RMRS Rocky Mountain Remediation Services L L C
protecting the environment

PROCEDURE

LOGGING ALLUVIAL AND BEDROCK MATERIAL

Procedure No RMRS OPS PRO 101
Revision 0
Date effective 12 31 98

APPROVED [signature] 12 22 98
Manager Water Operations Waste Operations Division — Date

USE CATEGORY 2

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1 0 PURPOSE

This document describes procedures that shall be used at the Rocky Flats Environmental Technology Site (RFETS) to describe (log) geologic materials These procedures shall be followed when logging any geologic materials at RFETS

Standardized logging procedures were implemented in 1991 to address inconsistencies in geologic descriptions made at different times or by different logging geologists By applying standardized procedures when logging geologic materials lithologic descriptions are comparable from year to year and geologist to geologist Reliable data can therefore be produced from which reliable interpretations can be made

2 0 SCOPE

This document, which supercedes procedure GT 01 constitutes a Standard Operating Procedure (SOP) applies to all Rocky Mountain Remediation Services (RMRS) personnel and subcontractors conducting geologic and related work at RFETS It describes the procedures that shall be used at RFETS to describe geologic materials in the field at the drill site and in a separate location such as a logging facility or laboratory although both phases may not be performed

In the mid 1990s it became a standard practice for geologic materials produced during the investigations to be logged in the field using only specific portions of this SOP with the remainder of the requirements presented in this document omitted The resulting reduction in effort was designed to meet the correspondingly reduced level of detail in the geologic data required to meet the objectives of the affected projects Depending on the level of detail required to meet the objectives of individual projects, only those activities and descriptive procedures described in this SOP that apply to field logging operations will routinely be followed All of the procedures described in this SOP will be completed only if specifically stated in the project work plan or other controlling documents or by written instructions from the RMRS project manager

At RFETS and for the purposes of this SOP the terms alluvial material and unconsolidated surficial material are often used as catch all terms that include alluvium colluvium fill and agronomic soils These materials are to be classified and described using the Unified Soil Classification System (USCS) and Item 10 1 in ASTM D2488 Description and Identification of Soils (Visual-Manual Procedure) Bedrock material, regardless of the degree of weathering shall be classified and described using many of the procedures and techniques described in Compton s *Manual of Field Geology* (1962) which has been incorporated with additional material in this SOP (Note that bedrock occurring at the surface does not fall within the definition of the term unconsolidated surficial material)

3 0 REQUIREMENTS

The following sections identify the personnel qualifications and equipment necessary to perform geologic logging

3 1 <u>Personnel Qualifications</u>

Personnel performing these procedures are required to have completed the initial 40-hour OSHA classroom training that meets Department of Labor Regulation 29 CFR 1910 120(e)(3)(i) and must maintain a current training status by completing the appropriate 8 hour OSHA refresher courses Personnel must also have read and signed the appropriate Health and Safety Plan(s) Any other RFETS training requirements that apply must also be fulfilled

Only qualified personnel shall be allowed to perform these procedures Required qualifications vary depending on the activity to be performed In general qualifications are based on education, previous experience, on-the job training, and supervision by qualified personnel Personnel who log geologic materials must be qualified geologists or geologic engineers The subcontractor s project manager shall document personnel qualifications related to this procedure in the subcontractor's project Quality Assurance (QA) files

Prior to engaging in geologic logging, personnel are required to have a complete understanding of the procedures described within this and certain related SOPs, and may be required to receive specific training regarding these procedures Personnel who log borehole cores must study the RFETS Alluvial Reference Set that contains examples of all 15 sample classifications within the U S C S System, and the Core Reference Set that contains 15 representative samples of the stratigraphic section in the RFETS area. The Alluvial and Core Reference Sets are used as reference standards to help ensure consistency among logging geologists

The RMRS project manager has the overall responsibility for implementing this SOP The subcontractor's project manager shall be responsible for assigning project staff to implement this SOP and for ensuring that the procedures are followed by all subcontractor personnel. The geologist(s) performing the activities described in this SOP shall be responsible for generating the appropriate high-quality records and deliverables in a timely manner

Each project staff member is responsible for reporting deviations from this SOP to the RMRS project manager When conditions require deviations from this SOP the RMRS project manager shall be notified immediately If the RMRS project manager agrees that the deviations are warranted and are so wide in scope to warrant it, he or she shall complete a Document Modification Request (DMR) in accordance with procedure 2-ER4-ADM-05 07 Within 48 hours following the deviation, the RMRS project manager shall put the DMR in writing and submit it for approval following the appropriate procedures

3 2 Equipment

The following equipment is necessary to log alluvial and bedrock material in the field

- Rock-color chart
- Logging forms (Forms PRO 101A, PRO 101B)
- Field logbook
- Hand lens
- Metal tape at least 6 feet long, marked in tenths of feet
- Core boxes with appropriately sized dividers (for example, for a 2- to 2-1/2-inch wide core a Boise Cascade No 17-505 top, bottom, and dividers would be appropriate)
- Wood blocks (3/4 inches thick and a length and width that is approximately equal to that of the core box divider slots) for marking depths, sample locations, and intervals of lost recovery
- Jars for cuttings
- Wentworth and/or Amstrat grain size charts
- USCS classification chart (Figure PRO 101-2)
- Lithologic symbol chart (Figure PRO 101-6)
- Pocket knife
- Putty knife
- Black waterproof (permanent) markers and pens
- Protective clothing and equipment (see Health & Safety Plan)
- Hammer
- Clipboard
- Table

- Plastic sheeting for covering working surfaces (e g table)
- Paper towels
- Flat bladed screwdriver
- Awl

The following additional equipment is required to log geologic materials at a logging facility

- Protractor
- Core reference set
- Alluvial reference set
- Camera (35 mm) with film (Kodak color patch)
- Flashlight
- Binocular microscope
- Nos 4 10 40 200 and 230 sieves (8 inch) with lid and base
- Mortar and pestle
- Acid (10 percent HCl) in squirt bottle
- Water in squirt bottle
- Hot plate
- Spot plate
- Beakers (500 ml are appropriate)
- Graduated cylinders (10 ml and 50 ml are appropriate)
- Watch glass

4 0 INSTRUCTIONS

This section describes procedures that shall be followed when logging core or cuttings whether in the field or in a separate logging facility It should be noted that use of the term core in this SOP also refers to cuttings except in certain obvious instances and therefore logging requirements for core also apply to cuttings

The RMRS project manager and the logging geologist shall ensure that all of the materials and equipment needed for logging are at the drill site and/or the separate logging facility Certain items of equipment typically will be kept and used in a separate logging facility and will not be transported to individual drilling locations

As discussed in Section 2 0 the entirety of this SOP may not be applicable to each and every geology related project Depending on the data required to meet the individual project objectives some logging activities described in this SOP may be omitted Unless specifically stated in the project work plan other controlling documents or in written instructions from the RMRS project manager only those tasks described in this SOP that apply to field geologic logging will be completed

If cores or drill cuttings are to be logged at a separate location removed from the drill site two forms shall be completed Form PRO 101B the Preliminary Borehole Field Log (which shall be copied onto the back of Form PRO 101A) shall be completed in the field by the rig geologist, and Form PRO 101A the Rocky Flats Environmental Technology Site Borehole Log shall be completed in the core logging facility by the logging geologist The rig geologist s field descriptions will be more general in nature and will be focused on aspects of the recovered core that typically change over short periods of time (e g changes in drilling rates or encountering perched saturated intervals) that would not be evident to the logging geologist The following information shall be recorded on Form PRO 101B immediately upon recovering the core from the borehole generalized lithologic descriptions moisture content, depth to water table and all geochemical and geotechnical sample numbers with corresponding sample depths and requested analyses In addition the first four columns of Form PRO 101A will either be filled out in the field or the information to properly fill out these columns will be provided on Form PRO 101B Cores and logging forms shall be delivered to the separate location within one day after filling each core box The logging geologist shall then complete Form PRO 101A by refining and adding to the geological descriptions completing the lithologic log, and adding other entries as necessary to fulfill the requirements of this SOP

If only field logging will be performed, Form PRO 101A shall be completed by the rig geologist (who under these circumstances will also fill the role of the logging geologist) to fulfill the requirements of this SOP except for those requirements that are specifically omitted in the project's controlling documents, as noted above. Form PRO 101B will typically not be completed in these instances

This Section is divided into a set of subsections describing general requirements, the description of surficial materials, and the description of bedrock materials Each subsection of the latter two sets focuses on a particular characteristic to be described and the procedures to be used in their description Rig and logging geologists shall be familiar with all the procedures presented in this SOP regardless of whether they apply to a particular sample or project, because many of the concepts and characteristics are of wider relevance than to a single sample or project.

4 1 <u>General Requirements</u>

The following requirements apply regardless of whether the material constitutes unconsolidated surficial materials or bedrock.

4 1 1 Scanning the Core or Cuttings

After an interval of core has been cut and the sampler has been retrieved, the open ends of the sampler shall be scanned for hazardous, and in many cases radioactive, contamination (The requirement to perform radioactive scans will depend on the location of the drill site and the individual project requirements.) A more thorough scan shall be made of the core after the sampler has been opened. Scanning shall also be performed on cuttings if cuttings are being collected instead of core The field use of monitors for the detection of volatile organics and radionuclides is discussed in SOPs FO 8 Handling of Drilling Fluids and Cuttings, FO 15 Photoionization Detectors (PIDs) and Flame Ionization Detectors (FIDs), and FO 16, Field Radiological Measurements Once the core has been scanned, it shall be handled in accordance with the appropriate Health and Safety Plan See the following subsection for a discussion on isolating geological material suspected of containing radioactive and/or hazardous substances

4 1 2 *Marking and Boxing the Core*

After the sampler has been opened and the core has been scanned, the core shall be consolidated in the sampler and measured to the nearest tenth of a foot. It may next be necessary to shave the layer of smeared outer material off the core to reveal its features. Then, if the core is competent, two parallel lines shall be etched down the length of the core An awl line shall be etched on the left side of the core, for the entire length of the core Using the flat of the blade, a screwdriver line shall be etched on the right side of the core, for the entire length of the core These etched lines denote the "up" orientation. All competent cores shall be etched with enough pressure to create readily visible lines, but not so much pressure that the core or its features are obliterated or altered.

The core shall then be boxed. Core boxes will come complete with column dividers, and will be similar to the model described in Subsection 3.2 above Boxes and column dividers shall be of a size that is appropriate for the core to be boxed, and shall be constructed of moisture-resistant material (for example, boxes typically used at RFETS are made of waxed cardboard) Core that has been segregated as potentially contaminated following scans discussed in Subsection 4 1 1 shall be further segregated according to its potential contaminant characterization (hazardous vs radioactive) and placed in boxes designated for potentially contaminated core

Wooden blocks shall be inserted at the top and bottom of each core run Black waterproof markers shall be used to mark footage values (in tenths of feet rather than inches) on the blocks Appropriately marked blocks shall also be inserted as necessary to designate intervals of no recovery intervals from which any high priority or time sensitive (e g those for volatile organic compounds or VOCs) analytical samples have been collected and intervals from which potentially contaminated core sections have been removed Wood blocks representing samples or potentially contaminated core shall be inserted in place of the core and shall be marked to indicate the depth interval of the core which has been removed and (for potentially contaminated core) where the removed core is located Corresponding blocks shall also be placed at the top and bottom of the sections of potentially contaminated core that are removed, noting the depth interval represented and the location of the rest of the core from which the removed sections were taken By so inserting and labeling the blocks it will be possible to properly reconstruct the core when necessary

If only cuttings are collected, a representative sample shall be collected every 2 feet If drilling rates or depth constraints make this impractical the collection interval shall be 5 feet The RMRS project manager shall determine the collection interval After being scanned, these cuttings shall be placed in labeled jars in the appropriate location in the appropriate core box (not contaminated or potentially contaminated, the latter being segregated by type of contamination)

Each core box and lid shall be marked (using a suitable indelible marker) with the following information

- Well/borehole number
- General area (e g East Buffer Zone IHSS 118 1)
- Depth interval
- Date
- Project name
- Rig geologist s initials
- Logger's initials (after logging is completed)
- Box number and the total number of boxes for that well/borehole
- Appropriate hazardous waste labels

The core boxes will be closed and secured in a manner such that core will not be disturbed or mixed up during transportation If scans performed as discussed in Subsection 4 1 1 indicate the presence of radioactive or hazardous contamination the top surface of each box top used for potentially contaminated core will be marked with the results of these scans Core boxes suspected of containing low-level radioactive substances will be labeled with a White I radioactive label Core boxes suspected of containing volatile organic or mixed substances will be labeled with a Department of Transportation Other Regulated Material Class E (ORM-E) label (see SOP FO 10 Receiving Labeling, and Handling Environmental Materials Containers) If the suspected contamination is mixed substances the core box shall also be marked with the words SUS RAD for suspected radioactive contamination The RMRS project manager shall be notified before core suspected of being contaminated is transported

Core that is determined to be potentially contaminated shall be stored in appropriately marked storage facilities All other core boxes shall be stored at the main core storage facility at RFETS However with the exception of potentially contaminated core core that is to be logged in a separate logging facility may be temporarily stored in that facilities until logs have been signed off by the appropriate RMRS personnel After the logs have been signed off the core shall be moved to the main core storage facility

4 1 3 *Sampling*

Time-sensitive samples such as those collected for the analysis of VOCs, shall be collected immediately after the core has been scanned, measured, and peeled (see Subsections 4 1 1 and 4 1.2) The core shall be handled and samples collected in a quick, efficient manner that will minimize the potential for offgassing and/or degradation of any VOCs or other time-sensitive analytes of interest that may be present. This will require that all necessary equipment and supplies (such as sampling trowels, sample containers, etc) be on hand and ready for use In addition, personnel will take care to prevent the core from being exposed to outside sources of contamination (such as vehicle exhaust, drilling fluids, lubricants, marking pens, etc) and from other conditions that may cause chemical changes (such as prolonged exposure to sunlight)

Samples collected for geophysical analyses or for other purposes should be removed only after the core has been logged and photographed, if appropriate

When a sample is collected, a wood block with the following information shall be placed in the core box at the point from which the sample was removed.

- Sample number
- Depth

If samples are collected at a later date, the wood block that is inserted should be marked with the above information as well as the following details

- Purpose
- Date
- Company

All information shall be marked on the wood block with a black waterproof (permanent) marker Blocks need not be inserted for samples collected for logging purposes, as very little core typically is consumed in describing grain size, rounding, sorting, composition, and so forth Similarly, blocks need not be inserted for samples that do not consume entire sections of core, such as composite samples that are composed of small aliquots taken from along a length of core

4 1 4 *Photographing the Core*

This procedure applies only if a core logging facility is to be used. Any and all photographing procedures must conform to plant security controls. This will require that the camera be cleared and left on site until the project is completed, that the photographer has a valid RFETS camera pass and that all film be processed by RFETS Each box of core should be photographed with a 35-mm camera prior to logging or sampling the core if this is applicable and appropriate, but after it has been shaved to reveal core features. An identification tag and a Kodak color patch should appear in each photograph The identification tag should contain.

- Well/borehole number
- Depth interval
- Box number and the total number of boxes for that well/borehole
- Date core was collected
- Project name and number

4 2 Description of Surficial Materials

The USCS is used at RFETS to describe all surficial geologic materials that are not bedrock As noted above examples of such materials that are common at RFETS include alluvium colluvium fill and agronomic soils

The USCS as used in this SOP has been modified from the Army Corps of Engineers Technical Memorandum No 3 357 The Unified Soil Classification System (1960) Physical characteristics that are normally determined through laboratory analyses are not included in this SOP because they are neither practical to do in the field nor appropriate for geologic logging

4 2 1 *Basis of Classification*

The USCS historically has been used to classify soils based on their textural properties liquid limit, and organic content The term soil has been used by engineers as a catchall term that includes all unconsolidated material Because engineers are concerned with how the soil behaves as a construction material this all inclusive approach has served them quite well However at RFETS it is more important to determine the possible paths of groundwater movement based on lithologic variability and geologic processes than it is to determine the engineering properties of a geologic material Some modifications to the USCS are therefore appropriate

In this SOP the USCS shall be applied only to unconsolidated surficial material This separates unconsolidated surficial material from bedrock which may have well defined sedimentary and depositional patterns regardless of the degree to which the bedrock has been weathered

4 2 2 *Texture*

4 2 2 1 Grain size scale

The USCS grain size scale is divided into four main categories (1) cobbles (2) gravel (3) sand and (4) fines The gravel sand, and fines are further subdivided into coarse and fine gravel coarse medium and fine sand and silt or clay fines

Table PRO 101 1 is a summary of the USCS Wentworth Atterberg and U S Department of Agriculture (USDA) grain size scales (Krumbein and Pettijohn 1966 Compton 1962) In this SOP the USCS grain size scale is used when logging alluvium colluvium fill and agronomic soils and the Wentworth scale is used for logging bedrock

Divisions between grain size classes (especially between gravel and sand and between sand and silt) vary from scale to scale This makes it somewhat difficult to compare USCS grain size analyses with analyses based on other scales Most geotechnical laboratories only report the USCS grain size ranges Figure PRO 101 1 shows both the USCS and Wentworth grain size ranges ASTM D422 Particle Size Analysis of Soils should be used to perform grain size analyses but should be modified to include a 230 sieve when bedrock is being analyzed

Sieves and grain size charts should be used regularly when grain size determinations are made Some error is unavoidable in grain size determinations made in the field and the RFETS core logging facility as compared with those derived by a geotechnical laboratory Field descriptions of grain size distributions are typically visual estimates logging facility analyses are based on volumetric (visual) measurements and geotechnical laboratory analyses utilize wet sieving and weight measurements However the procedures employed in this SOP significantly reduce the error

Table PRO 101 1 Grain size scales (in millimeters [mm]).

USCS (Variable scale)	Wentworth (Base 2)	Atterberg (Base 10)	USDA (Variable scale)	Component
>76.2	256-64	200-20	>80	Cobbles
--	64-32*	--	--	Very Coarse Gravel
76.2 19	32 16*	--	--	Coarse Gravel
--	16-8*	20-2*	80-2	Medium Gravel
19-4 76	8-4*	--	--	Fine Gravel
--	4-2	--	--	Granule
--	2 1	--	2 1	Very Coarse Sand
4 76-2	1-0 5	2-0.2	1-0.5	Coarse Sand
2 42	0 5-0.25	--	0 5-0.25	Medium Sand
42 074	0 25-0 125	0.2-0 02	0 25-0 1	Fine Sand
--	0 125-0 0625	--	0 1-0 05	Very Fine Sand
< 074	0 0625-0 0039	0 02-0.002	0.05-0 002	Silt
--	<0 0039	<0 002	< 002	Clay

*Pebbles

The following steps shall be followed when logging core at a logging facility to determine the grain size distribution of a sample

1 The core shall be subdivided into intervals of similar lithologies

2 From each interval, a small representative sample shall be collected, dried, disaggregated (separated into its component class), and sieved using the appropriate sieve nest. Care should be taken to disaggregate the sample without pulverizing it and thereby creating more fines Because of the tendency for clays to clump disaggregation of the fine fraction may need to be repeated in order to separate silts from clays

3 The volume of material in each size class (gravel, sand, silt, and clay) shall be measured using graduated cylinders and beakers, then converted to percentages of the representative sample Coarser materials, when placed in a graduated cylinder typically pack so poorly that the volume of material includes abundant pore space This problem can be addressed by pouring a known volume of water into the graduated cylinder adding the coarse materials, measuring the new total volume, and reporting the difference in volumes as the volume of coarse materials Relative percentages of silt and clay can be estimated by placing a small amount of the silt/clay fraction on a watch glass, adding enough water to saturate and further dissagregate the material and using a binocular microscope to visually distinguish between silt and clay The percentage diagrams in Figure PRO 101-5 and the soil reference set shall be used when appropriate

4 All percentages should normalize to 100% and be recorded in the grain size column of the logging form Because of the inherent variability of geologic materials especially the surficial materials that are common at RFETS the percentages determined for the sieved sample may be slightly different for another sample of the same interval It is therefore appropriate in some cases to record ranges of percentages rather than a single value (e g 5 10% silt rather than 8% silt)

For typical projects grain size distributions shall be estimated in the field Because grain size distribution is the major determinant in the USCS soil classification and is also a controlling factor in fluid flow behavior the logger shall exercise an enhanced level of thoroughness and care in estimating grain sizes

4 2 2 2 Graded Material

The USCS definition of the term graded is very different from its sedimentologic definition In USCS classifications the concept of graded material is used to describe the number of grain size ranges that are present within the central portion (approximately 80 percent) of the grain size distribution for samples with less than 5 percent fines (silt and clay) If 80 percent of the sample contains predominantly one or two grain size ranges (such as medium and fine sand) it is poorly graded and is assigned the symbol (P) If it contains three or more grain size ranges (such as fine gravel and coarse medium and fine sand) it is well graded and is assigned the symbol (W)

4 2 3 *Estimates of Plasticity*

The plasticity characteristics of fine grained unconsolidated surficial materials (i e those in which the fine fraction constitutes more than 50% of the representative sample) should be estimated per USCS procedures This procedure is <u>best performed in a logging facility or laboratory</u> The following paragraph and paragraph excerpts are taken from the *The Unified Soil Classification System Appendix A Characteristics of Soil Groups Pertaining to Embankments and Foundations* (pp 15 &16)

> Particles larger than about the No 40 sieve size are removed (by hand) and a specimen of soil about the size of a 1/2 inch cube is molded to the consistency of putty If the soil is too dry water must be added and if it is sticky the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation The sample is rolled by hand on a smooth surface or between the palms into a thread about 1/8 inch in diameter The thread is then folded and rerolled repeatedly During this manipulation the moisture content is gradually reduced and the specimen stiffens finally loses its plasticity and crumbles when the plastic limit is reached After the thread crumbles the pieces should be lumped together and a slight kneading action continued until the lump crumbles The higher the position of the soil above the 'A line on the plasticity chart the stiffer are the threads as their water content approaches the plastic limit and the tougher are the lumps as the soil is remolded after rolling

Samples with a low plasticity form a weak thread and cannot be lumped together into a coherent mass below the plastic limit

Samples with a medium plasticity form a medium tough thread (easy to roll) as the plastic limit is approached but when the threads are formed into a lump and kneaded below the plastic limit, the soil crumbles readily '

Samples with a high plasticity form a stiff thread as their water content approaches the plastic limit and the tougher are the lumps as the soil is remolded after rolling '

4 2 4 *Moisture Content*

Accurate descriptions of moisture content are extremely important at RFETS for the proper design of groundwater monitoring wells and because of other groundwater related issues. Moisture must be described immediately upon recovering the core as it typically evaporates quickly due to exposure to air and drilling-related warming of the core

The core shall be described as dry, slightly moist, moist, or saturated, and the depth to the top of the saturated interval shall be recorded. If a static water level can be measured, it shall be noted in the logbook and on Form GT 1B or the back of the core logging form (Form PRO 101A) if Form PRO 101B is not being used The moisture content shall be included in the core description

4 2 5 *USCS Sample Classification*

The USCS sample classifications are illustrated in Figure PRO 101-2 In order to classify unconsolidated surficial material, it is necessary first to estimate the percent of all the grain size ranges in the sample and determine the plasticity of the fines if they constitute more than 50 percent of the sample This information and Figure PRO 101-2 are used to match the textural, plasticity, and organic characteristics of the sample to its USCS classification.

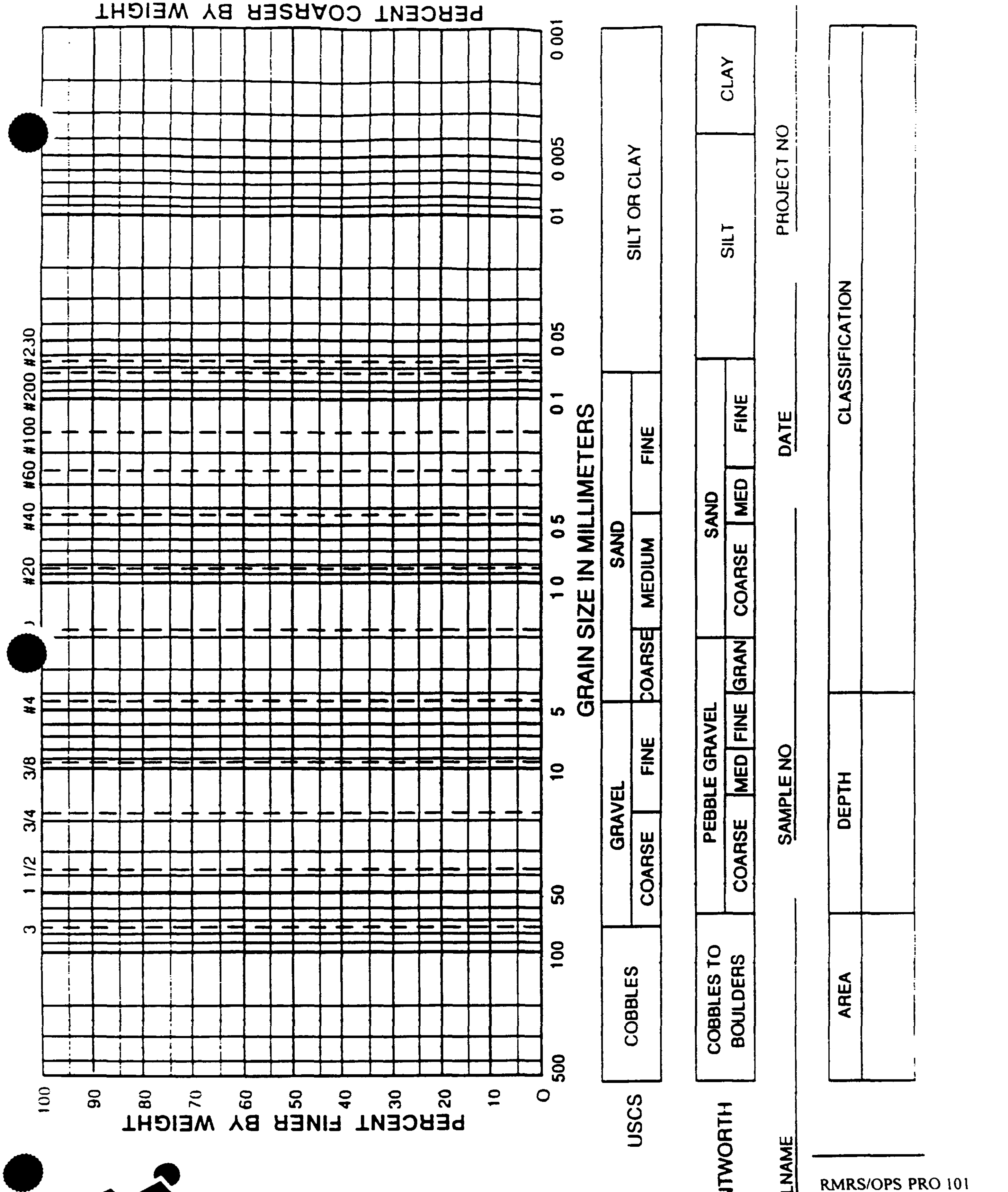
Figure PRO 101-2 uses an "if/then" sequence of decisions that ultimately leads to the proper sample classification As is evident on this Figure, borderline gravel and sand classifications having a fines content ranging from 5 to 12 percent are assigned a split classification based on the two dominant soil types. The main type will be listed first on the log form (Form PRO 101A) Split classifications are also justified for gravel and sand soil types having equivalent percentages of material that pass and that are retained by the no 4 sieve, and for coarse and fine grained soils having equivalent percentages of material that pass and that are retained by the no 200 sieve

If sieve analyses are not being performed but rather grain size distributions are being estimated in the field, the logger shall exercise an enhanced level of thoroughness and care in estimating grain sizes. Even so, the potential for error in these estimates is greater than if the distribution is determined using sieves Split classifications are therefore more appropriate in these cases.

Log descriptions should identify the appropriate USCS symbol(s) and associated lithologic (graphic) log The sample should be 'named" according to its most frequent grain size, with modifiers added if appropriate following the guidelines presented for the classification of bedrock units (see Section 4 3 5).

Two examples follow

- Example 1 Seventy-five percent of the material is greater than the no 200 sieve, 53 percent greater than the No 4 sieve (gravel), 22 percent is sand, and 25 percent is fines (10 percent silt and 15 percent clay) The proper classification for this sample is sandy gravel with some clay and silt (GC)



RMRS

U S STANDARD SIEVE SIZE

FIGURE PRO 101-1

- Example 2 Eighty-five percent of the material is smaller than the no 200 sieve, 5 percent is gravel 10 percent is sand 30 percent is silt, and 55 percent is clay that has a low to medium plasticity The proper classification for this sample is silty clay with some sand and a trace of gravel (CL)

Note Both examples use the range of abundance terms defined in Section 4 3 3 1

Generally, sample descriptions should be made in the following order

- Main textural classification with modifiers
- Color
- Grain size
- Grading
- Angularity (ASTM D2488)
- Plasticity
- Composition
- Bedding
- Moisture content
- Top of bedrock, if present

*See Section 4 3 4 for guidelines on describing color For coarse-grained materials, the color reported shall be that of the matrix

4 2 6 *Problems With the USCS*

A change of 1 or 2 percent in coarse or fine material on either side of the 50 percent boundary may cause the sample classification to vary considerably For example, a clayey gravel (GC) or a clayey sand (SC) could easily change to a gravelly clay or a sandy clay with low plasticity (CL) or a sandy clay with high plasticity (CH) Clearly a classification system that is this sensitive is subject to errors, especially in the field.

Another problem is that it is all but impossible to determine a liquid limit in the field. For the purposes of this SOP the liquid limit has been replaced by field estimate of plasticity (see Subsection 4.2 3) All loggers shall refer to the RFETS Alluvial Reference Set as an aid in making plasticity determinations.

The USCS also lacks the textural property of angularity that helps to determine the maturity of sediments

Finally the USCS is a purely descriptive classification that has been designed for construction purposes and concentrates heavily on the physical properties of clay Because of this, the USCS has 15 sample classifications and is very cumbersome

4 3 Descriptions of Bedrock

All bedrock material should be classified and described by using many of the procedures and techniques described in Compton (1962) which has been incorporated with additional material into this SOP

FIGURE PRO 101-2 SOIL TYPES

Major Divisions			Letter	Symbol	Description
Coarse Grained Soils	Gravel and Gravely Soils	Clean Gravels (< 5% fines)	GW		Well graded gravels or gravel-sand mixtures, little or no fines. Uc > 4 (lab only)
			GP		Poorly graded gravels or gravel-sand mixtures, little or no fines.
	More than 50% of coarse fraction retained on no. 4 sieve	Gravels with Fines (> 12% fines)	GM		Silty gravels gravel-sand-silt mixtures.
			GC		Clayey gravels, gravel-sand-clay mixtures.
	Sand and Sandy Soils	Clean Sand (< 5% fines)	SW		Well-graded sands or gravelly sands little or no fines. Uc > 6 (lab only)
More than 50% of material is larger than no 200 sieve size			SP		Poorly-graded sands or gravelly sands little or no fines.
	More than 50% of coarse fraction passed no. 4 sieve	Sands with Fines (> 12% fines)	SM		Silty sands, sand-silt mixtures.
			SC		Clayey sands, sand-clay mixtures.
Fine Grained Soils	Silts and Clays	Low Plasticity	ML		Inorganic silts and very fine sands rock flour silty or clayey fine sands, or clayey silts with slight plasticity
			CL		Inorganic clays of low to medium plasticity gravelly clays, sandy clays silty clays lean clays.
			OL		Organic silts and organic silty clays of low plasticity
		High Plasticity	MH		Inorganic silts, micaceous or diatomaceous fine sand or silty soils
More than 50% of material is smaller than no 200 sieve size			CH		Inorganic clays of high plasticity fat clays
			OH		Organic clays of medium to high plasticity organic silts
Highly Organic Soils			PT		Peat, humus, swamp soils with high organic contents

Note Dual Symbols are used to indicate borderline soil classifications whose fines range from 5 to 12%

Unified Soil Classification System

Modified from Water Well Design and Construction Development in Geotechnical Engineering 60 by R L Harlan K E Koln and E D Gutentag Elsevier 1989

4011 30-0131 930XF gure T1 X0V01N)

4 3 1 *Basis of Classification*

Compton classifies sedimentary rocks on the basis of their texture, fabric, and composition Rock descriptions such as conglomerate sandstone, siltstone and shale (or claystone and mudstone) are textural classifications based solely on grain size When other properties like sorting, roundness, bed thickness and contacts cross-stratification color composition, cement, porosity and fossil content are included, it is possible to make interpretations of where how, and under what conditions the sediments were deposited.

4 3.2 *Texture*

4 3 2 1 Grain size scale

The Wentworth grain size scale is divided into six main categories (1) cobbles, (2) pebbles, (3) granules, (4) sand, (5) silt, and (6) clay The pebble and sand categories are subdivided into very coarse, coarse, medium, and fine pebbles and very coarse, coarse, medium, fine, and very fine sand (see Table PRO 101-1) The scale is a geometric series with a base of two

Unlike the USCS scale in which the sand/silt boundary occurs at 0 074 mm, in the Wentworth scale this boundary occurs at 0 0625 mm Geotechnical laboratories generally plot grain size analyses on graph paper that is compatible with the U S C S , therefore, if samples of bedrock are to be sent to a geotechnical lab for grain size analyses, it is important to ensure that the lab also includes the range of Wentworth grain size intervals on the graph paper (Figure PRO 101 1) The grain size distribution of bedrock materials is made using the sieving techniques as described in Section 4 2.2 1

4 3 2 2 Sorting

Sorting is a measure of the extent to which sediments have been winnowed or reworked during transport. It also is a good indicator of the maturity of a sediment, the energy of the transporting agent, and the environment of deposition Sorting can also be a controlling factor in the porosity and permeability of sediments which are very important considerations at RFETS

In order to determine the degree of sorting, Compton (1962) states, "an estimate is made of the range of grain sizes that include the bulk (here 80 percent) of the detrital materials " It is then necessary to count the number of size ranges that are contained in the 80 percent sample (see Table PRO 101-1) The number of size ranges is then compared with Figure PRO 101-3 to determine the degree of sorting that describes the sample best.

4 3 2 3 Degree of rounding

Rounding is a measure of the amount of abrasion a grain has undergone However it is <u>not</u> generally used to describe sediments that are much finer than sand, because grains finer than sand tend to have elastic collisions that have a minimal effect on their shape Two properties that must be considered when estimating the degree of rounding are (1) the composition and (2) the original shape of the grain Rounding can be an indication of sediment maturity, sediment transport history and sometimes provenance It is therefore very important that grains not be broken during the disaggregation and sieving process, as this would artificially skew the sample towards greater angularity The shapes shown in Figure PRO 101-4 should be used to estimate the degree of rounding of individual grains

4 3 2 4 Porosity

Porosity is not always an easy property to estimate in the field because the bedrock can be drastically altered during drilling and coring Generally samples exhibit more porosity than the rock actually contains

Porosity shall be estimated at 20X using a binocular microscope to examine a representative fragment of core and will be expressed as a percentage of the total rock volume The abundance charts shown in Figure PRO 101 5 shall be used The porosity seen at 20X power is an estimate of the effective aquifer porosity

4 3 3 *Estimate of Abundance*

Figure PRO 101 5 shows the field of view seen through a microscope or hand lens Each circle contains a number of black areas Below each circle is the actual percentage of the circle represented by black area All loggers should review Figure PRO 101 5 until they are adept at estimating the percentages contained in the circles

Often it is necessary to estimate the relative abundance of a component In these cases the terms trace some and abundant are useful These terms generally follow a with statement, such as sandstone light olive gray (5Y6/1) very fine to fine grained with a trace of carbonaceous material" The ranges for these terms are given in Table PRO 101 2

Table PRO 101 2 Range of abundance terms

Division	Range of Percent
Trace	>0 to 5
Some	6 to 25
Abundant	26 to 100

4 3 4 *Color*

Color can convey a great deal of information It helps to identify the components of the sediment or rock as well as the cement In addition color indicates the current chemical environment from which the sample was taken For example at RFETS highly weathered (oxidized) sandstone is commonly brownish-orange while unweathered sandstone is light olive gray Transitions from one color to another can be similarly important and should be described, together with the depths of the transitions, when present

To ensure that the color descriptions are accurate and standardized, each sample should be described while it is wet by using one of the standardized color charts based on the Munsell system Either the Geological Society of America Rock color Chart or the Munsell Soil Color Chart shall be used, both of which are in the form of booklets appropriate for field use Both color charts are based on the Munsell system and are taken from the Munsell Book of Color but the Rock-color Chart contains a more abridged selection of colors than is present in the Soil Color Chart

If the sample has dried, it should be moistened with clean water from a squirt bottle Sunglasses shall be removed when a color is being determined If logging indoors, either natural light (sunlight) or incandescent light shall be used Color determination shall not be made under fluorescent lights as they can change the apparent colors and differences between colors Both the color name and its numerical designation shall be reported on the logging form (Form PRO 101A) such as silty sandstone with some clay, light olive gray (5Y6/1)

TERMS FOR DEGREE OF SORTING

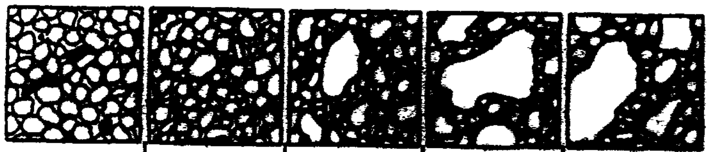


FIGURE PRO 101-3

Terms for degrees of sorting. The numbers indicate the number of size-classes included by the great bulk (80 percent) of the material The drawings represent sandstones as seen with a hand lens Silt and clay-size materials are shown diagramatically by the fine stipple Taken from Compton, 1962

TERMS FOR DEGREE OF ROUNDING

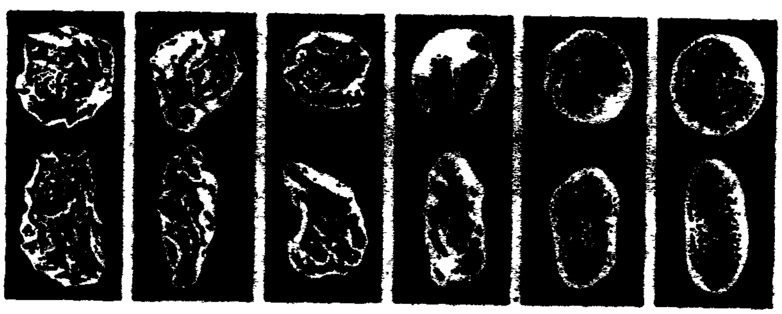
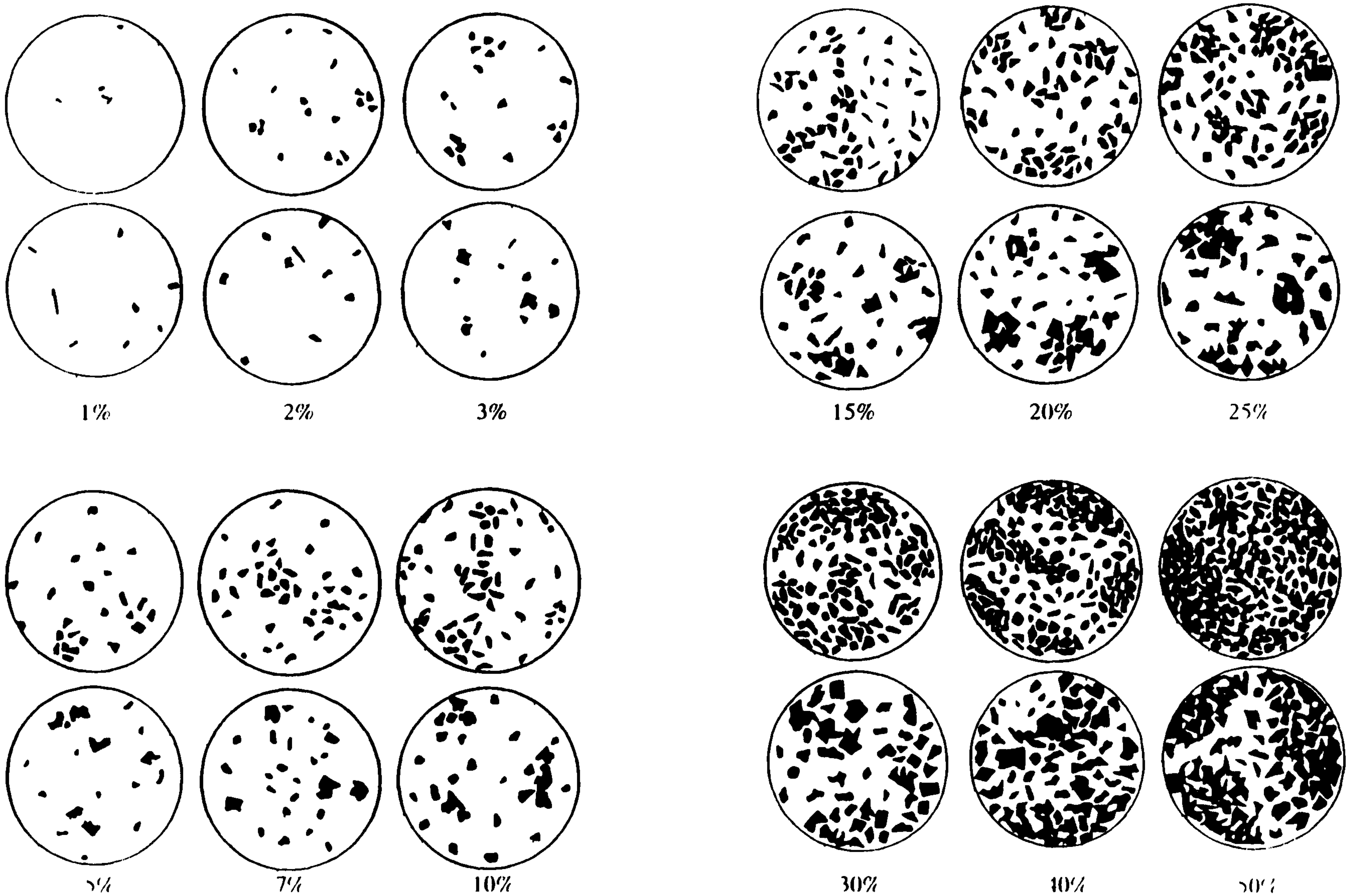


FIGURE PRO 101-4

Terms for degree of rounding grains as seen with a hand lens After Powers M C 1953 Journal of Sedimentary Petrology v 23 p 118 Courtesy of the Society of Economic Paleontologists and Mineralogists Taken from Compton, 1962

CHARTS FOR ESTIMATING PERCENTAGE COMPOSITION OF ROCKS AND SEDIMENT



Prepared by R D Terry and G V Chilingar for Journal of Sedimentary Petrology (v 25 pp 229-234 1955) reprinted as Data Sheet 6 of Geotimes available from the American Geological Institute 2101 Constitution Ave N W Washington D C Reprinted here by permission of the authors and the Society of Economic Paleontologists and Mineralogists Taken from Compton 1962

FIGURE PRO 101-5

4 3 5 *Rock Classification*

Clastic rocks are primarily classified on the basis of the dominant grain size present The majority of the bedrock recovered from boreholes at RFETS is claystone, siltstone sandstone, and hybrids of these end members The second and sometimes third most frequent constituents act as modifiers and precede the major rock name in the description such as silty sandstone' or ' clayey siltstone However, if a rock is composed of 80 percent or more of one constituent, then it should be named solely as that rock type The secondary textural modifiers should be included in the description following a "with" statement, such as "silty sandstone with clay' Figure PRO 101-6 shows the rock classifications and corresponding lithologic symbols that shall be used when logging bedrock at RFETS

4 3 6 *Cement*

The nature of the cementing medium should be described whenever possible Typical cementing agents at RFETS include clay (argillaceous cement), calcium carbonate (caliche), iron and iron/manganese oxides, and silica. If the cement composes a major constituent of the rock (e g., iron oxide nodules in an iron oxide-cemented rock, or caliche nodules in a calcium carbonate-cemented rock, the appropriate lithologic symbols shall be added to the lithologic log

4 3 7 *Friability*

The tendency of a rock to crumble is related to how well it is cemented and the extent to which it has been weathered or otherwise altered Table PRO 101-3 shows the degree of friability Note that friability refers to a rock breaking between individual grains. It is not the same as fissility, the tendency of a rock to break along bedding planes joints, or other sedimentary structures

Table PRDO 101-3 Degree of friability

Term	Coarser Material (e.g., sandstone)	Finer Material (e g. claystone)
Highly Friable	Crumbles readily into individual grains under light finger pressure	Will powder or smear readily under light finger pressure
Moderately Friable	Will crumble into individual grains with repeated rubbing	Will powder or smear with repeated rubbing
Slightly Friable	Breaks into individual grains if scraped with a knife	Will powder or smear if scraped with a knife
Non-Friable	Cannot be broken into individual grains by any of the methods described above	Cannot be made to powder or smear by any of the methods described above

4 3 8 *Composition*

It is not the objective of this SOP to classify sedimentary rocks on the basis of their mineral content, for example by using ternary diagrams labeled quartz/chert, feldspar, and lithic fragments at the corners Instead, the logging geologist is concerned with describing only dominant and accessory minerals, fossils,
And other components that distinguish one rock from another The descriptive term(s) should follow a "with' statement, such as "silty sandstone light olive gray (5Y6/1), very fine grained, with some gneiss rock fragments

4 3 9 *Bedding and Internal Structure*

In sedimentarv rocks bedding may be evident from apparent differences in texture composition and color and reflects changes in the depositional environment the source material or both Depending on the depositional processes that were involved bedding boundaries may or may not represent a specific moment in time

Compton (1962) classifies bedding as repeated sequences of beds shapes of individual beds and cross bedding (cross-stratification) Repeated sequences of beds are produced by cyclic changes in the sedimentary processes Shapes of individual beds are classified as tabular lenticular linear wedge shaped or irregular Cross stratification is classified on the basis of its external and internal characteristics External forms of cross stratification are tabular wedge shaped, and trough shaped Internal descriptive terms that are commonly used are graded massive laminated, and tangential (Figure PRO 101 7) Other internal features to be described include ripple marks flow structures, burrows and tubes load casts and desiccation cracks (mud cracks)

4 3 10 *Fractures and Slickensides*

Fractures should be described whenever they are present, and drawn in the appropriate column on the logging form (Form PRO 101A) Fractures occur naturally in bedrock and should not be confused with breaks induced by coring and handling Fracture characteristics that should be recorded include

- Whether the fracture is opened or healed
- The composition of the material filling the fracture if any
- The angle of the fracture from the horizontal
- The apparent displacement of bedding across the fracture
- Whether Slickensides are present and the angle of any striations from the horizontal

4 3 11 *Moisture Content*

As previously noted, accurate descriptions of moisture content are extremely important for the proper design of groundwater monitoring wells and because of other groundwater-related issues at RFETS Moisture must be described immediately upon recovering the core as it typically evaporates quickly due to exposure to air and drilling related warming of the core Moisture content shall be described as discussed in Subsection 4 2 4

4 3 12 *Lithologic Description*

Generally lithologic descriptions should be made in the following order or in an order that is comprehensive and includes all of the following descriptions in a logical or applicable sequence

- Top of bedrock, if present
- Main rock type with modifiers
- Color(s)
- Grain size
- Degree of sorting
- Degree of rounding
- Porosity
- Cement
- Friability
- Composition

- Bedding and internal structure
- Fractures and Slickensides
- Moisture content

5 0 RECORDS

Immediately after all lithologic descriptions core data and borehole/well data for a boring has been recorded on Form PRO 101A, the logging geologist shall contact the appropriate RMRS oversight personnel to arrange for a core log quality control check and sign-off by an approved RMRS geologist. The RMRS geologist responsible for the core log quality control sign-off shall visually inspect the core against the core log to assure that the logger is in compliance with the core logging procedures as specified in this SOP and/or any other controlling documents if applicable The RMRS geologist may request that additional comments be incorporated into the description or request a check of the sieve analysis or other procedures to confirm the description of the core intervals in question An example of a completed Form PRO 101A is included as Figure PRO 101-8

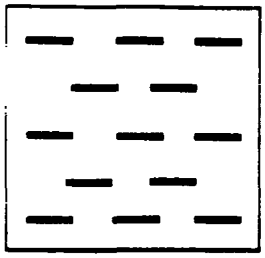
After the RMRS geologist has signed off on the log, all data shall be entered into electronic format using the RMRS-specified core log software program and format. Draft hard copy logs and the associated electronic files shall be delivered to RMRS within 3 weeks after the sign-off date RMRS personnel shall inspect the draft copies and if necessary they will stipulate changes. The subcontractor will make changes within a week of receipt of the RMRS comments and shall deliver a second draft log in both hard copy and digital format.

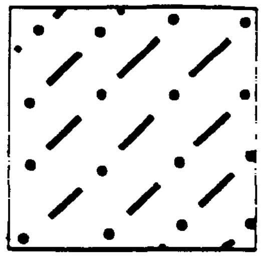
Final logs and core photographs shall be delivered to RMRS at a time specified by the RMRS contract or project manager All final logs and photographs shall be delivered in the RMRS standard format.

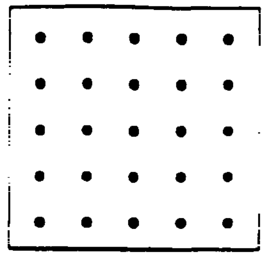
A permanent record of the implementation of this SOP shall be kept by documenting all information required by the SOP on the Borehole Log form (Form PRO 101A) If core is being logged onsite by a rig geologist and in more detail in a core logging facility by a logging geologist, the rig geologist shall also complete Form PRO 101B Drilling activities shall also be documented on the appropriate drilling field activities report forms (see SOPs OPS-PRO 114 Drilling and Sampling Using Hollow-Stem Auger Techniques, OPS-PRO 116 Rotary Drilling and Rock Coring, and OPS-PRO 124, Push Subsurface Soil Sample) In most cases, the logger and/or rig geologist will also keep a field logbook Logbooks shall serve as supporting documentation for all forms

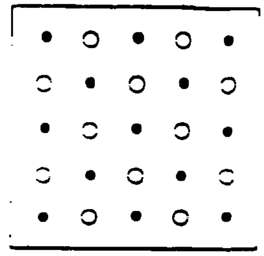
The logging geologist will bear the primary responsibility for following each procedure within this SOP, or those procedures within this SOP that apply to the ongoing project as defined by the appropriate work plan or other controlling document or written RMRS communication

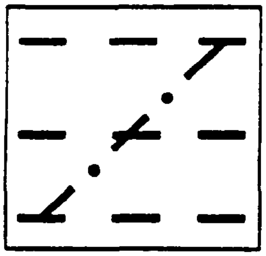
FIGURE PRO 101-6 LITHOLOGIC SYMBOLS FOR COMMON CLASTIC ROCKS

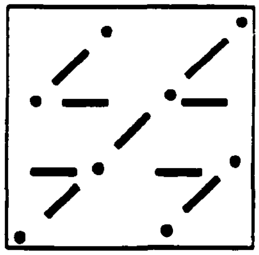

CLAYSTONE

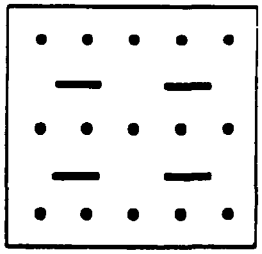

SILTSTONE

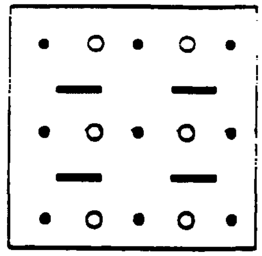

SANDSTONE

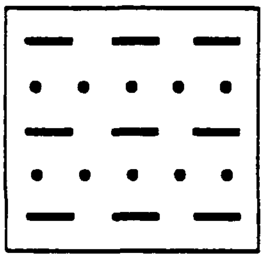

CONGLOMERATE

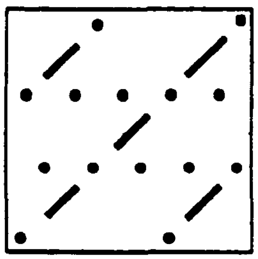

SILTY CLAYSTONE

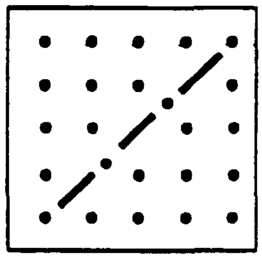

CLAYEY SILTSTONE

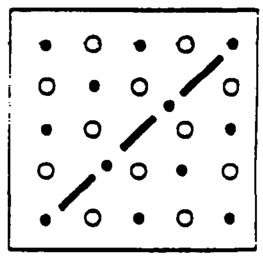

CLAYEY SANDSTONE

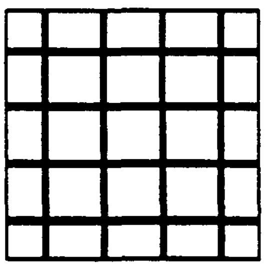

CLAYEY CONGLOMERATE

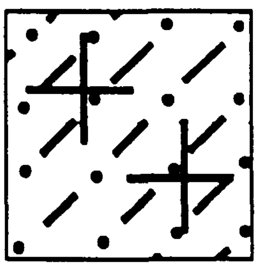

SANDY CLAYSTONE

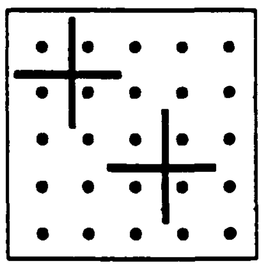

SANDY SILTSTONE

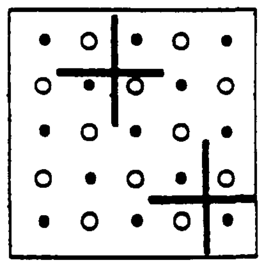

SILTY SANDSTONE

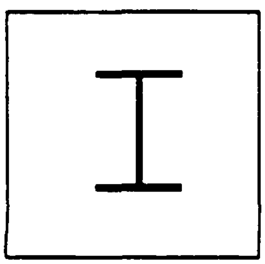

SILTY CONGLOMERATE

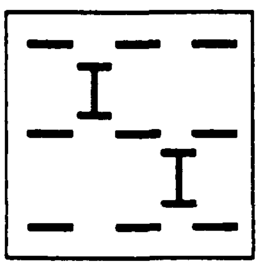

CALICHE


SILTSTONE W/ CALICHE

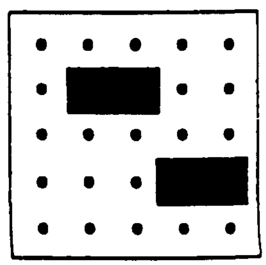

SANDSTONE W/ CALICHE


CONGLOMERATE W/ CALICHE

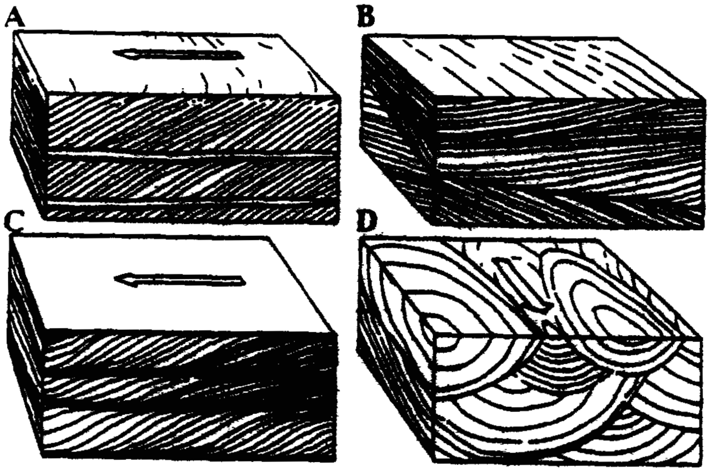

IRONSTONE OR IRONOXIDE MODULES


CLAYSTONE W/ IRONOXIDE MODULES

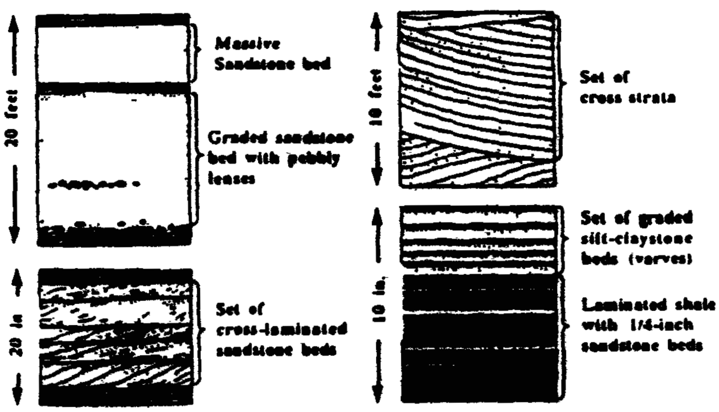

COAL


SANDSTONE W/ CARBONACEOUS MATERIAL

BEDDING AND INTERNAL STRUCTURES



Cross-bedded rocks. (A) Tabular sets with diagonal patterns (B) Wedge sets showing considerable erosion between each set (C) Tabular to lenticular sets with tangential patterns typically these are laminated marine beds (D) Symmetrical trough sets with distinctly linear axes typically these are large-scale fluvial features. The arrows indicate current directions Taken from Compton 1962



Various beds and sets of beds Taken from Compton, 1962

FIGURE PRO 101-7

6 0 REFERENCES

6 1 Source References

The following references were reviewed before this procedure was written

American Society for Testing and Materials (ASTM) 1989 *Method for Particle-Size Analysis of Soils Soil and Rock Dimensions Stone and Geo-Synthetics* Vol 04 08 Sec D422

American Society for Testing and Materials (ASTM) 1989 *Practice for Description and Identification of Soils for Engineering Purposes (Visual-Manual Procedures) Soil and Rock Dimensions Stone and Geo-Synthetics* Vol 04 08 Sec D2488

Blatt, H G Middleton R Murray 1972 *Origin of Sedimentary Rocks* Prentice Hall

Compton, Robert R. 1962 *Manual of Field Geology* John Wiley & Sons Inc

Harlan R L K E Kolm E D Gutentag 1989 *Water-Well Design and Construction* Development in Geotechnical Engineering #60 Elsevier

Krumbein W C F J Pettijohn 1966 *Manual of Sedimentary Petrography* Appleton-Century Crofts

Unified Soil Classification System 1960 *Appendix A Characteristics of Soil Groups Pertaining to Embankments and Foundations Appendix B Characteristics of Soil Groups Pertaining to Roads and Airfields* U S Army Engineer Waterways Experiment Station Vicksburg MS

6 2 Internal References

Related SOPs cross referenced by this SOP are these

SOP RMRS/OPS PRO 114 Drilling and Sampling Using Hollow Stem Auger Techniques

SOP RMRS/OPS PRO 116 Rotary Drilling and Rock Coring

SOP RMRS/OPS-PRO 124 Push Subsurface Soil Sample

SOP FO 8, Handling of Drilling Fluids and Cuttings

SOP FO 10 Receiving Labeling and Handling Environmental Materials Containers

SOP FO 15 Photoionization Detectors (PIDs) and Flame Ionization Detectors (FIDs)

SOP FO 16 Field Radiological Measurements

U S DEPARTMENT OF ENERGY ROCKY FLATS PLANT

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 2 OF 7

Borehole Number Well or BH Number
Location North 749718.7 East 2086747.7
Date 11/17/91
Geologist JBP/Stratigrapher Initials
Drilling Equip CME 75

Surface Elevation 5962 ft
Area East Trenches
Total Depth 72.0 ft
Company Subcontractor Project No OU #
Sample Type Continuous Core

RMRS LOGGING SUPERVISOR
APPROVAL ____________ DATE ____________

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
10.0; Box 2 of 8 10.0'-16.5'	10.0; Run6; 12.0; Run 7; 14.0	10.0; 2.0'; 1.9'	Sample Number; Sample Number; Sample Number			Gravel 37% Sand 52% Silt 7% Clay 4%	SM	10–14		SM-SW 10.0'-12.7' Gravelly Sand. Dark yellowish brown (10YR 4/2) to moderate yellowish brown (10YR5/4). Sand coarse grained, subangular. Gravel avg size = 0.5 inches, max. size = 1.0 inch, subangular to angular. Well graded, sand predom Quartz, gravel predom Quartzite and feldspar. T... alcite, dry
			C			Sand 40% Silt 4...%		14–16.5		... 14.0'-16.5' Sandy Clay with trace of silt. Dusky yellowish brown (10YR 2/2) to dark yellowish brown (10YR 4/2). Sand fine grained, subangular. Low plasticity, dry. Top of Bedrock at 16.5'
16.5; Box 3 of 8 16.5'-22.0'	Run8; 19.0	4.3'	Sample Number; C			>95% Clay		16.5–20		Claystone 16.5-20.5'. Dusky yellowish brown (10YR 4/2). Some carbonaceous material, moderately friable, moist

EXAMPLE

NOTES General USCS is modified for this log as follows
Materials amounts are estimated by % volume instead of % weight
(1) Badly broken core accurate footage measurements not possible
(2) Core breaks cannot be matched accurate footage measurements not possible

Procedure No RMRS/OPS-PRO 101
Revision 0
Date effective 12/31/98

(4011 930-0134-930) Form GT (AX03/01/97)

FIGURE PRO 101-8

U S DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO 101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE ____ OF ____

Borehole Number ____________________ Surface Elevation ____________________

Location North ____________ East ____________ Area ____________________

Date ____________________ Total Depth ____________________

Geologist ____________________ Company ____________ Project No ____________

Drilling Equip ____________________ Sample Type ____________________

RMRS LOGGING SUPERVISOR

APPROVAL ____________________ DATE ____________________

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION

NOTES General USCS is modified for this log as follows
Materials amounts are estimated by % volume instead of % weight
(1) Badly broken core accurate footage measurements not possible
(2) Core breaks cannot be matched accurate footage measurements not possible

Procedure No RMRS/OPS PRO 101
Revision 0
Date effective 12/31/98

14011 930-0134 930X Form GT 1AX03/01

FORM PRO 101B Preliminary Borehole Field Log

Date ____________________

Rig Geologist ____________________ Company ____________________

Notes