Take another control measurement when the core is measured.
14. Repeat steps 2 through 12.
15. Regularly clean the protective glass cover on the aperture.

## DATA SPECIFICATIONS

### *“Spectralog” Output File*

Spectralog is the original ODP data acquisition program for the Minolta CM-2002 which outputs the spectral measurements as well as scores of calculated parameters. The list below shows the ODP-customized Spectralog output, consisting of space-delimited records written to one file per hole. Column headers are not written by that program. During past legs, the output has produced three columns at the end of the file which are not defined.

Table 7—1 *Spectralog (expected) output.*

Short description	Description	Output file designation
Leg	Leg	[Spectralog 1-4] leg
Site	Site	[Spectralog 8-11] site
Hole	Hole	[Spectralog 13] hole
Core	Core	[Spectralog 15-17] core
Core type	Core type	[Spectralog 19] core_type
Section	Section	[Spectralog 21-22] section_or_std
Top	Interval top (cm)	[Spectralog 24-28] interval_top
Bottom	Interval bottom (cm)	[Spectralog 30-34] interval_bottom
(Depth)	Empty for depth	[Spectralog 36-42]
L*	Calculated L*	[Spectralog] l_star
a*	Calculated a*	[Spectralog] a_star
b*	Calculated b*	[Spectralog] b_star
Munsell HVC	Calculated Munsell hue-value/chroma	[Spectralog] munsell_hvc
395-405	395–405 nm bin	[Spectralog] 395–405_nm
405-415	405–415 nm bin	[Spectralog] 405–415_nm
415-425	415–425 nm bin	[Spectralog] 415–425_nm
...	etc.	etc.
695-705	695–705 nm bin	[Spectralog] 695-705_nm
	Undefined value	
	Undefined value	
	Undefined value	

The Spectralog program is being replaced by an updated version which will also acquire the tristimulus values X, Y, Z. The database model is designed accordingly.

## Database Model

Table 7—2 RSC database model

RSC Section	RSC Control	RSC Run	RSC Calibration
section_id [PK1] [FK] leg [PK2] [FK] rsc_run_num [PK3] [FK]	standard_id [PK1] [FK] leg [PK2] [FK] rsc_run_num [PK3] [FK]	leg [PK1] [FK] rsc_run_num [PK2] rsc_num_meas rsc_run_date_time rsc_calib_date_time	rsc_calib_date_time [PK1] rsc_comment rsc_illumination_condition rsc_num_meas rsc_observer_angle rsc_reflectance_corr rsc_specular_status rsc_zero_calib_flag system_id
		RSC Run Data leg [PK1] [FK] rsc_run_num [PK2] [FK] top_interval [PK3] bottom_interval rsc_cielab_l_star rsc_cielab_a_star rsc_cielab_b_star rsc_height rsc_height_assumed_flag rsc_munsell_hvc rsc_tristimulus_x rsc_tristimulus_y rsc_tristimulus_z rsc_first_channel rsc_last_channel rsc_channel_increment rsc_spectra	

## Standard Queries

Table 7—3 RSC report.

Short description	Description	Database
<b>A: Colorimetry results</b>		
Sample ID	ODP standard sample designation	Link through [RSC Section] section_id
Depth	User-selected depth type	Link through [RSC Section] section_id
L*	First L*a*b* parameter	[RSC Run Data] rsc_cielab_l_star
a*	Second L*a*b* parameter	[RSC Run Data] rsc_cielab_a_star
b*	Third L*a*b* parameter	[RSC Run Data] rsc_cielab_b_star
Munsell	Munsell hue, value, chroma	[RSC Run Data] rsc_munsell_hvc
X	Tristimulus value X	[RSC Run Data] rsc_tristimulus_x
Y	Tristimulus value Y	[RSC Run Data] rsc_tristimulus_y
Z	Tristimulus value Z	[RSC Run Data] rsc_tristimulus_z
<b>B (optional): Spectral results</b>		
Spectrum	String of 31 spectral reflectance values (% intensity)	[RSC Run Data] rsc_spectra
<b>C (optional): Measurement parameters</b>		
Run	Run number on a leg	[RSC Run] rsc_run_number
Date/time	Run data and time	[RSC Run] rsc_run_date_time
No. of Meas.	Number of measurements for each data point	[RSC Run] rsc_num_meas
Cal. date/time	Date and time of last calibration	[RSC Run] rsc_calib_date_time
Height	Distance between aperture and core surface	[RSC Run Data] rsc_height
First lambda	Wavelength of first channel	[RSC Run Data] rsc_first_channel
Last lambda	Wavelength of last channel	[RSC Run Data] rsc_last_channel
Increment lambda	Wavelength increment between channels	[RSC Run Data] rsc_channel_increment

Table 7—4 RSC control 1 data (to be implemented).

Short description	Description	Database
Run	Run number on a leg	[RSC Run] rsc_run_number
Date/time	Run data and time	[RSC Run] rsc_run_date_time
No. of Meas.	Number of measurements for each data point	[RSC Run] rsc_num_meas
Cal. date/time	Date and time of last calibration	[RSC Run] rsc_calib_date_time
Height	Distance between aperture and core surface	[RSC Run Data] rsc_height
First lambda	Wavelength of first channel	[RSC Run Data] rsc_first_channel
Last lambda	Wavelength of last channel	[RSC Run Data] rsc_last_channel
Increment lambda	Wavelength increment between channels	[RSC Run Data] rsc_channel_increment
L*	First L*a*b* parameter	[RSC Run Data] rsc_cielab_l_star
a*	Second L*a*b* parameter	[RSC Run Data] rsc_cielab_a_star
b*	Third L*a*b* parameter	[RSC Run Data] rsc_cielab_b_star
Munsell	Munsell hue, value, chroma	[RSC Run Data] rsc_munsell_hvc
X	Tristimulus value X	[RSC Run Data] rsc_tristimulus_x
Y	Tristimulus value Y	[RSC Run Data] rsc_tristimulus_y
Z	Tristimulus value Z	[RSC Run Data] rsc_tristimulus_z
Spectrum	String of 31 spectral reflectance values (% intensity)	[RSC Run Data] rsc_spectra

Table 7—5 RSC calibration data (to be implemented).

Short description	Description	Database
Date/time	Calibration date and time	[RSC Calib] rsc_calib_date_time
Comments	Number of measurements for each data point	[RSC Calib] rsc_comment
Illumination	Illumination type/condition	[RSC Calib] rsc_illumination_condition
No. of Meas.	Number of measurements averaged	[RSC Calib] rsc_num_meas
Observer angle	Observer angle	[RSC Calib] rsc_observer_angle
Correction	Reflectance correction applied or not	[RSC Calib] rsc_reflectance_corr
Specular	Specular components measured or not	[RSC Calib] rsc_specular_status
Zero calib.	Zero (black) calibration performed or not	[RSC Calib] rsc_zero_calib_flag