REGION V SOIL JUDGING HANDBOOK

South Dakota State University
In Cooperation with the USDA-NRCS (SD)

October 1 - 6, 2023

Amber Anderson, Nic Jelinski, Becky Young, Judith Turk, Kerry Clark, Deann Presley, Colby Moorberg, Kris Osterloh, Ashlee Deere and past region 5 soil judging coaches. **Fall 2023 Editors:** Kris Osterloh, Kent Cooley (USDA-NRCS), Lance Howe (USDA-NRCS), and Steve Winter (USDA-NRCS)

PREFACE

South Dakota State University and SD-NRCS are looking forward to welcoming you to the Black Hills region in western South Dakota Oct 1-6th, 2023.

This handbook provides information about the 2023 Region 5 Soil Judging Contest. This manual provides the rules, scorecard instructions, and additional information about the contest. This material has been adapted from previous handbooks, with some modification. Other references used to develop this handbook include *Soil Survey Manual* (Soil Division Staff, 2017), *Field Book for Describing and Sampling Soils v 3.0* (Schoeneberger et al., 2012), *Keys to Soil Taxonomy 13th edition* (Soil Survey Staff, 2022), *Soil Taxonomy 2nd edition* (Soil Survey Staff, 1999) and the *Illustrated Guide to Soil Taxonomy v 2* (Soil Survey Staff, 2015). In keeping with recent contests, emphasis is placed on fundamentals such as soil morphology, taxonomy, and soil-landscape relationships.

Soil Judging remains the most important experiential opportunity for soils students. In a short period of time, students gain a tremendous depth of experience in reading landscapes, describing soil profiles, and making use of suitability interpretations. In a much deeper sense, students learn to be bridge builders, connecting with people through a shared love of the land and the soil resource that crosses cultural, socioeconomic, and political boundaries. For this reason, Soil Judgers are world-changers, representing the heart and soul of our institutions.

We are appreciative of the support we are receiving in this planning process, particularly the landowners of Snyder Ranch, US Forest Service, and the Bureau of Land Management; tours provided by Badlands and Wind Cave National Parks; and financial support from the Hills Area Conservation Districts, Millborn Seeds, Professional Soil Scientist Association of South Dakota, and the South Dakota Soil Health Coalition.

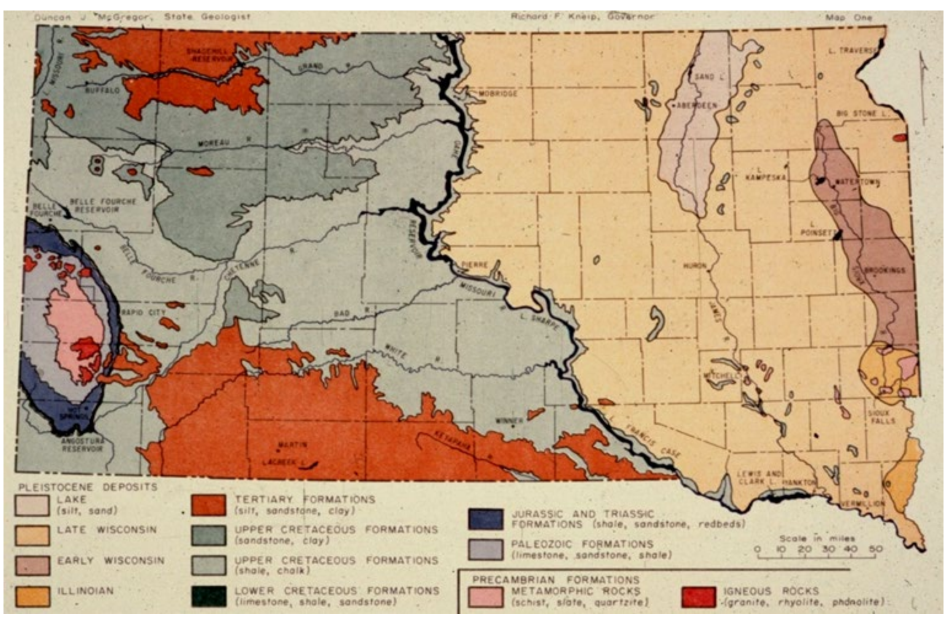


Figure 1 - Geologic Map of SD (McGregor, 1993).

TABLE OF CONTENTS

INTRODUCTION

Soil judging provides an opportunity for students to study soils through direct experience in the field. Students learn to describe soil properties, identify different kinds of soils and associated landscape features, and interpret soil information for agriculture and other land uses. These skills are developed by studying a variety of soils formed from a wide range of parent materials and vegetation in different topographic settings. It is hoped that by learning about soils and their formation, students will gain an appreciation for soil as a natural resource. We all depend on soil for growing crops and livestock, building materials, replenishing water supplies, and waste disposal. It is increasingly clear that if we do not take care of our soils, loss of productivity and environmental degradation follow. By understanding more about soils and their management through activities like soil judging, we stand a better chance of conserving soil and other natural resources for future generations.

Students in soil judging participate in regional and national contests held annually in different states. These contests are an enjoyable and valuable learning experience, giving students an opportunity to get a first-hand view of soils and land use outside their home areas. As an activity within the American Society of Agronomy, soil judging in the United States is divided into seven regions. Our Region V includes universities from the states of Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. Collegiate soil judging originated in the southeastern United States in 1956 and began in the Midwest in 1958 with a contest hosted by Kansas State University. Today, over 40 universities are involved with soil judging through the American Society of Agronomy.

This guidebook is organized into several sections that describe the format and content of the contest. The contest involves soil description and interpretation at sites by students, who record their observations on a scorecard. The content sections of this guidebook follow the organization of soil and related information given on the contest scorecard. Those sections include site characteristics, soil morphology, soil hydrology and profile properties, soil classification, and soil interpretations.

This guidebook contains information related to the 2023 Region V Soil Judging Contest. Coaches are encouraged to consult other sources of information as well including the *Soil Survey Manual* (Soil Division Staff, 2017), *Field Book for Describing and Sampling Soils v 3.0* (Schoeneberger et al., 2012), Simplified version of *Keys to Soil Taxonomy 13th edition* (Soil Survey Staff, 2022), *Soil Taxonomy 2nd edition* (Soil Survey Staff, 1999) and the *Illustrated Guide to Soil Taxonomy v 2* (Soil Survey Staff, 2015). Other resources available for coaches to consult include web soil survey, official series descriptions, Google Earth, and traditional soil surveys for block diagrams and narratives. Specific sources of information for this contest are also included in the References section. Many portions of the text in this guidebook have been adapted from previous Region V contest guidebooks and we recognize that contributions of those writers to this effort.

CONTEST RULES, SCORING, AND PROCEDURES

Table 1. Contest Events and Schedule

Date/Time	Activity	Location	Notes
Sunday, Oct 1 8:00 am to 5:00 pm	Tours of Badlands and Wind Cave National Parks	Near Interior and Hot Springs, SD	Lunch and dinner on your own.
Monday, Oct 2- Wed, Oct 4	Practice Pits Geology Overview Monday Evening (TBD)	Deadwood Elks Lodge Deadwood, SD	Team rotation schedule will be provided. Coaches meeting is planned to be Tuesday @ 7:00PM.
Wednesday, Oct 5	Contest Banquet	TBD	Dinner provided by Renovo Seeds / South Dakota Soil Health Coalition and official contestants must be identified by 7:00PM
Thursday, Oct 6	Contest Day	TBD	Lunch provided with registration
Friday, Oct 7 7:30 am	Awards Breakfast	TBD	Breakfast provided by Hills Area Conservation Districts.

Individual and Team Contests

The individual and team contests will be held on **Thursday, October 6th** and will consist of five sites: two individual-judged sites in the morning and three team-judged sites in the afternoon. At each site, a pit will be excavated, and control area(s) will be designated for the measurement of horizon depths and boundaries. The control area will constitute the officially scored profile and must remain undisturbed and unblocked by contestants. A tape measure will be fixed within the control area.

The site number, number of horizons to be described, the profile depth to be described, and any additional information or laboratory data deemed necessary for correct classification will be provided to contestants. Typically, six horizons will be described at each pit. However, up to seven horizons could be required to give the best understanding of the parent materials for each pit. Some pits may also have less than six horizons. A marker (i.e. nail) will be placed at the base of the third horizon. A pit/site monitor at each site will enforce the rules, answer any questions, keep time limits, clean the soil from the base of the pit as needed and/or requested, and assure all contestants have an equal opportunity to judge the soil.

A team usually consists of four contestants from each school but can be as few as three. A limited number of alternates may participate in the judging of the contest sites, depending upon space availability (check with contest leader(s) in advance). However, the coach must designate the four official contestants prior to the contest (by 7:00 pm Wednesday, Oct 5, 2023). The individual scorecards of the alternates will also be graded but not counted in the team score for the contest. Alternates are eligible for individual awards and can participate in the team judging. Each school will be allowed one team for the "Team Judging" part of the contest.

General Grading Criteria

All scorecards will be graded by hand. In order to avoid ambiguity, all contestants are urged to write clearly and use only those abbreviations provided. Ambiguous or unrecognizable answers will receive no credit. Designated abbreviations or the corresponding, clearly written terminology will be graded as correct responses. Scorecards will be graded by a minimum of two coaches, assistant coaches, or contest personnel from different schools. A coach or assistant coach cannot be the first to grade a scorecard from their own students. Coaches and assistant coaches may be the second to grade scorecards from their own students if necessary.

Contest Equipment and Materials

Contestants provide the following materials for their own use:

- clipboard	- acid bottle (10% HCl)
- calculator	- clinometer or Abney level
- water bottle	- pencils (number 2 pencil is required)*
- hand lens	- Munsell Color Charts
- knife	- containers for soil samples
- rock hammer	- 2mm sieve
- tape measure	- hand towel

*A number 2 pencil is required because of the waterproof paper used for the official scorecards. An ink pen will not work when the scorecards are wet.

This will be an "open book" contest. Any relevant written materials (including this handbook and practice sheets) will be allowed in the contest. A clinometer, knife, and color book will be provided at each pit for emergency situations as well as extra water, acid (10% HCl), and blank scorecards. Contestants are not allowed to have mobile phones during the contest under any circumstances. If a contest official sees one, that contestant will be disqualified for both the individual and team events.

Each site will have its own scorecard designated by a unique border color. Each individual or team contestant will be given a packet during the contest that contains color scorecards corresponding to each site. Since this is an open book contest, an extra set of abbreviations will not be provided, and contestants should use the set of abbreviations in their handbook.

Student Scorecard Responsibilities

Students must correctly enter the pit number and nail depth on their scorecard. Scorecard entries must be recorded according to the instructions for each specific feature to be judged (see following sections of the handbook). Only one response should be entered in each blank, unless otherwise specified. The official judges may decide to recognize more than one correct answer to allow partial credit for alternative answers. Entries for soil morphology may be recorded using the provided abbreviations or as a complete word. Contestants should enter the depth of the last horizon (if a boundary) or a dash to specify a completed response.

Contest Timing
Contestants will be allowed sixty (60) minutes to judge each individual site. The time in and out of the pit for the individually judged sites will be as follows: 5 minutes in/out, 5 minutes out/in, 10 minutes in/out, 10 minutes out/in, 5 minutes in/out, 5 minutes out/in, and 20 minutes free time for all to finish. The contestants who are first "in" and "out" will switch between the two individual pits to allow equal opportunity for all contestants to be first in or first out (i.e. each contestant should be in the pit first on one pit and out of the pit first on the other pit). Two members of each team will describe the left pit face and other two team members will describe the right pit face. NOTE: This timing schedule may be modified depending on the number of teams and contestants participating. However, each individual will have at minimum 60 minutes at each site.

For team judging, the tentative timing will be 10 minutes in, 10 minutes out, 10 minutes in, 10 minutes out, 10 minutes in, 10 minutes to finish. Each team will have a minimum of 60 minutes at each site, including 30 minutes alone at the control section. The timing may change if coaches request a change.

Team Scoring
The overall team score will be the aggregate of the top three individual scores at each individually judged sites plus the team-judged sites. In the case where a team is comprised of only three members, all individual scores will count towards the team's overall score. Individual scores will be determined by summing the three site scores for each contestant (Table 2).

Table 2. Example team score calculation for individual sites.

Contestant	Individual Site 1	Individual Site 2	Individual Score
1	212	196	408
2	230	204	434
3	**190**	183	373
4	200	**174**	374
Team Score	642*	583*	

*Top three scores added for team score for each site. Scores in **bold** were the lowest individual scores for each pit and were not used to compute the team score. The final team score will consist of scores from the three team judged pits plus the top three scores for the individually judged pits.

Jumble Judging
In 2021, Region V debuted "Jumble Judging". The Jumble Judging portion of the contest will not count towards individual or team awards but will have associated awards as a category in and of itself. For Jumble Judging, all students will be assigned to inter-school teams based on pairings of schools that will be present at the same practice sites from Monday-Wednesday. The final pit of each practice day will not have an associated key provided to coaches beforehand. Instead, coaches will work together to organize their students into pre-defined inter-collegiate teams (the assigned teams will be announced at the Geology Overview on Monday, Oct 2nd). Coaches will be responsible for establishing and maintaining rotations. The tentative timing for jumble judging will be a total of 1.5 hours, consisting of 10 minutes in, 10 minutes out, 10 minutes in, 10 minutes out, 10 minutes in, 10 minutes to out, 15 minutes in, 15 minutes out. Coaches will collect scorecards on site and turn them in to contest organizers at the end of each day. Awards will be presented to the top 3 jumbled teams, based on the combined score of 3 pits (one from each practice day).

Tie-Break Rules
The clay content of one horizon at one of the individually judged sites will be used to break ties in team and individual scores. In order to break a tie in team scores, the mean clay content will be calculated from the estimates provided by all the contestants of a given team. The team with the mean estimate closest to the actual value will receive the higher placing. If this method does

not break the tie, the next lowest horizon of the same site will be used in the same manner until the tie is broken. In the event of a tie in individual scores, the clay content of the tie breaker horizon will be compared to that estimated by each individual. The individual with the estimate closest to the actual value will receive the higher placing. If this does not break the tie, the next lowest horizon at the same site will be used in the same manner until the tie is broken.

Contest Results
Final contest results will be announced at a breakfast awards ceremony on Friday morning, October 6th, 2023. Awards were donated by Professional Soil Scientist Association of South Dakota (PSSASD). Every effort will be made to avoid errors in determining the contest results. However, the results presented at the awards ceremony are final. Trophies will be awarded to the top four teams overall, the top four teams in team judging competition, and the top five individuals. Placings in the overall team score will be used to determine the teams qualifying for the National Collegiate Soil Judging Contest. According to current rules, the top three, if 4-7 teams participate, or four, if 8-9 teams participate, from Region 5 will qualify for the 2024 National Contest.

SCORECARD INSTRUCTIONS

The scorecard (attached at the end of this guidebook) consists of five parts:

A. Morphology
B. Soil Hydrology and Profile Characteristics
C. Site Characteristics
D. Soil Classification
E. Site Interpretations

Numbers in parentheses after each item in a section indicate the points scored for one correct judgment. If a pedon has more than one parent material, diagnostic subsurface horizon, applicable subgroup, or reason number for site interpretations, five points will be awarded for each correct answer. In these sections of the scorecard, negative credit (minus 5 points for each incorrect answer, with a minimum score of zero for any section) will be used to reduce guessing. More than one entry in other items of the scorecard will be considered incorrect and will result in no credit for that item. Sections with multiple numbers listed in parentheses (e.g. Hydraulic Conductivity) will give partial credit for the next closest answers.

Official judges, in consultation with a quorum of coaches, have the prerogative of giving full or partial credit for alternative answers to fit a given site or condition. (e.g., hydraulic conductivity where 3 points are given if the answer is close to the correct answer).

A. SOIL MORPHOLOGY

For entering answers in the morphology section of the scorecard, the provided standard abbreviations may be used or the word(s) may be written out. Abbreviations or words that are ambiguous or may be interpreted as an incorrect answer will not receive credit. The Munsell color notation (e.g., 10YR 4/2) should be used and not the color names. If spaces on the scorecard for the soil morphology section do not require an answer (e.g., if no concentrations are present in a horizon), a dash or blank in those spaces will be considered correct. The *Field Book for Describing and Sampling Soils* (version 3.0, 2012), Chapter 3 of the *Soil Survey Manual* (2017) entitled, "Examination and Description of Soils", and Chapter 18 of *Keys to Soil Taxonomy 13th Edition* (2022) entitled "Designations for Horizons and Layers" should be used as a guide for horizon symbols and descriptions.

A-1. DESIGNATION FOR HORIZONS AND LAYERS

The number of horizons to be described and the total depth of soil to judge will be provided on an information card at each site. Narrow transition horizons (< 8 cm thick) should be regarded as a gradual boundary and the center used as the measuring point for the boundary depth. ***Horizons that can be thinner than 8 cm and should be described are A or E. These horizons must be at least 2 cm thick to be described***. **<u>O horizons will not be described for this contest</u>.**

Three kinds of symbols are used in various combinations to designate horizons and layers in Section A of the contest scorecard: capital letters, lower case letters, and Arabic numerals. Capital letters are used to designate master horizons (or in some cases, transition horizons). Lower case letters are used as suffixes to indicate specific characteristics of the master horizon and layers. Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon or layer and as prefixes to indicate lithologic discontinuities.

<u>Prefix</u>: Lithologic discontinuities will be shown by the appropriate Arabic numeral(s). A dash or a blank will receive credit where there is no prefix on the master horizon.

<u>Master</u>: The appropriate master horizon (A, E, B, C, R), as well as any transitional horizons (e.g., BC) or combination horizons having dual properties of two master horizons (e.g., B/E), should be entered as needed. ***Combination horizons (e.g. B/E) – only the dominant horizon will be described***. If a horizon is close to a 50/50 split, either the B or E horizon (in this example) will be given credit which is up to the discretion of the judges.

<u>Horizon Suffixes</u>: Enter the appropriate lower case letter or letters, according to the definitions given in Chapter 18 of *Keys to Soil Taxonomy 13th edition* (2022). For this contest you should be familiar with the following letter suffixes: b, g, k, n, p, r, ss, t, w, y, and z. If used in combination, the suffixes must be written in the correct sequence in order to receive full credit. If a horizon suffix is not applicable, enter a dash or leave the space blank.

Number: Arabic numerals are used as suffixes to indicate vertical subdivisions within a horizon or layer. Sequential subhorizons having the same master horizon and suffix letter designations should be numbered to indicate a vertical sequence. For other horizons, enter a dash or leave the space blank.

Primes: Primes are used when the same designation is given to two or more horizons in a pedon, but where the horizons are separated by a different kind of horizon. The prime is used on the lower of the two horizons having identical letter designations and should be entered with the capital letter for the master horizon (e.g., Ap, E, Bt, E', B't, Btk, C).

A-2. BOUNDARY

A-2-1. Depth of Lower Boundary

Boundary depths are determined (in centimeters) from the soil mineral surface to the middle of the lower boundary of each horizon (if an O horizon is present, measurements begin at the base of the O horizon). For a reference as to the position of the soil surface, the depth from the soil surface to the nail in the **base of the third horizon** is posted on the pit card or information sheet. The total soil profile depth to be described will also be given on the pit information card or sheet.

If the total soil profile depth corresponds to the lower boundary of the last horizon, the horizon boundary depth should be described. Otherwise, a dash or the total soil profile depth with a + sign (e.g., 100+) should be entered on the scorecard. Note that boundary depths should be judged from the tape measure anchored to the pit face and vertical to the nail within the control section. Measurements of boundary depth should be made in the undisturbed area of the pit reserved for this purpose. Therefore, for horizons with wavy boundaries, the boundary depth at the tape should be recorded rather than an estimate of the middle of the wavy boundary across the control section.

Boundary measurements should be made at the center of the boundary separating the two horizons, particularly when the boundary distinctness is not abrupt. Answers for lower boundary depths will be considered correct if within the following limits above or below the depth determined by the official judges: for **abrupt** (including very abrupt) boundaries +/- 1 cm; for **clear** boundaries +/- 2 cm; for **gradual** boundaries +/- 4 cm; and for **diffuse** boundaries +/- 8 cm. Partial credit for depth measurements may be given at the discretion of the official judges where the boundary is not smooth.

If a lithic or paralithic contact occurs at or above the specific judging depth, the contact should be marked as a subsurface feature in Part D of the scorecard and should be considered in evaluating the hydraulic conductivity, effective rooting depth, and water retention to 150 cm. Otherwise, the lowest horizon should be mentally extended to a depth of 150 cm for making all relevant evaluations. When a lithic or paralithic contact occurs within the specified judging depth, the contact should be considered as one of the requested horizons, and the appropriate horizon nomenclature should be applied (e.g., Cr or R). However, morphological features of Cr or R horizons need not be provided in Part A of the scorecard. If the contestant gives morphological information for a designated Cr or R horizon, the information will be ignored and will not count against the contestant's score. If you are not sure a layer is a Cr horizon or not, you are encouraged to fill in the morphological information for that layer, so you do not lose many points if the layer is not a Cr horizon.

A-2-2. Distinctness of Boundary

The distinctness of boundaries separating various horizons must be described if they fall within the designated profile depth indicated by the judges for each site. Categories of distinctness of boundaries are:

Table 3. Soil horizon boundary distinctness category.

Boundary	Abbreviation	Boundary Distinctness
Abrupt	**A**	< 2 cm
Clear	**C**	2.1 to 5 cm
Gradual	**G**	5.1 to 15 cm
Diffuse	**D**	> 15 cm

There will be no distinctness category given for the last horizon, unless a lithic or paralithic contact exists at the lower boundary. A dash or a blank is acceptable for distinctness of the last horizon to be described when a lithic or paralithic contact is not present.

A-3. COLOR

Munsell soil color charts are used to determine the moist soil matrix color for each horizon described. Color must be designated by hue, value, and chroma. Space is provided to enter the hue, value, and chroma for each horizon separately on the scorecard. At the discretion of the official judges, more than one color may be given full credit. Color is to be judged for each horizon by selecting soil material to represent that horizon. The color of the surface horizon will be determined on a moist, rubbed (mixed) sample. For lower horizons (in some soils this may also include the lower portion of the epipedon) selected peds should be collected from near the central part of the horizon and broken to expose the matrix. If peds are dry, they should be moistened before the matrix color is determined. Moist color is that color when there is no further change in soil color when additional water is added. For Bt horizons with continuous clay films, care should be taken to ensure that the color of a ped interior rather than a clay film is described for the matrix color. For neutral colors (N hues), the chroma is 0.

A-4. TEXTURE & ROCK FRAGEMENTS

A-4-1. Texture

Texture refers to the proportion of sand, silt, and clay-sized particles in soil. These proportions are expressed on a percentage basis, with sand, silt, and clay always adding up to 100%. Textural classes, shown in the USDA texture triangle (see Abbreviations & USDA Textural Triangle), group soil textures that behave and manage similarly.

A-4-2. Rock Fragment Modifier

Modifications of texture classes are required whenever rock fragments > 2 mm occupy more than 15% of the soil volume. If rock fragments are present, the percentage should be recorded in the corresponding box, even if the soil contains under 15% rock fragments. Credit will be given for within +/- 5% of the value.

For this contest, the terms "gravelly, cobbly, stony, bouldery, channery, and flaggy" will be used (Table 4). For a mixture of sizes (e.g., both gravels and stones present), the largest size class is named. A smaller size class is named only if its quantity (%) exceeds 2 times the quantity (%) of a larger size class. The total rock fragment volume is used (i.e. sum of all the separate size classes) to determine which modifier goes with the fragment term (none, very, or extremely). For example, a horizon with 30% gravel and 14% stones (44% total fragments) would be named very gravelly (**GRV**), but only 20% gravel and 14% stones (34% total fragments) would be named stony (**ST**).

Table 4. Rock fragment modifier size and shape requirements and symbols

Size (Diameter)	Adjective	Symbol
Rounded, Subrounded, Angular, Irregular		
0.2 cm - 7.5 cm	Gravel	GR
7.6 cm - 25.0 cm	Cobbly	CB
25.1 cm - 60.0 cm	Stony	ST
> 60.0 cm	Bouldery	BD
Flat		
0.2 cm - 15.0 cm	Channery	CH
15.1 cm - 38.0 cm	Flaggy	FL
38.0 cm - 60.0 cm	Stony	ST
> 60.0 cm	Bouldery	BD

Additional requirements for rock fragment modifiers based upon percent of soil volume occupied are list in Table 5 below.

Table 5. Modifiers by percent rock fragment (> 2 mm) present by volume

Percent Rock By Volume	Rock Fragment Modifier
< 15%	No special term used with the soil texture class. Enter a dash or leave blank.
15 - 35%	Use "gravelly", "cobbly", "stony", "bouldery", "channery" or "flaggy" as a modifier of the texture term (e.g. gravelly loam or GR-L)
35 - 60%	Use "very (V) + size adjective" as a modifier of the texture term (e.g. very cobble fine sandy loam or CBV-FSL).
60 - 90%	Use "extremely (X) + size adjective" as a modifier of the texture term (e.g.. extremely stony clay loam or STX-CL)
> 90%	Use "coarse fragment noun" as the coarse fragment term (e.g. boulders or BD) and dash or leave blank the soil texture class and the % sand/clay boxes.

A-4-3. Texture Classes

Soil texture classes are those defined in the *Soil Survey Manual* (2017). Any deviation from the standard nomenclature will be considered incorrect (e.g., silty loam). Sandy loam, loamy sand, and sand should be further specified (see textures and abbreviations listed in Table 4 on the following page) if the soil is dominated by a particular size of sand other than medium sand. Include very coarse sand with coarse sand.

Table 6. Textural Classes and Abbreviations

Texture	Symbol	Texture	Symbol
Coarse Sand	COS	**Sandy Loam**	SL
Sand	S	**Loam**	L
Fine Sand	FS	**Sandy Clay Loam**	SCL
Very Fine Sand	VFS	**Silt Loam**	SIL
Loamy Coarse Sand	LCOS	**Silt**	SI
Loamy Sand	LS	**Silty Clay Loam**	SICL
Loamy Fine Sand	LFS	**Clay Loam**	CL
Loamy Very Fine Sand	LVFS	**Sandy Clay**	SC
Coarse Sandy Loam	COSL	**Silty Clay**	SIC
Fine Sandy Loam	FSL	**Clay**	C
Very Fine Sandy Loam	VFSL		

Contestants will determine soil texture classes by hand. The official judges will use field estimates along with laboratory data on selected samples to determine the soil texture class.

A-4-4. Sand Percentage

Sand percentage estimates should be entered in the space provided. Answers within ± 5% of the official value will be given credit.

A-4-5. Clay Percentage

Clay percentage estimates should be entered in the space provided. Answers within ± 4% of the official value will be given credit.

A-5. STRUCTURE

Soil structure refers to the aggregation of primary soil particles into secondary compound groups or clusters of particles. These units are separated by natural planes, zones, or surfaces of weakness. Dominant type (formerly called shape) and grade of structure for each horizon are to be judged. If the horizon lacks definite structural arrangements, ***has 60-90% coarse fragments***, or if there is no observable aggregation, "**structureless**" should be recorded in the grade column and either "**massive**" or "**single grain**" (whichever is appropriate) should be recorded in the type column. Clear depositional layers, potentially due to aeolian deposition, alluvial deposits, or glacial till over- consolidation will not be recognized as developed structure, so "**geologic structure**" should be indicated on the structure type box, with a "0" for grade. (see Table 7 for structural grades/codes and Table 8 for structural types/abbreviations)

If various types of structure exist within the horizon, contestants should record the type and grade of structure that is most dominant. Compound structure (e.g., prismatic parting to angular or subangular blocky structure) is common in some soils. In this case, structure having the stronger grade should be described. If the structures are of equal grade, the structure type with the largest peds should be described. **The term "blocky" always requires a modifier, either angular or subangular blocky.** Blocky will not receive full credit if used alone.

A-5-1. Grade

The grade of structure is determined by the distinctness of the aggregates and their durability. Expression of structure grade is often moisture dependent and so may change with drying of the soil.

Table 7. Structural Grades

Grade	Code	Description
Structureless	0	The condition in which there is no observable aggregation or no definite, orderly arrangement of natural lines of weakness.
Weak	1	The soil breaks into very few poorly formed, indistinct peds, most of which are destroyed in the process of removal. The shape of structure is barely observable in place.
Moderate	2	The soil contains well-formed, distinct peds in the disturbed soil when removed by hand. They are moderately durable with little unaggregated material. The shape of structure observed in the undisturbed pit face may be indistinct.
Strong	3	Durable peds are very evident in undisturbed soil of the pit face with very little or no unaggregated material when peds are removed from the soil. The peds adhere weakly to one another, are rigid upon displacement, and become separated when the soil is disturbed.

A-5-2. Type

Types of soil structure are described below, modified from the *Field Book for Describing and Sampling Soils*, version 3.0, 2012.

Table 8. Structural Types

Type	Abbreviation	Description
Granular	GR	Spheroids or polyhedrons bound by curved planes or very irregular surfaces which have slight or no accommodation to the faces of surrounding peds. The aggregates may or may not be highly porous.
Platy	PL	Plate-like with the horizontal dimension significantly greater than the vertical dimension. Plates are approximately parallel to the soil surface.
Subangular Blocky	SBK	Polyhedron-like structural units that are approximately the same size in all dimensions. Peds have mixed rounded and flattened faces with many rounded vertices. These structural units are casts of the molds formed by the faces of the surrounding peds
Angular Blocky	ABK	Similar to subangular blocky but block-like units have flattened faces and many sharply angular vertices.
Prismatic	PR	Prism-like with the two horizontal dimensions considerably less than the vertical. Vertical faces are well defined and arranged around a vertical line with angular vertices. The structural units have angular tops or caps.
Columnar	COL	Same as prismatic but with rounded tops or caps.
Wedge	WE G	Elliptical, interlocking lenses that terminate in acute angles, bounded by slickensides. Characteristic in Vertisols but may be present in other soils.
Massive	MA	No structure is apparent, and the material is coherent.
Single-Grained	SGR	No structure is apparent, and soil fragments and single mineral grains do not cohere (e.g., loose sand).
Geologic or depositional	GS	These unaltered depositional layers may break out in plate-like shapes (alluvial or aeolian sand) or unweathered glacial till that breaks out with sharp corners/edges due to consolidation. Associated with a "C" horizon.

A-6. MOIST CONSISTENCE

Soil consistence refers to the resistance of the soil to deformation or rupture at a specified moisture level and is a measure of internal soil strength. Consistence is largely a function of soil moisture, texture, structure, organic matter content, and type of clay, as well as adsorbed cations. As field moisture will affect consistence, contestants should use their personal judgment to correct for either wet or dry conditions on the day of the contest. These corrections also will be made by the official judges. Contestants should judge the consistence of moist soil (midway between air-dry and field-capacity) for a ped or soil fragment from each horizon as outlined in the *Field Book for Sampling and Describing Soils, version 3.0, 2012.*

Table 9. Moist Consistence

Consistence	Abbreviation	Description
Loose	L	Soil is non-coherent (e.g., loose sand).
Very Friable	VFR	Soil crushes very easily under gentle pressure between thumb and finger but is coherent when pressed.
Friable	FR	Soil crushes easily under gentle to moderate pressure between thumb and forefinger and is coherent when pressed.
Firm	FI	Soil crushes under moderate pressure between thumb and forefinger, but resistance to crushing is distinctly noticeable.
Very Firm	VFI	Soil crushes or breaks only when strong force is applied between thumb and forefinger.
Extremely Firm	EF	Soil cannot be crushed or broken between thumb and forefinger but can be by squeezing slowly between hands. “Rigid” consistence will be included in this category.

A-7. SOIL FEATURES

Redoximorphic (redox, RMF) features are caused by the reduction and oxidation of iron and manganese associated with soil wetness/dryness and not rock color. Characteristic color patterns are created by these processes. Redox features are colors in soils resulting from the concentration (gain) or depletion (loss) of pigment when compared to the soil matrix color. Reduced iron ($Fe2+$) and manganese ($Mn2+$) ions may be removed from a soil if vertical or lateral fluxes of water occur. Wherever iron and manganese are oxidized and precipitated, they form either soft masses or hard concretions and nodules. Redox features are used for identifying aquic conditions and determining soil wetness class.

The color of redox features must differ from that of the soil matrix by at least one color chip to be described, except in the case of a depleted matrix in which case the matrix is a redox feature. Colors associated with the following mottled features will not be considered as redox features: carbonates, krotovina, rock colors (lithochromic colors), roots, or mechanical mixtures of horizons such as B horizon materials in an Ap horizon. Movement of iron and manganese as a result of redox processes in a soil may result in redoximorphic features that are defined as follows:

A-7-1. Redox Concentrations

These are zones of apparent pedogenic accumulation of Fe-Mn oxides, and include: nodules and concretions (firm, irregular shaped bodies with diffuse to sharp boundaries; masses - soft bodies of variable shapes in the soil matrix; zones of high chroma color ("red/orange" for Fe and "black"/purple for Mn); and pore linings (zones of accumulation along pores). Dominant processes involved are chemical dissolution and precipitation; oxidation and reduction; and physical and/or biological removal, transport, and accrual.

If redox concentrations are present, contestants should mark the scorecard indicating the presence of concentrations using the following classes and abbreviations:

Present: (Y) should be entered in the box for the presence either iron or manganese concentrations
If redox concentrations are absent, contestants should mark the box as follows:
Absent: (N) redox concentrations are not present

A-7-2. Redox Depletions

These are zones of apparent pedogenic translocation or loss of Fe-MN oxides. For determination of a seasonal high-water table, depletions with a chroma of 2 or less and value of 4 or more must be present. If this color requirement is not met, the depletions should be described, but the depletions do not affect the soil wetness class or site interpretations. Low chroma (≤ 2) in the soil may be due to drainage, parent material, or other features. However, parent material variations and other such features should not be considered in evaluating soil wetness or soil drainage characteristics.

Depleted Matrix – This is a soil matrix that has low chroma (2 or less) and values of 4 or more. Low chroma matrix colors caused by dark colors (values of 3 or less), especially those close to the surface, are assumed to be due to organic matter, except when iron concentrations are present in the same horizon. A depleted matrix is indicated by using the "g" suffix designation. This feature is an exaggerated form of redox depletions; thus, the Redox Depletion column should be marked as present (Y) if a depleted matrix is present. This feature is not included separately on the scorecard.

If redox depletions are present, contestants should mark the scorecard indicating the presence of redox depletions using the following classes and abbreviations:

Present: (Y) should be entered in the box for the presence redox depletions

If redox depletions are present in the form of a depleted matrix, contestants should use the **"g" suffix designation** for that horizon **AND** mark the scorecard indicating the presence of redox depletions using the following classes and abbreviations:

Present: (Y) should be entered in the box for the presence of redox depletions

Absent: (N) redox depletions are not present

A-7-3. Matrix Concentrations

Give the type of concentrations that occur in the soil matrix (including soft, non-cemented masses; excluding soft, rock fragments) that are present in any horizon. Concentrations are identifiable bodies found in the soil matrix. Concentrations contrast sharply with surrounding soil material in terms of color and composition (p 168-176 in *Soil Survey Manual*, 2017). Water movement and the extent of soil formation can be related to concentration location and abundance within the soil profile as well as orientation within a horizon. To avoid problems with variability within the pit, only the type of concentrations will be determined. If more than one type of concentration occurs, identify all type(s) that are present. If no concentrations are present, enter a dash in the "Concentration Type" column for full credit. Official judges will use the following type of information.

For the purposes of this contest, three types of concentrations (based on composition) will be described: carbonates (K), gypsum and other soluble salts (YZ), and iron-manganese (FM). If more than one type of concentration occurs in a horizon, describe all types present. At each contest site the pH, EC, SAR, and other appropriate data will be provided. The concentration types recognized for this contest include:

None (dash): No visible concentrations are present in the horizon studied.

Carbonates (K): In many western South Dakota soils visible calcium and magnesium carbonates accumulate in the lower parts of the profile. In some instances, carbonates can accumulate at or near the soil surface as a result of capillary water movement from a close water table. Carbonates are recognized by their white appearance and strong to violent reaction with 10% HCl. The symbol used to identify the presence of carbonates is a "K." ***Carbonates accumulated under rock fragments or small limestone fragments will not be considered pedogenic if the surrounding soil matrix does not effervesce.*** (NOTE: This is the same symbol that may be used as a subordinate distinction [subhorizon] designation.)

Gypsum/other soluble salts (YZ): In many of the soils in western South Dakota there is an abundance of gypsum and other soluble salts (excluding calcium carbonate) that is common in the lower parts of the profile. Gypsum and other soluble salts maybe present as white threads of salt or as crystals (sometimes gypsum is seen in a rose formation of crystals). Gypsum and other soluble salts are recognized by their visual appearance, their lack of reaction with 10% HCl solution, and their influence on EC (raising of EC values, in some cases causing the soil material to become saline. The YZ symbol is used to identify the visible presence of gypsum and other soluble salts. (NOTE: These symbols are the same as may be used for subordinate distinction [subhorizon] designation [Y for gypsum and Z for all other salts more soluble than CaCO3].

Iron-manganese (FM): Fe-Mn (FM) concentrations are sometimes found in horizons where seasonal changes in the reduction-oxidation state occur. Fe-Mn concentrations vary from red to yellowish brown to black or dark purple. rounded to irregular bodies, or soft non-cemented masses, that usually can be crushed between fingers or cut with a knife. They are sometimes referred to as "buckshot.' The symbol used to identify Fe-Mn concentrations is "FM."

A-8. EFFERVESENCE

Calcium carbonate is an important constituent to many parent materials and soils in western South Dakota. Additionally, erosion can bring parent materials within the grass or crop rooting zone, impacting production.

Carbonates may be visible as whitish masses in the field, or they may be disseminated and not visible. Dilute hydrochloric acid (10% or 1M HCl) is used to test for carbonates in the field. Calcium carbonate effervesces when treated with the HCl. Be sure to determine the presence of effervescence in the soil matrix and not rock fragments or the underside of rocks. To avoid problems with variability, presence, or absence of carbonate as judged by visible effervescence will be determined, rather than classes of effervescence as given in the *Soil Survey Manual (2017)*. Team members should have their own acid bottles for this determination.

Presence: Yes (Y) – Effervescence in any degree

Absence: No (N, -, or blank) – No effervescence

B. SOIL HYDGOLOGY AND PROFILE CHARACTERISTICS

B-1. HYDRAULIC CONDUCTIVITY

In this contest, the vertical, saturated hydraulic conductivity of the surface horizon (Hydraulic Conductivity/ Surface Layer) and the most limiting horizon (Hydraulic Conductivity/Limiting Layer) within the depth specified to be described by the official judges will be estimated. "Limiting layer" refers to the horizon or layer with the slowest hydraulic conductivity. If lithic or paralithic contact occurs at or above the specified judging depth, the hydraulic conductivity for the limiting layer is very low. The presence of a natric horizon at or above the specified judging depth will move the hydraulic conductivity class to the next lower class. In some soils, the surface horizon is the limiting horizon with respect to saturated hydraulic conductivity. In this case, the surface conductivity would be reported in two places on the scorecard. For a discussion of factors affecting hydraulic conductivity, refer to the *Field Book for Describing and Sampling Soils (2012)* and *Soil Survey Manual (2017).* (NOTE: Please see how the official judges handle restrictive layers at the practice sites.) Rock fragments will usually increase the saturated hydraulic conductivity.

Due to the difficulty in measuring and estimating hydraulic conductivity of the surface and the limiting layer, the contest scoring will be 5 points for the correct response and 3 points if the adjacent category (higher or lower) is selected.

Table 10. Hydraulic Conductivity Classes

Class	Hydraulic Description Conductivity	
Very High	> 100 µm/s (> 36.0 cm/hr)	Usually includes textures of coarse sand, sand, and loamy coarse sand. It also includes textures of loamy sand and sandy loam if they are especially "loose" because of high organic matter content. Horizons containing large quantities of rock fragments with insufficient fines to fill many voids between the fragments are also in this class.
High	10 to 100 µm/s (3.7 to 36.0 cm/hr)	Usually includes textures of fine sand, very fine sand, loamy sand, loamy fine san, loamy very fine sand, coarse sandy loam, sandy loam, and fine sandy loam.
Moderately High	1 to 10 µm/s (0.36 to 3.6 cm/hr)	Includes textures of very fine sandy loam, sandy clay loam, loam, silt loam, and silt.
Moderately Low	0.1 to 1 µm/s (0.36 to 3.6 cm/hr)	Includes textures of sandy clay, clay loam, silty clay loam. It also includes a texture of silt loam if it has a low organic matter content and a high clay content.

Low	0.01 to 0.1 µm/s (0.0036 to 0.036 cm/hr)	Usually includes textures of clay and silty clay that have moderate structure and a moderate organic matter content as well as low to moderate shrink-swell potential (mixed or kaolinitic mineralogy).
Very Low	< 0.01 µm/s (< 0.0036 cm/hr)	Usually includes textures of clay and silty clay with a low organic matter content and weak or massive structure or clay or silty clay textures with moderate to high shrink-swell potential (smectitic mineralogy). Mark very low on the scorecard if a lithic or paralithic contact occurs at or above the specified judging depth.

B-2. EFFECTIVE SOIL DEPTH

The depth of soil to a restrictive layer, or effective soil depth, is the depth of soil that can be easily penetrated by plant roots. Soil materials must be loose enough so that roots do not experience severe physical resistance and yet fine enough to hold and transmit moisture. Horizons that provide physical impediments to rooting limit the effective depth of the soil. For this contest, materials considered restrictive to plant roots include: lithic and paralithic contacts, and layers of coarse sand and fragments with insufficient fines (<10%) to fill the voids if the layer is > 15 cm thick. Soils that are clayey throughout, abrupt textural changes, and seasonal high-water tables do not restrict the depth of rooting. A natric horizon will not be considered as a root restrictive layer.

The depth to a restricting layer is measured from the soil surface (excluding O horizons). Besides its direct importance for plant growth, this property also relates to key factors such as water relationships and nutrient supplying capacity. The presence or absence of roots may be helpful in determining the effective soil depth, but it is not always the sole indicator. In many cases, the plants growing at the site may be shallow rooted or, conversely, a few roots may penetrate into or through the restrictive layer, particularly along fractures or planes of weakness. At all sites, actual profile conditions should be considered and observed. A soil is considered very deep if no root restricting layers appear in the upper 150 cm (Table 11). If the profile is not visible to a depth of 150 cm, or if you are requested to describe a soil only to a shallower depth, then you may assume that the conditions present in the last horizon described extend to 150 cm.

Table 11. Effective Soil Depth Classes

Depth Class	Depth to Restricting Layer
Very Deep	> 150 cm
Deep	100.1 – 150 cm
Moderately Deep	50.1 – 100 cm
Shallow	25.1 – 50 cm
Very Shallow	< 25 cm

B-3. WATER RETENTION DIFFERENCE

Water retention difference (WRD) refers to the soil water held between 0.033 MPa (field capacity) and 1.5 MPa tension (permanent wilting point), which approximates the range of available water for plants. WRD depends on the effective depth of rooting, the texture of the fine earth fraction (< 2 mm) (Table 12), and the content of rock fragments in the soil. The amount of available water stored in the soil is calculated for the top 150 cm of soil or to a root-limiting layer, whichever is shallower. Total WRD is calculated by summing the amount of water held in each horizon (or portion of a horizon if it extends below 150 cm). If a horizon or layer is restrictive (all except natric horizons) to roots, this and all horizons below should be excluded from WRD calculations. For natric horizons and all horizons below the natric horizons, the available water content is reduced by 50%. If the depth that is designated for describing soil morphology is less than 150 cm, contestants should assume that the water retention properties of the last horizon extend to 150 cm or to the top of a lithic or paralithic contact if either of these is observed at a depth shallower than 150 cm.

Rock fragments are assumed to hold no water that is available for plant use. Therefore, if a soil contains rock fragments, the volume occupied by the rock fragments must be estimated, and the water retention difference corrected accordingly. For example, if a silt loam A horizon is 25 cm thick and contains coarse fragments which occupy 10% of this volume, the available water-holding capacity (AWHC) of that horizon would be 4.5 cm of water rather than 5.0 cm. ***Round individual horizons' calculated AWHC to the nearest hundreth. Only round to the nearest tenth the Total AWHC.***

Once the water retention difference is calculated for the appropriate soil profile depth, the water retention class can be determined using Table 13. An example water retention difference calculation and classification for a theoretical soil profile can be found on the following page.

Rock fragments are assumed to hold no water that is available for plant use. For horizons that contain rock fragments, first determine the water retention difference for the fine earth (<2 mm), and then reduce this amount by the value proportionate to the volume of rock fragments.

Table 12. Texture and Water Retention Difference Relationships

Texture Class or Material Type	cm water/cm soil
All sands, loamy coarse sand	0.05
Loamy sand, loamy fine sand, loamy very fine sand, coarse sandy loam	0.10
Sandy loam, fine sandy loam, sandy clay loam, sandy clay, silty clay, clay	0.15
Very fine sandy loam, loam, silt loam, silt, silty clay loam, clay loam	0.20

Table 13. Water Retention Difference Classes

Water Retention Difference Class	cm of available water
Very Low	< 7.5 cm of available water
Low	7.5 to < 15.0 cm of available water
Medium	15.0 to < 22.5 cm of available water
High	≥ 22.5 cm of available water

Example of calculation of water retention difference (WRD) for the following soil:

Horizon	Depth (cm)	Texture Class	Rock fragment %
A	15	SL	5
Bt1	60	CL	10
Bt2	80	L	10
2C	150	S	50

Calculation:

Horizon	Thickness	Texture WRD	Rock Frag Correction		cm H_2O/horizon(s)
A	15	0.15	0.95	=	2.14
Bt1/Bt2	65	0.20	0.90	=	11.70
2C	70	0.05	0.50	=	1.75

Total: 15.59 = **15.6 cm WRD**

The water retention class in this example is **MEDIUM (15.0 to < 22.5 cm of available water)**.

B-4. SOIL WETNESS CLASS

Soil wetness is a reflection of the rate at which water is removed from the soil by both runoff and percolation. Position, slope, infiltration rate, surface runoff, hydraulic conductivity (permeability), and redoximorphic features are significant factors influencing the soil wetness class. The shallowest depth of either:

1) distinct or prominent chroma ≤ 2 and value ≥ 4 redox features (i.e. redox depletions) due to wetness. **For the purpose of this contest, redox features will be interpreted as relict redox features.**
2) color value and chroma of 2/1, 2.5/1 or 3/1 containing distinct or prominent redox concentrations and occurring contiguously above a horizon with a reduced matrix.

Table 14. Soil Wetness Classes

Class	Depth to Wetness features (from soil surface)
1	> 150 cm
2	100.1 – 150 cm
3	50.1 – 100 cm
4	25.1 – 50 cm
5	< 25 cm

C. SITE CHARACTERISTICS

C-1. Landform

A landform is a physical, recognizable form or feature of the Earth's surface that usually has a characteristic shape and is produced by natural causes. Parent materials are commonly associated with particular landforms. **Only one landform will be identified at each site.** ***For this competition, mountain landforms (mountain slope and mountain terrace) will only be used in coniferous forested areas in the Black Hills. The other landforms except Hogback will be used in grassed areas.***

The landforms recognized for this contest are:

Fan: A gently sloping, fan-shaped mass of detritus forming a section of a low-angle cone commonly at a place where there is notable decrease in gradient; specifically, an alluvial fan.

Hill: An area of land surface, rising as much as 300 meters above surrounding lowlands, usually of restricted summit area relative to surrounding surfaces and having a well-defined outline; hill slopes generally exceed 15%. The distinction between a hill and a mountain is often dependent on local usage.

Hogback: A sharp-crested, symmetric (homoclinal) ridge formed by highly tilted resistant rock layers (see figure 1); produced by differential erosion of inter-layered resistant and weak rocks with dips greater than about 25 degrees (45%). ***For this competition, use this landform in coniferous tree areas outside the Black Hills located in the Dakota Hogback.***

*"**Homo-clinal ridges** formed by the resistant beds are typically asymmetrical (if the strata don't dip too steeply) with a steep **scarp slope** and a more gentle **dip slope**. The dip slope lies at or less than the angle of dip of the beds while the scarp slope maintains a steep slope by undermining and mass wasting due to rapid weathering of a less resistant stratum below."*

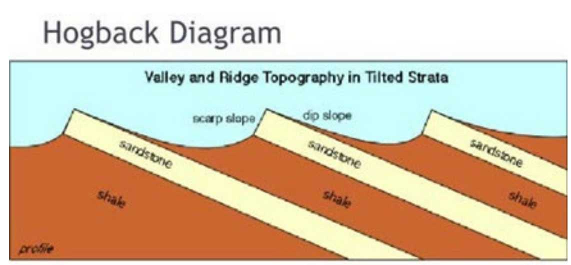


Figure 2. Hogback cross-section.

Mountain Slope: A part of a mountain between the summit and the foot.

Mountain Terrace: A mountain step-like surface, bordering a mountain valley floor or remnant valley floor that represents the former position of a floodplain. Mountain terrace slopes generally are less than 15%. Sediments may or may not be stratified. Sites may or may not be forested.

Ridge: A long, narrow elevation of the land surface, usually sharp crested with steep sides and forming a extended upland between valleys.

Terrace: A step-like surface, bordering a valley floor that represents the former position of a floodplain. The term is usually applied to both the relatively flat summit surface (tread), cut or built by stream, and the steeper descending slope (scarp, riser), graded to a lower base level of erosion. Sediments may or may not be stratified. Moderate to strong profile development is often present.

C-2. PARENT MATERIAL

Parent material refers to the material in which soils form. Parent materials include bedrock, various kinds of unconsolidated sediments, and "pre-weathered" materials. Soils may be developed in more than one parent material and this should be indicated on the scorecard. For this contest, a parent material should be ≥ 30 cm thick if it is on the surface or ≥ 10 cm thick if at least 30 cm below the soil surface to be indicated on the scorecard. A different parent material should also be indicated if it is present in the last horizon of the described profile.

Alluvium: Alluvium consists of sediment transported and deposited by running water and is associated with landforms such as floodplains, fans, and stream terraces. As running water sorts sediment by particle size, these materials are often stratified. Rock fragments are often rounded in shape. Alluvium may occur on terraces above present streams (old alluvium) or in the normally flooded bottomland of existing streams (recent alluvium). The sediments may be of either a general or local origin. Stratification may or may not be evident.

Colluvium/Local Alluvium: Material that has accumulated near the base of slopes (ex. footslopes and lower sideslopes of hills or mountains), in depressions, or along small upland intermittent streams through the combined action of gravity and unconcentrated water. The material is of local origin.

Loess: Loess consists of fine-textured, wind-deposited sediment that is dominantly of silt size (or in some cases very fine sands). Loess may contain significant amounts of clay, depending on the distance from the loess source. Silt loam and silty clay loam textures are commonly found in the loess of this area.

Glacial Till: Unstratified glacial drift deposited directly by glacier and consists of a heterogeneous mixture of sand, silt, clay, and coarse fragments. Located in ground moraine, end moraine, esker, and kame landforms found on till plains.

Residuum: Residuum is bedrock that has weathered in place into an unconsolidated state. In this contest, we will be separating residuum into 3 types:

Igneous *- Igneous residuum in this area is primarily formed from intrusive granites. Hard bedrock and quite resistant to weathering. Formed from the slow cooling of molten materials into crystalline rock.*

Metamorphic *- Metamorphic residuum is unconsolidated material formed from other rocks subjected to high heat and pressure into schists (often foliated, ex. mica schists), marble, slates, and quartzites.*
Relatively hard and more resistant to weathering when compared to sedimentary rocks.

Sedimentary *- Sedimentary residuum is unconsolidated materials formed from pre-existing rocks or pieces of once-living organisms carried by water and deposited, often with distinctive layering or bedding, which become cemented to form rocks like limestone, shale, siltstone, gypsum, mudstone, and sandstone. Relatively soft bedrock and relatively easy to weather.*

C-3. SLOPE

Slope refers to the inclination of the ground surface and has length, shape, and gradient. Gradient is usually expressed in percent slope and is the difference in elevation, in length units, for each one hundred units of horizontal distance. Slope may be measured by an Abney level or by a clinometer. Slope classes are based on the gradient. Stakes or markers will be provided at each site for determining slope and the slope should be measured between these two markers. **The tops of the markers will be placed at the same height, but it is the responsibility of the contestant to make sure that they have not been disturbed.** If the slope measurement falls on the boundary between two slope classes, contestants should mark the steeper class on the scorecard. Contestants may want to write the actual slope value in the margin of the scorecard to aid in the completion of the interpretations section.

C-4. HILLSLOPE PROFILE POSITION

The slope positions are given below and shown in the diagram (from Ruhe, 1969) represent geomorphic segments of the topography in which the soil is located. These slope components have characteristic geometries and greatly influence soils through differences in slope stability, water movement, and other slope processes. **Slope positions at the contest site should be determined by the dominant position between the slope markers**.

Summit: The highest level of an upland landform with a relatively gentle slope. It is often the most stable part of a landscape. If the site is on a summit and has a slope < 2%, the summit should be selected on the scorecard.

Shoulder: The rounded (convex-up) hillslope component below the summit. It is the transitional zone from the summit to the backslope and is erosional in origin.

<u>Backslope</u>: The steepest slope position that forms the principal segment of many hillslopes. It is commonly linear along the slope and is also erosional in origin. It is located between the shoulder and footslope positions.

<u>Footslope</u>: The slope position at the base of a hillslope that is commonly rounded, concave-up along the slope. It is transitional between the erosional backslope and depositional toeslope. Accumulation of sediments often occurs at this slope position.

<u>None</u>: This designation will be used when slope at the site is < 2% and the site is not in a well-defined example of one of the slope positions given above. This includes toeslope positions, or broad nearly level positions on upland plains, terraces, or floodplains.

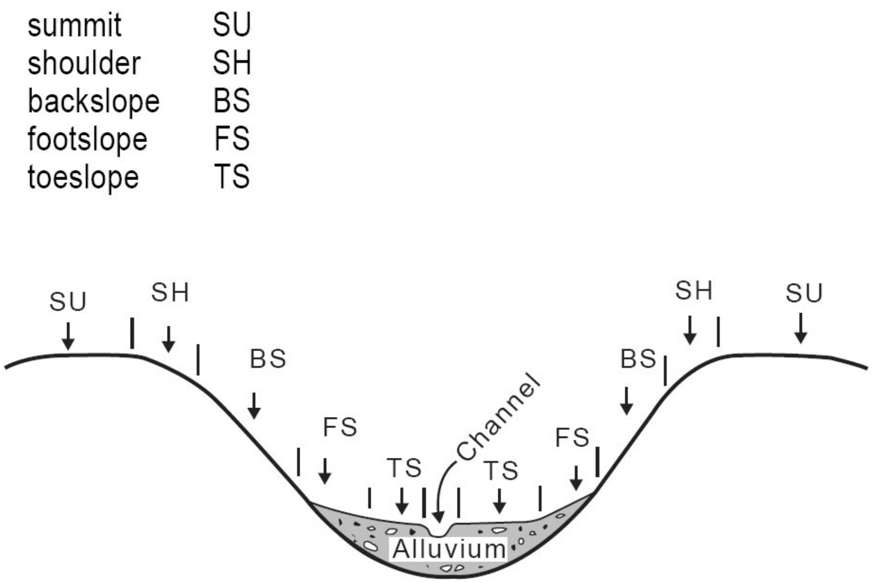


Figure 3. Slope Profile Components. Modified from Ruhe, 1969.

C-5. Surface Runoff

Surface runoff refers to the relative rate at which water is removed by flow over the ground surface. The rate and amount of runoff are determined by soil characteristics, management practices, climatic factors (e.g., rainfall intensity), vegetative cover, and topography. For this contest, we will use the six runoff classes described in the *Soil Survey Manual (2017).* The following table, which illustrates the relationship between soils with various slopes and surface hydraulic conductivity (infiltration), will be used to determine the surface runoff class. The amount of vegetative cover should also be considered. **Where there is good vegetative cover or an O horizon at the surface, use the next lower surface runoff class. Vegetative cover should be judged between the slope stakes.** Students should mark "Negligible" for sites in topographic depressions with no surface runoff (i.e., sites subject to ponding).

Table 15. Surface Runoff Classes

Slope %	Saturated Hydraulic Conductivity Class					
	Very High	**High**	**Moderately High**	**Moderately Low**	**Low**	**Very Low**
< 2%	Negligible	Negligible	Very Low	Low	Low	Medium
2 - 6%	Negligible	Very Low	Low	Low	Medium	High
6 - 9%	Very Low	Low	Low	Medium	High	Very High
9 - 15%	Low	Low	Medium	High	Very High	Very High
15 - 25%	Low	Medium	High	Very High	Very High	Very High
> 25%	Medium	High	Very High	Very High	Very High	Very High

D. SOIL CLASSIFICATION

D-1. CLASSIFICATION INFORMATION PROVIDED AND EPIPEDONS

Each contest profile will be classified using *Keys to Soil Taxonomy 13th edition* (2022) and a simplified set of criteria and options as explained herein and via additional supplements. Family classification will only identify textural class. Classification criteria for each Order, Suborder, Great Group and Subgroup possible for this contest are considerably simplified. These simplified classification criteria are the official ones for this contest. Ambiguities will be clarified during discussion at the Region V Coaches meetings.

Flooding and ponding conditions as well as USLE T value will be given at each site. On a horizon-by-horizon basis, the following laboratory information will be given for each practice and contest profile: weight percentage of calcium carbonate equivalent (CCE), percentage base saturation (BS), electrical conductivity (EC), weight percentage of gypsum (G), and weight percentage of organic carbon (OC). Exchangeable sodium percentage (ESP) will be given in some cases. Please note, some of this information will be measured using standard laboratory methodologies and some will be estimated based upon prior data.

The following are the classification options and their definitions as used in this contest. Epipedon options are Mollic, Umbric and Ochric. Options for diagnostic subsurface horizons and features are Albic, Argillic, Calcic, Cambic, Glossic, Gypsic, Lithic or Paralithic Contact, Lithologic Discontinuity, Natric, Slickensides, and None. Lamellae, by definition, are layers less than 7.5 cm in thickness and will not be recognized for this competition even if apparent in the soil profile.

Mollic Epipedons are thick, black organic rich epipedons. Mollic epipedons have between 18 and 25 cm or more thick (cumulative) that throughout have moist value/chroma of 3/3 or darker, 0.6% or more OC and 50% or more base saturation. The upper boundary of a Mollic epipedon must be within 25 cm of the soil surface. This can occur in the case where there has been significant upslope recent erosion. Mollic epipedons are allowed to be "split" by an albic E horizon.

Umbric epipedons have the same criteria as the Mollic except base saturation is less than 50%.

Note, it is possible there will be profiles with – say – 60 cm with "mollic" colors and OC content but only part of that thickness will have BS at or above 50%. In this case the distinction between Umbric and Mollic epipedons will be whether or not there is 25 cm of cumulative thickness with BS at or above 50%.

Ochric epipedons are those that do not meet all the criteria of Mollic or Umbric.

D-2. DIAGNOSITIC SUBSURFACE HORIZONS AND FEATURES

Keys to Soil Taxonomy will be used for official determination of diagnostic subsurface horizons. Diagnostic subsurface horizons form below the soil surface. They can be exposed at the surface rarely due to truncation. Typically, diagnostic subsurface horizons are B horizons, but may include parts of A or E horizons. Indicate all diagnostic subsurface horizons and characteristics that are present. More than one may be present. If none is present, mark "none" for full credit. Remember that negative credit will be given for incorrect answers to **discourage** guessing (although a total score for one answer will never be less than zero). Possible diagnostic horizons or features include: **Albic, Argillic, Calcic, Cambic, Glossic, Gypsic, Lithic/paralithic Contact, Lithologic Discontinuity, Natric, Slickensides/pressure faces, or None.**

Albic horizons are "white" E (eluvial) horizons. Refer to *Keys to Soil Taxonomy 13th Edition* (2022). Albic horizons normally have platy structure. **Only moist color will be used to determine if a horizon(s) meets Albic criteria.**

Argillic horizons are diagnostic subsurface pedogenic horizons of phyllosilicate enrichment, not due to parent material change, and are most commonly identified as "Bt or Btg or Btk" but other possibilities exist especially with multiple parent materials and such. Argillic must have clay films, organoclay coatings and/or clay bridging. Argillic horizons must contain clay content that is ≥1.2-times the minimum amount of some horizon above it.

Calcic horizons ("Bk" and such) are diagnostic subsurface pedogenic horizons of calcite enrichment. The CCE content of a Calcic horizon must be ≥1.15-times that of an underlying horizon. Typical field evidence of a Calcic horizon is apparent calcite precipitates and very strong to violent effervescence although neither of these are requirements.

Cambic horizons ("Bw" and such) are subsurface diagnostic horizons where there is enough color and/or structure change to no longer be a C horizon but not so much pedogenic change to classify as one of the other diagnostic horizons herein. This cannot be used in the same profile as an albic, argillic, calcic, or natric.

Glossic horizons develop as a result of the degradation of an argillic or natric horizon from which clay and free iron oxides are removed. The material between the peds resulting from this removal is albic material. **Only moist color criteria can be used to determine if a horizon(s) meet glossic criteria.** .

Gypsic horizons are diagnostic subsurface horizons where gypsum has accumulated or transformed. The minimum thickness is 15 cm, is non or weakly cemented, is 5% gypsum by weight and has 1% by volume visible secondary/transformed gypsum, and thickness (cm) times gypsum content (% by weight) is ≥150.

Lithic or Paralithic Contact refers to the depth where "rock" begins; more specifically, a R or Cr horizon begins. A lithic contact is rock hard enough that a rock hammer is needed to chip it while a paralithic contact is one where a spade can be used to dig in it. Lithic contacts are primarily found in the Black Hills and consist of limestone, metamorphic (schist and slate), and igneous (granite) rocks. Paralithic contacts consist of shale, gypsum rock, sandstone, and the other sedimentary rock strata.

Lithologic Discontinuity refers to any change in parent material including alluvial strata stacked on alluvial strata provided the depositional environment of the two strata resulted in a significant difference in texture (including coarse fragment content) or organic matter content. A couple of the common lithological discontinuities in the contest region include (a) loess over till or outwash or aeolian sands; (b) colluvium – both natural and human-induced - over alluvium, loess, till or outwash.

Natric horizons are argillic horizons that in addition to meeting all the requirements of the argillic horizon (above) also have both columnar structure and ESP $\geq$15 for a thickness of at least 8 cm.

Slickensides or pressure faces refer to morphological features produced when aggregates containing high content of expanding phyllosilicates slide past each as swelling occurs as the soil wets.

None is an option only if none of these are present in the profile.

D-3 ORDER, SUBORDER, GREAT GROUP

D-3-1. Order (select 1)

Alfisol: Profile with an argillic horizon having greater than 35% base saturation.

Entisol: Profile lacking in B horizons.

Inceptisol: Profile with other B horizons.

Mollisol: Profile with a mollic epipedon and greater than 50% base saturation throughout the solum.

Vertisol: Profile containing more than 35% clay throughout the solum with all or part of the B-horizon having slickensides or pressure faces.

D-3-2. Suborder (select 1)

"Alb" is used for Mollisol profiles with an albic horizon.

"Aqu" is used for all profiles with Soil Wetness Class of 4 or 5.

"Fluv" is used for Entisol profiles exhibiting fluvial bedding planes within 50 cm of the surface.

"Orth" is used with Entisol profiles with Soil Wetness Class 1, 2 or 3 and family particle size class of loamy, coarse loamy, fine loamy, coarse silty, fine silty, clayey, fine, very fine, loamy-skeletal, clayey-skeletal or contrasting.

"Psamm" is used with Entisol profiles having family particle size class of sandy or sandy-skeletal.

"Ud" is used with coniferous forested areas in the Black Hills and Dakota Hogback (including grassy meadows within these landscapes) with Alfisol and Mollisol profiles.

"Ust" is used for all other profiles.

D-3-3. Great Group (select 1)

"Argi" is used with Mollisol suborders having argillic horizons.

"Calci" is used with Vertisol, Mollisol, and Inceptisol suborders having calcic horizons.

"Endo" is used with Aquerts, Aquolls, Aqualfs, Aquepts, and Aquents wherein the redoximorphic features formed due to reducing water tables originating from within the profile

"Epi" is used with Aquolls, Aqualfs, Aquepts, Aquerts, and Aquents wherein the redoximorphic features formed due to reducing water tables originating from ponding or flooding having long duration residence times.

"Gloss" is used with Udalf suborders with a glossic horizon.

"Hapl/Hap" is used with all other Udoll, Udalf, and Ustept suborders.

"Fluv" is used with Entisol profiles having fluvial bedding planes not recognized in the Subgroup level.

"Natr" is used with Mollisol and Alfisol suborders having natric horizons.

"Psamm" is used with Aquents having family particle size class of sandy or sandy skeletal.

"Ud" is used with Fluvents in coniferous forested areas in the Black Hills and Dakota Hogback (including grassy meadows within these landscapes)

"Ust" is used in all other cases.

Decision outline for assigning the soil moisture regime designator for a profile.
***** For this competition, all Alfisols and Mollisols in forested areas (Mountain landscapes), including meadows within forested areas, will be placed in the Udic moisture regime (Black Hills and Hogback). All grassland areas not forested, excluding meadows in forested areas and grassed areas with an albic horizon near forested areas, will be considered to have an Ustic moisture regime.

D-4. PARTICLE SIZE CONTROL SECTION AND FAMILY PARTICLE SIZE CLASS

Determine the family particle-size class control section for the soil; calculate the weighted percentage sand, silt, clay, and, if needed, rock fragment content in the control section; and determine the family particle-size class. For soils with contrasting particle-size classes, just mark that this is the case on the scorecard without specifying the class.

D-4-1. Depth of Particle-Size Control Section

Contestants should select the proper depth of the family particle-size control section based on the soil properties present in the judged profile from those listed below.

1. 0 cm to a root limiting layer (where the root limiting layer is less than 36 cm deep)
2. 25 to 100 cm
3. 25 cm to a root limiting layer (where the root limiting layer is between 36 and 100 cm)
4. Upper 50 cm of the argillic
5. Upper boundary of the argillic to 100 cm (contrasting particle size class)
6. All of the argillic where it is less than 50 cm thick

D-4-2. Family Particle-Size Class

Once the family particle-size class control section for the soil profile has been determined, contestants should calculate the weighted percentage sand, silt, clay, and, if needed, rock fragment content within that control section. The family particle-size class can then be determined using the guide listed below (also see textural triangles in Appendix). Contestants should know when to select only the three broad particle size classes, the skeletal classes, and when to use the seven more specific particle size classes. If two or more strongly contrasting particle-size classes are present within the control section, name the two most contrasting classes.

1. Sandy: texture is S or LS
2. Loamy: texture is LVFS, VFS, or finer with clay < 35%
   a. Coarse-loamy: ≥ 15% FS or coarser + < 18% clay
   b. Fine-loamy: ≥ 15% FS or coarser + 18-34% clay
   c. Coarse-silty: < 15% FS or coarser + < 18% clay
   d. Fine-silty: < 15% FS or coarser + 18-34% clay
3. Clayey: ≥ 35% clay
   a. Fine: 35- 59% clay
   b. Very-fine: ≥ 60% clay
4. Sandy-skeletal: ≥ 35% coarse fragments + sandy particle size class
5. Loamy-skeletal: ≥ 35% coarse fragments + loamy particle size class
6. Clayey-skeletal: ≥ 35% coarse fragments + clayey particle size class
7. Contrasting particle size classes - transition zone < 12.5 cm thick
   a. Loamy-skeletal over clayey: absolute difference of 25% clay of the fine earth fraction

NOTE: Subclasses of the loamy and clayey particle size classes will always be used unless a root limiting layer occurs within 50 cm.

E. SOIL INTERPRETATIONS

This section illustrates applications of soil information to land use and ecological site suitability. Soil interpretations involve the determination of the degree of limitation within each soil for a specified use. The most restrictive soil property determines the limitation rating. In cases where the base of the pit does not extend to the depth indicated in the following tables (i.e. 180 cm for some criteria), assume that the lowest horizon in the pit extends to the depth of interest.

For this competition, each interpretation has numbered criteria. If the criteria places the site in a Moderate or Severe Rating, then list the number for the criteria giving the most limiting rating on the scorecard. If there are multiple criteria placing the site in the most limiting rating, list all the numbers. Partial credit will be given for each correct answer and incorrect answers will be subtracted from the score with a minimum score of 0.

E-1. SEPTIC TANK ABSORPTION FIELDS

The following table is used for evaluating limitations for septic tank absorption fields. The soil between the depths of 60 cm and 180 cm should be considered in making septic tank ratings. If the profile is not visible to 180 cm, assume the last visible horizon continues to 180 cm.

Table 16. Septic Tank Absorption Fields

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
1. Hydraulic Conductivity of the most limiting layer (60 - 180 cm)	Moderately High, Moderately Low	---	Very High, High, Low, or Very Low
2. Wetness Class	1	2	3, 4, 5
3. Average rocks > 7.5 cm diameter (60 - 180 cm)	< 15%	15 – 35%	> 35%
4. Depth to Bedrock (Cr or R)	> 180 cm	100 – 180 cm	< 100 cm
5. Slope	< 9%	9 – 15%	> 15%
6. Flooding/Ponding	None	---	Any

E-2. LOCAL ROADS AND STREETS

The following table is used for evaluating soil limitations for local roads and streets. The soil between the depths of 25 cm and 100 cm should be considered for local roads and streets. If the profile is not visible to 100 cm, assume the last visible horizon continues to 100 cm.

Table 17. Local Roads and Streets

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
1. Texture of the most limiting horizon (25 – 100 cm)	S, LS, SL	L, SCL	SI, SIL, SICL, SIC, CL, SC, C
2. Average Rocks > 7.5 cm diameter (60 – 180 cm)	< 25%	25 – 50%	> 50%
3. Wetness Class	1, 2	3, 4	5
4. Depth to Hard Bedrock (R)	> 100 cm	50 – 100 cm	< 50 cm
5. Depth to Soft Bedrock (Cr)	> 50 cm	< 50 cm	---
6. Slope	< 9%	9 – 15%	> 15%
7. Flooding/Ponding	None	Rare	Occasional or More

E-3. DWELLINGS WITHOUT BASEMENTS

The following table is used for evaluating soil limitations for dwellings without basements. The soil between the depths of 25 cm and 100 cm should be considered for dwellings without basements. If the soil is not visible to 100 cm assume the last horizon continues to the 100 cm depth.

Table 18. Dwellings without Basements

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
1. Texture of the most limiting horizon (25 – 100 cm)	S, LS, SL, L, SIL	CL, SICL, SCL	SC, SIC, C
2. Average Rocks > 7.5 cm diameter (60 – 180 cm)	< 25%	25 – 50%	> 50%
3. Wetness Class	1, 2	3	4, 5
4. Depth to Hard Bedrock (R)	≥ 150 cm	150 – 100 cm	< 100 cm
5. Depth to Soft Bedrock (Cr)	> 100 cm	50-100 cm	< 50 cm
6. Slope	< 9%	9 – 15%	> 15%
7. Flooding/Ponding	None	N/A	Any flooding

E-4. LAWNS, LANDSCAPING, AND GOLF FAIRWAYS

The following table is used for evaluating soil limitations for lawns, landscaping, and golf fairways.

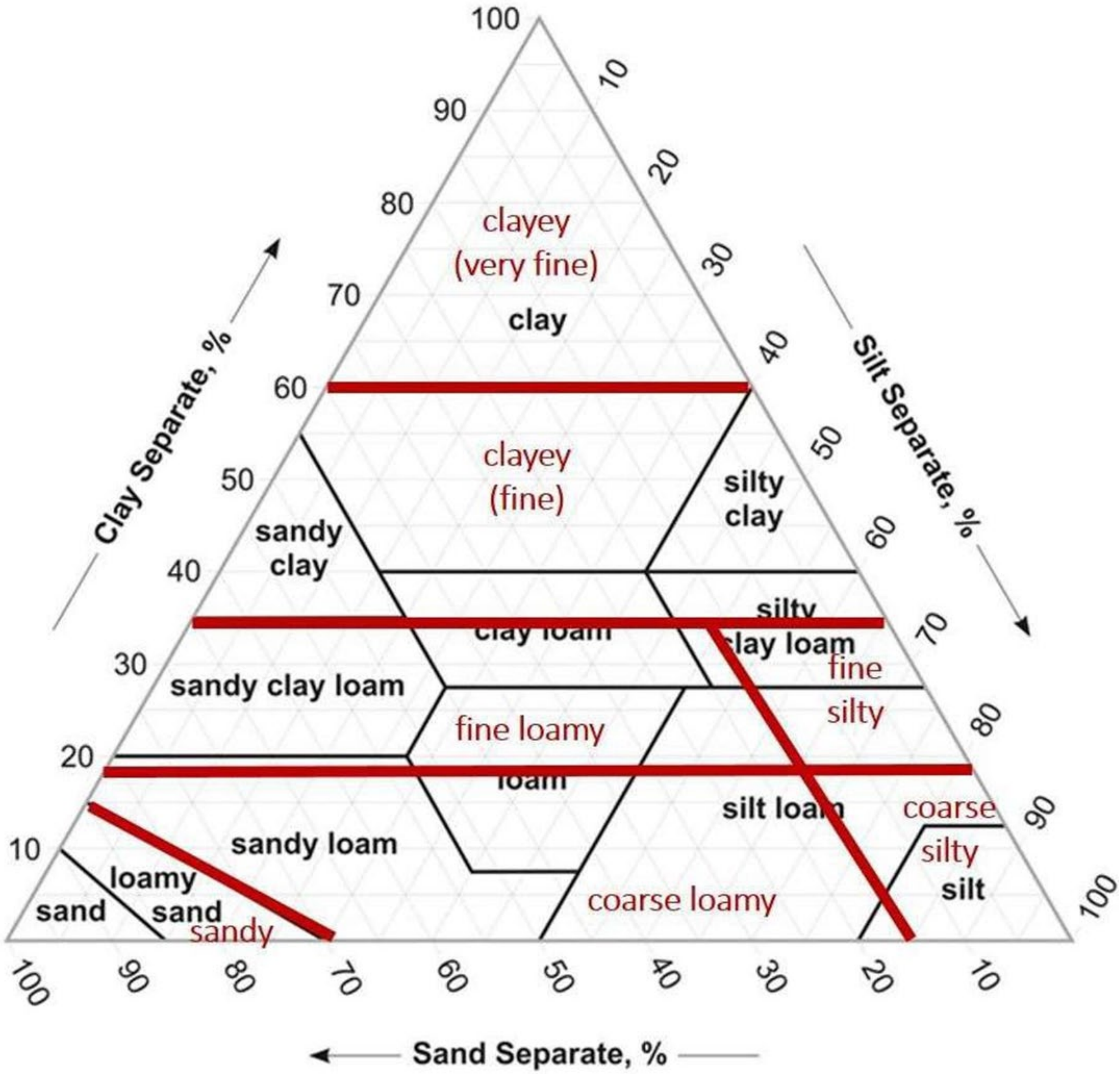
Table 19. Lawns, Landscaping, and Golf Fairways

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
1. Surface Texture	All other textures	LCS, S	SC, SIC, C, CS
2. Ponding/Flooding	None	Rare	Occasional or more
3. Surface salinity (dS/m)	< 4	4 - 8	> 8
4. SAR (surface horizon)	------	------	> 12
5. pH (surface horizon)	------	------	< 3.5
6. Wetness Class	1, 2	3, 4	5
7. Available Water Holding Capacity (cm/cm, average to 100 cm depth)	> 0.10	0.05 to 0.10	< 0.05
8. Volume (%) surface rock (>7.5 cm)	<5	5 - 30	> 30
9. Volume (%) surface rock (2 mm - 7.5 cm)	< 25	25 – 50	> 50
10. Depth to Bedrock (Cr or R)	> 100 cm	50 – 100 cm	< 50 cm
11. Calcium Carbonate (%)	------	------	> 40%
12. Slope	< 9%	9 – 15%	> 15%

ABBREVIATIONS & USDA TEXTURAL TRIANGLE

Abbreviations are provided in Tables throughout this guidebook. A sheet of abbreviations will be given to contestants on the day of the contest.

Combined USDA Soil Textural Triangle (black) and Family Particle-Size Classes (red).



SITE INFORMATION & ROTATION

<u>Example of Information to be Posted at Each Judging Site:</u>

SITE #

Describe 6 horizons between the surface shown by the top of the ruler and a depth of 150 cm.
The yellow scorecard will be used at this site. (Any additional instructions or data will be indicated here.)

Note: Identification of horizons, diagnostic horizons and characteristics, and taxa will primarily be based on morphology. If morphological criteria are met, assume lab-determined criteria are too, unless lab data are given. For example, if the soil meets the moist color, base saturation, thickness, lack of stratification, and organic carbon criteria for a mollic epipedon, it can be assumed that all other criteria for the mollic epipedon and Mollisols are met. Lab data will be provided.

<u>Site and Rotation Procedures:</u>

Each site will have its own color-marked scorecard. Each contestant will be given a packet at the beginning of the contest that has scorecards, a sheet of abbreviations, interpretation tables, and a texture triangle. Extra copies of the scorecard will be available at each site for emergencies. The information posted at each site will include scorecard color information. Rotation may be changed due to participant numbers or weather conditions.

<u>Individual Sites:</u>

An example of a full contestant number is as follows: 1AL-In. The "1" is the team number and the "A" is the contestant number. Each contestant ID number will contain either an "L" or an "R". This tells whether the left or the right face is to be judged. Finally, there is an "-In" or an "-Out". This designates whether the contestant starts in or out of the judging pit first at the first site. If a contestant starts in the judging pit at the first site, that contestant will start out of the judging pit at the second site, and vice versa.

Each contestant will be in the pit first one time and out of the pit first one time during the individual part of the contest. In addition, two team members of each team will describe the left face and two team members will describe the right face. Alternates will be assigned to even out contestant numbers at each site.

REFERENCES

Dixon, J.C. 2015. Soil Morphology in the Critical Zone: The Role of Climate, Geology, and Vegetation in Soil Formation in the Critical Zone. Developments in Earth Surface Processes 19:147-172.

Rhue, R.V. 1969. Quaternary landscapes in Iowa. Iowa State University Press, Ames.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE. https://www.nrcs.usda.gov/sites/default/files/2022-09/field-book.pdf

Soil Survey Division Staff. 2017. Soil survey manual. USDA Handbook 18. U.S. Government Printing Office, Washington, DC. https://www.nrcs.usda.gov/sites/default/files/2022-09/The-Soil-Survey-Manual.pdf

Soil Survey Staff. 2022. Keys to Soil Taxonomy, 13th edition. USDA-Natural Resources Conservation Service, Washington, DC. https://www.nrcs.usda.gov/sites/default/files/2022-09/Keys-to-Soil-Taxonomy.pdf

Soil Survey Staff. 1999. Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys. USDA-NRCS Agricultural Handbook 436. 2nd edition. U.S. Government Printing Office, Washington, D.C. https://www.nrcs.usda.gov/sites/default/files/2022-06/Soil%20Taxonomy.pdf

Soil Survey Staff. 2015. Illustrated guide to soil taxonomy. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska. https://www.nrcs.usda.gov/sites/default/files/2022-06/Illustrated_Guide_to_Soil_Taxonomy.pdf

U.S. Department of Agriculture, Natural Resources Conservation Service. 2017. National Soil Survey Handbook, title 430-VI. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=48824.wba

Vepraskas, M.J. 1999. Redoximorphic features for identifying aquic conditions. North Carolina Agricultural Research Service Technical Bulletin no. 301. North Carolina State University, Raleigh

REFERENCES

Region V and National Soil Judging Contest Dates and Locations

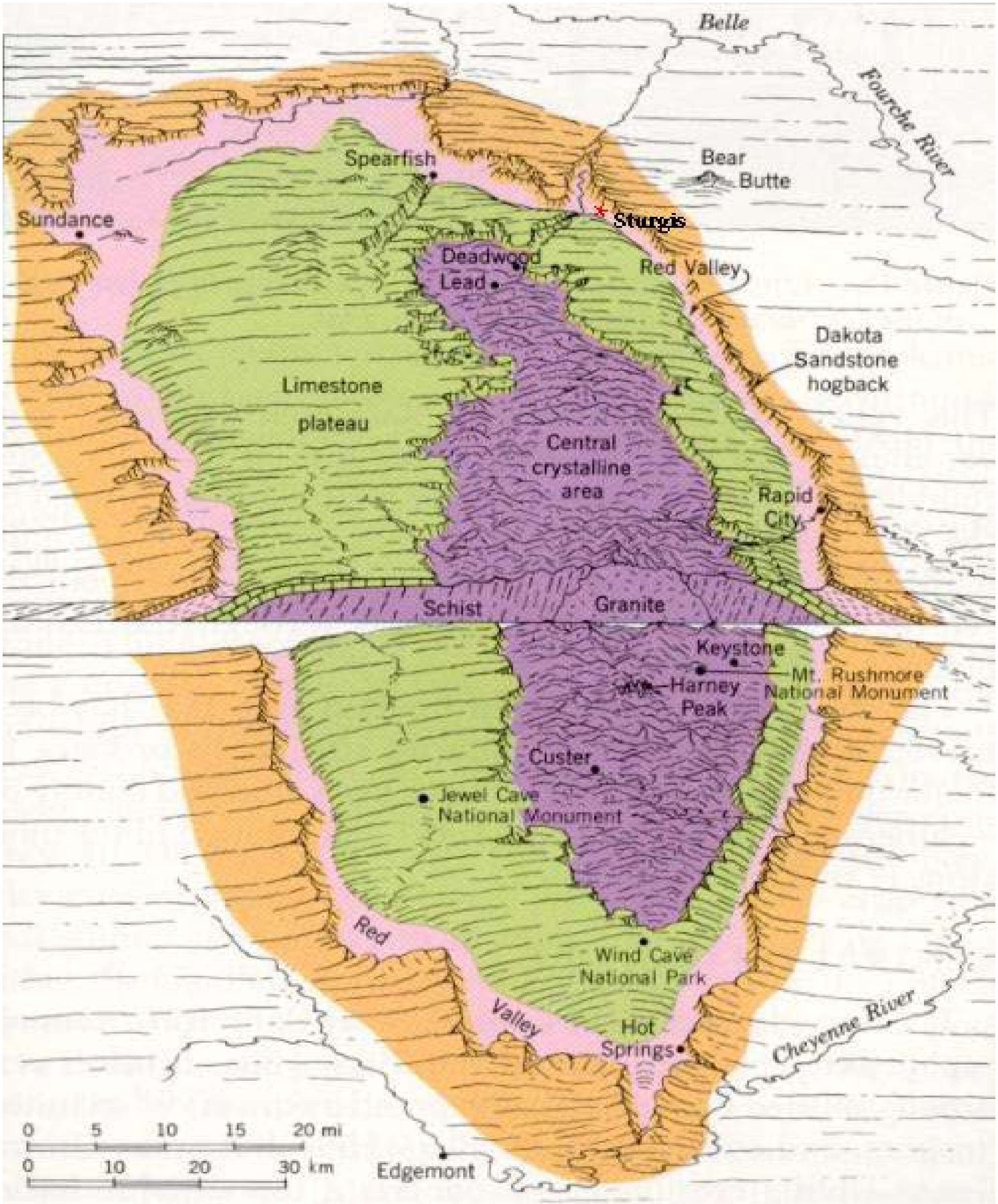
(Most information compiled by M.D. Ransom and O.W. Bidwell, Kansas State University).

Date	Region V Location	National Location	
1958	Manhattan, KS	---	---
1959	Brainerd, MN	---	---
1960-61	Lincoln, NE	Lexington, KY	2
1961-62	None	St. Paul, MN	5
1962-63	None	Lubbock, TX	4
1963-64	None	Madison, WI	3
1964-65	None	Raleigh, NC	2
1965-66	Ames, IA	Las Cruces, NM	6
1966-67	Manhattan, KS	Ithaca, NY	1
1967-68	St. Paul, MN	Manhattan, KS	5
1968-69	Lincoln, NE	Stillwater, OK	4
1969-70	Rolla, MO	Lansing, MI	3
1970-71	Ames, IA	Tucson, AZ	6
1971-72	Manhattan, KS	Blacksburg, VA	2
1972-73	St. Paul, MN	University Park, MD	1
1973-74	North Platte, NE	Boone, IA	5
1974-75	Fargo, ND	College Station, TX	4
1975-76	Columbia, MO	Urbana, IL	3
1976-77	Brookings, SD	Clemson, SC	2
1977-78	Manhattan, KS	Las Cruces, NM	6
1978-79	Ames, IA	Bozeman, MT	7
1979-80	Brainerd, MN	State College, PA	1
1980-81	Brookings, SD	Lincoln, NE	5
1981-82	Manhattan, KS	Fayetteville, AR	4

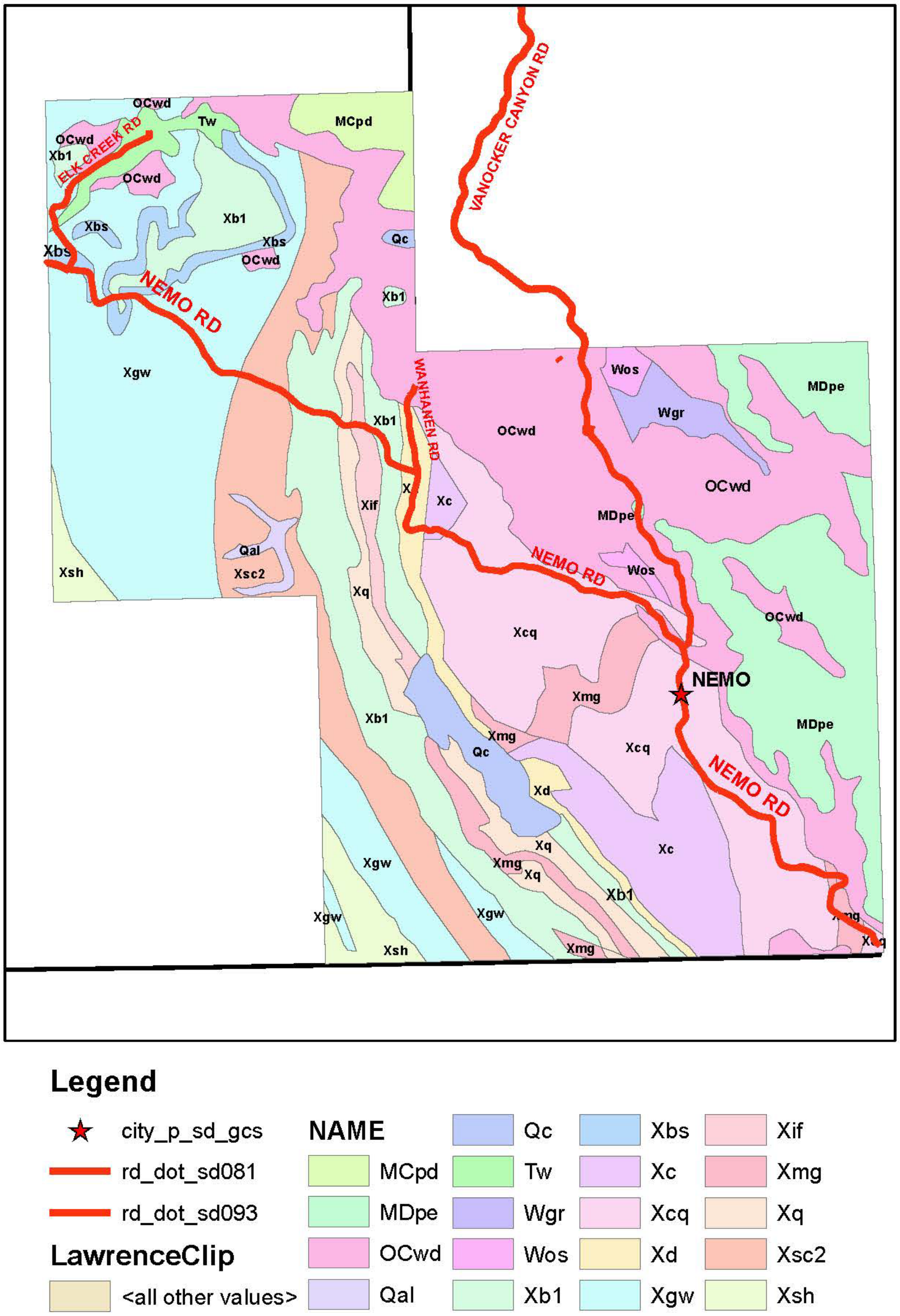
1982-83	Ames, IA	Columbus, OH	3
1983-84	Elba, MN	San Luis Obispo, CA	6
1984-85	Lincoln, NE	Knoxville, TN	2
1985-86	Lake Metigoshe, ND	Fort Collins, CO	7
1986-87	Lake of the Ozarks, MO	Ithaca, NY	1
1987-88	Rock Springs Ranch, KS	Near Brookings, SD	5
1988-89	Roaring River State Park, MO	Stephenville, TX	4
1989-90	Boone County, IA	West Lafayette, IN	3
1990-91	Long Lake Conservation Camp, MN	Murray, KY	2
1991-92	Aurora, NE	Davis, CA	6
1992-93	Brookings, SD	Corvallis, OR	7
1993-94	Rock Springs, KS	Near College Park, MD	1
1994–95	Poplar Bluff, MO	Lake of the Ozarks, MO	5
1995-96	Near Ames, IA	Stillwater, OK	4
1996-97	Camp Ihduhapi, Minnesota	Madison, WI	3
1997-98	Holt County, Nebraska	Athens, GA	2
1998-99	Brookings, SD	Tucson, AZ	6
1999-2000	Manhattan, KS	Moscow, ID	7
2000-2001	Mt. Vernon, MO	University Park, PA	1
2001-2002	Decorah, IA	Red Wing, MN	5
2002-2003	Lake Shetek, MN	College Station, TX	4
2003-2004	Columbia, MO	Normal, IL	3
2004-2005	Norfolk, NE	Auburn, AL	2
2005-2006	Sturgis, SD	San Luis Obispo, CA	6
2006-2007	Manhattan, KS	Logan, UT	7
2007-2008	Griswold, IA	West Greenwich, RI	1
2008-2009	Cloquet, MN	Springfield, MO	5
2009-2010	Columbia, MO	Lubbock, TX	4
2010-2011	North Platte, NE	Bend, OR	7
2011-2012	Pierre, SD	Morgantown, WV	2

2012-2013	Maryville, MO	Platteville, WI	3
2013-2014	Springfield, MO	Delaware Valley College, PA	1
2014-2015	Ames, IA	Monticello, AR	4
2015-2016	Grand Rapids, MN	Manhattan, KS	5
2016-2017	Lincoln, NE	DeKalb, IL	3
2017-2018	Redfield, SD	Martin, TN	2
2018-2019	Manhattan, KS	San Luis Obispo, CA	6
2019-2020	Grand Island, NE	Columbus, OH* *cancelled due to COVID-19	N/A
2020-2021	University of Missouri – Virtual* *virtual due to COVID-19	Virtual* *virtual due to COVID-19	N/A
2021-2022	Crookston, MN	Columbus, OH	1
2022-2023	Okoboji, IA	Oklahoma	4
2023-2024	Sturgis, SD	Ames, IA	5

Generalized Physiography of the Black Hills, Foothills, Red Valley, and Hogback



Geology of Lawrence County, Southeast



Lawrence County SE Geology Map Legend Descriptions

MCpd – Pahasapa Limestone, Englewood Limestone, Whitewood Limestone, Winnipeg Formation, and Deadwood Formation (Lower Mississippian to Cambrian)

MDpe – Madison Group (Lower Mississippian and Upper Devonian)

Pahasapa Limestone (Lower Mississippian) - White, light gray to tan, fine- to medium-grained limestone and dolomite containing brown to gray chert. Solution features include collapse breccia, sinkholes, and caves. Thickness 300-630 ft (91-192 m).

Englewood Limestone (Lower Mississippian and Upper Devonian) - Pink to lavender to light- gray, thin- to medium-bedded, fine- to medium-grained, argillaceous, dolomitic limestone. Thickness 30-63 ft (9-19 m).

OCwd – Whitewood Limestone, Winnipeg Formation, and Deadwood Formation (Upper Ordovician to Middle Cambrian)

Whitewood Limestone (Upper Ordovician) - Mottled tan and gray to lavender, fine- to medium- grained, sparsely fossiliferous limestone and dolomite. Thickness up to 70 ft (21 m).

Winnipeg Formation (Upper Ordovician) - Tan calcareous siltstone and sandy shale with limestone lenses overlying gray and light-green fissile shale. Thickness up to 110 ft (34 m).

Deadwood Formation (Lower Ordovician and Middle Cambrian) - Variegated, yellow to red, brown, gray, and green glauconitic conglomerate, sandstone, shale, dolomitic limestone, and dolomite. Thickness 4-400 ft (1-122 m).

Qal – Alluvium (Quaternary) - Clay- to boulder-sized clasts with locally abundant organic material. Thickness up to 75 ft (23 m).

Qc – Colluvium (Quaternary) - Clay- to boulder-sized clasts forming rubble residuum and talus. Thickness up to 30 ft (9 m).

Tl – Latitic intrusive rocks (Eocene and Paleocene) - Dark-gray to greenish-gray laccoliths and sills of latite, latitic andesite, and quartz latite. Contains phenocrysts of andesine, oligoclase, biotite, hornblende, and sphene in a fine-grained andesine-biotite-quartz groundmass.

Tr – Rhyolitic intrusive rocks (Eocene and Paleocene) - Light-tan to light-gray stocks and small laccoliths of rhyolite. Contains phenocrysts of oligoclase, quartz, and biotite in a fine-grained orthoclase or sanidine-quartz groundmass.

Tw – White River Group (Oligocene and Eocene) - Includes the Brule, Chadron, Chamberlain Pass, and Slim Buttes Formations (see Meade County for descriptions).

Wgr – Granite (Upper Archean) - Pink and gray, strongly foliated, medium- to coarse-grained, locally pegmatitic, biotite-muscovite granite and gneissic granite.

Wos – Older metasedimentary rocks (Upper Archean) - Gray phyllite, mica schist, and biotite-plagioclase schist. Approximately 500 ft (152 m) exposed.

Xb1 – Metabasalt (Lower Proterozoic) - Dark-green amphibolite, actinolite schist, and greenstone, locally with pillow structures. Interflow units consist of graphitic schist, chert, and carbonate- and silicate-facies iron-formation.

Xbs – Metamorphosed black shale (Lower Proterozoic) - Dark-gray biotite schist, biotite- muscovite schist, pyritic biotite schist, and locally massive chert beds. Thickness approximately 2,000-4,000 ft (610-1,219 m).

Xc – Metaconglomerate (Lower Proterozoic) - Tan to light-gray, conglomeratic siliceous schist, feldspathic schist, and minor marble. Thickness locally over 6,000 ft (1829 m).

Xcq – Metaconglomerate and metaquartzite (Lower Proterozoic) - Light-gray to gray, conglomeratic and feldspathic schist, biotite schist, taconite, and phyllite. Individual conglomerate and fanglomerate tongues from 100-1,500 ft (30-457 m) thick. Total thickness over 10,000 ft (3,048 m).

Xd – Metamorphosed dolomite (Lower Proterozoic) - Light-gray to light-tan marble, phyllite, and calcareous phyllite. Thickness 60-300 ft (18-91 m).

Xgw – Metagraywacke (Lower Proterozoic) - Light- to dark-gray, siliceous mica schist and impure quartzite. Differentiated where possible into three primary tongues or lenses (Xgw1, Xgw2, and Xgw3). Thickness from 1,000 ft (305 m) to over 5,000 ft (1,524 m).

Xif – Iron-formation (Lower Proterozoic) - Banded, dark-green, reddish-brown, and white iron-formation, ferruginous chert, and minor mica schist. Includes three or more ages of oxide-, carbonate-, silicate-, and sulfide-facies iron-formation and interbedded tuffaceous rocks. Thickness 20-500 ft (6-152 m).

Xmg – Metagabbro (Lower Proterozoic) - Dark-green sills of amphibolite, actinolite schist, greenstone, and serpentine. Thickness of sills variable; maximum thickness 1,000 ft (305 m).

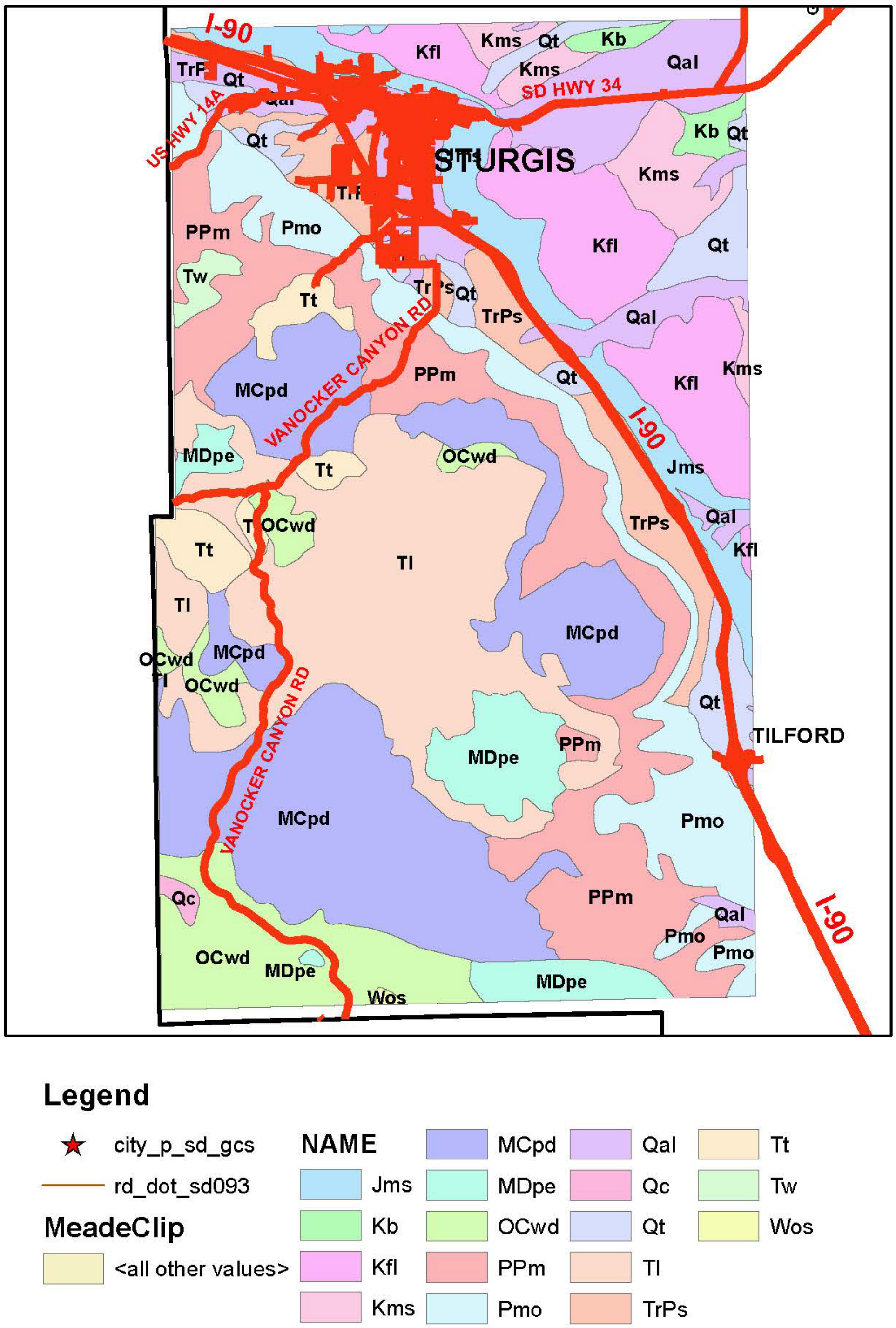
Xq – Metaquartzite (Lower Proterozoic) - Light-tan quartzite, siliceous schist, and minor chert. Thickness 800-5,000 ft (244-1,524 m).

Xsc2 – Metamorphosed carbonaceous shale (Lower Proterozoic) - Dark-gray to gray, siliceous biotite phyllite and schist. Thickness greater than 2,500 ft (762 m).

Xsh – Metamorphosed shale (Lower Proterozoic) - Gray to dark gray phyllite, slate, and mica schist. Estimated thickness at least 5,000 ft (1,524 m).

Xsi – Metamorphosed siltstone (Lower Proterozoic) - Medium-gray to dark-greenish-gray phyllite, slate, and biotite schist containing minor chert and amphibolite. Locally intruded by thin metagabbro sills. Laterally equivalent to Xms. Thickness 1,000-3,000 ft (305-914 m).

Geology of Meade County, Southwest



Meade County SW Geology Map Legend Descriptions

Jms – Morrison Formation, Unkpapa Sandstone, Sundance Formation, and Gypsum Spring Formation (Upper and Middle Jurassic)

Morrison Formation (Upper Jurassic) - Light-gray to green and variegated red, brown, yellow, or lavender, siliceous claystone, shale, and siltstone containing interbedded sandstone and fresh-water limestone lenses. Thickness up to 150 ft (46 m).

Unkpapa Sandstone (Upper Jurassic) - White, massive to thin-bedded, fine-grained, argillaceous sandstone. May be variegated or banded red, yellow, brown, and lavender. Up to 267 ft (81 m) thick.

Sundance Formation (Upper and Middle Jurassic) - Greenish- gray, yellow, tan, red to orange, and white, variegated, interbedded, fine- to coarse-grained sandstone, siltstone, clay, and limestone. Thickness 250-350 ft (76-107 m).

Gypsum Spring Formation (Middle Jurassic) - Massive white gypsum and minor maroon siltstone and shale. Thickness up to 40 ft (12 m).

Kb – Belle Fourche Shale (Upper Cretaceous) - Dark-gray to black bentonitic shale containing minor limestone lenses, bentonite layers, fossiliferous calcarenite, and large, ferruginous, carbonate concretions. Thickness 150-350 ft (46-107 m).

Kfl – Inyan Kara Group (Lower Cretaceous) - Includes the Fall River and Lakota Formations.

Fall River Formation (Lower Cretaceous) - Variegated brown, red, and gray to purple, calcareous, well-sorted, fine-grained sandstone, siltstone, and shale containing mica. Thickness 100-200 ft (30-61 m).

Lakota Formation (Lower Cretaceous) - Yellow, brown, red-brown, and gray to black claystone, silty pebble conglomerate, and massive to thin-bedded, cross-bedded sandstone. Locally interbedded with fresh-water limestone and bituminous coal beds. Thickness 35-500 ft (11-152 m).

Kms – Mowry Shale, Newcastle Sandstone, and Skull Creek Shale (Lower Cretaceous)

Mowry Shale (Lower Cretaceous) - Black to gray, siliceous, fissile shale and siltstone containing bentonite layers and sparse sandstone dikes. Thickness 125-250 ft (38-76 m).

Newcastle Sandstone (Lower Cretaceous) - Gray and light-brown to yellow, discontinuously distributed siltstone, claystone, sandy shale, and fine-grained sandstone. Thickness up to 290 ft (88 m).

Skull Creek Shale (Lower Cretaceous) - Dark-gray to bluish-gray shale containing ferruginous and carbonate concretions. Thickness 150-275 ft (46-84 m).

MCpd – Pahasapa Limestone, Englewood Limestone, Whitewood Limestone, Winnipeg Formation, and Deadwood Formation (Lower Mississippian to Cambrian)

MDpe – Madison Group (Lower Mississippian and Upper Devonian)

Pahasapa Limestone (Lower Mississippian) - White, light gray to tan, fine- to medium-grained limestone and dolomite containing brown to gray chert. Solution features include collapse breccia, sinkholes, and caves. Thickness 300-630 ft (91-192 m).

Englewood Limestone (Lower Mississippian and Upper Devonian) - Pink to lavender to light- gray, thin- to medium-bedded, fine- to medium-grained, argillaceous, dolomitic limestone. Thickness 30-63 ft (9-19 m).

OCwd – Whitewood Limestone, Winnipeg Formation, and Deadwood Formation (Upper Ordovician to Middle Cambrian)

Whitewood Limestone (Upper Ordovician) - Mottled tan and gray to lavender, fine- to medium- grained, sparsely fossiliferous limestone and dolomite. Thickness up to 70 ft (21 m).

Winnipeg Formation (Upper Ordovician) - Tan calcareous siltstone and sandy shale with limestone lenses overlying gray and light-green fissile shale. Thickness up to 110 ft (34 m).

Deadwood Formation (Lower Ordovician and Middle Cambrian) -Variegated, yellow to red, brown, gray, and green glauconitic conglomerate, sandstone, shale, dolomitic limestone, and dolomite. Thickness 4-400 ft (1-122 m).

Pmo – Minnekahta Limestone and Opeche Shale (Permian)

Minnekahta Limestone (Upper and Lower Permian) - Purple to gray, fine-grained, thin- to medium-bedded limestone with varying amounts of red shale. Thickness 30-50 ft (9-15 m).

Opeche Shale (Lower Permian) - Red siltstone, argillaceous sandstone, and shale with interbedded caliche layers. Thickness 85-130 ft (26-40 m).

PPm – Minnelusa Formation (Lower Permian and Upper Pennsylvanian) - Variegated, yellow to red, gray to brown, pink to purple, and black, interbedded sandstone, siltstone, shale, limestone, dolomite, calcarenite, chert, and brecciated beds. Thickness 394-1,175 ft (120-358 m).

Qal – Alluvium (Quaternary) - Clay- to boulder-sized clasts with locally abundant organic material. Thickness up to 75 ft (23 m).

Qc – Colluvium (Quaternary) - Clay- to boulder-sized clasts forming rubble residuum and talus. Thickness up to 30 ft (9 m).

Qt – Terrace deposits (Quaternary) - Clay- to boulder-sized clasts deposited as pediments, paleochannels, and terrace fills of former flood plains. Thickness up to 75 ft (23 m).

Tl – Latitic intrusive rocks (Eocene and Paleocene) - Dark-gray to greenish-gray laccoliths and sills of latite, latitic andesite, and quartz latite. Contains phenocrysts of andesine, oligoclase, biotite, hornblende, and sphene in a fine-grained andesine-biotite-quartz groundmass.

TrPs – Spearfish Formation (Lower Triassic and Upper Permian) - Red sandy shale, siltstone, sandstone, and minor limestone. Interbedded with abundant gypsum. Thickness 328-559 ft (100-170 m).

Tt – Trachytic intrusive rocks (Eocene and Paleocene) - Tan to reddish-brown, iron-stained stocks, laccoliths, sills, and dikes of trachyte, quartz trachyte, and alkalic rhyolite. Contains phenocrysts of sanidine, orthoclase, anorthoclase, aegirine-augite, and biotite in a fine-grained orthoclase-quartz-biotite groundmass.

Tw – White River Group (Oligocene and Eocene) - Includes the Brule, Chadron, Chamberlain Pass, and Slim Buttes Formations.

Brule Formation (Oligocene) - White, pink, light-green, and light-brown, massive to thin- bedded, bentonitic claystone, tuffaceous siltstone, and well-bedded, calcareous, tuffaceous quartz sandstone. Thickness up to 150 ft (46 m).

Chadron Formation (Eocene) - Upper beds are gray to light brown to maroon bentonite, claystone, siltstone, and tuffaceous fine-grained sandstone, with local silicified carbonate lenses. Basal portion consists of poorly cemented, white, coarse-grained arkose and conglomerate. Thickness up to 160 ft (49 m).

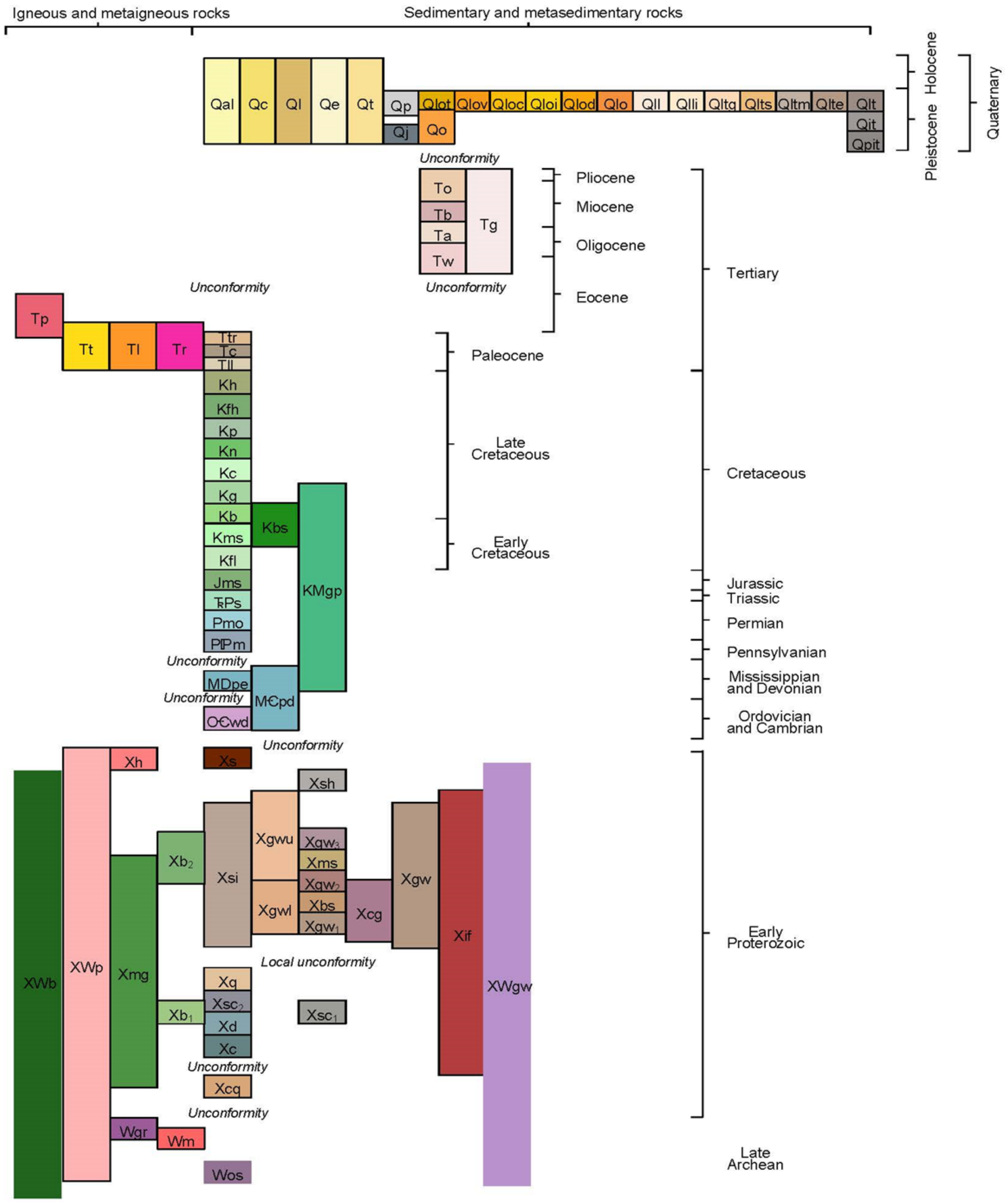
Chamberlain Pass Formation (Eocene) - Pale-olive to pale-red, mottled mudstone containing white, cross-bedded channel sandstone with basal conglomerate. Thickness up to 32 ft (10 m).

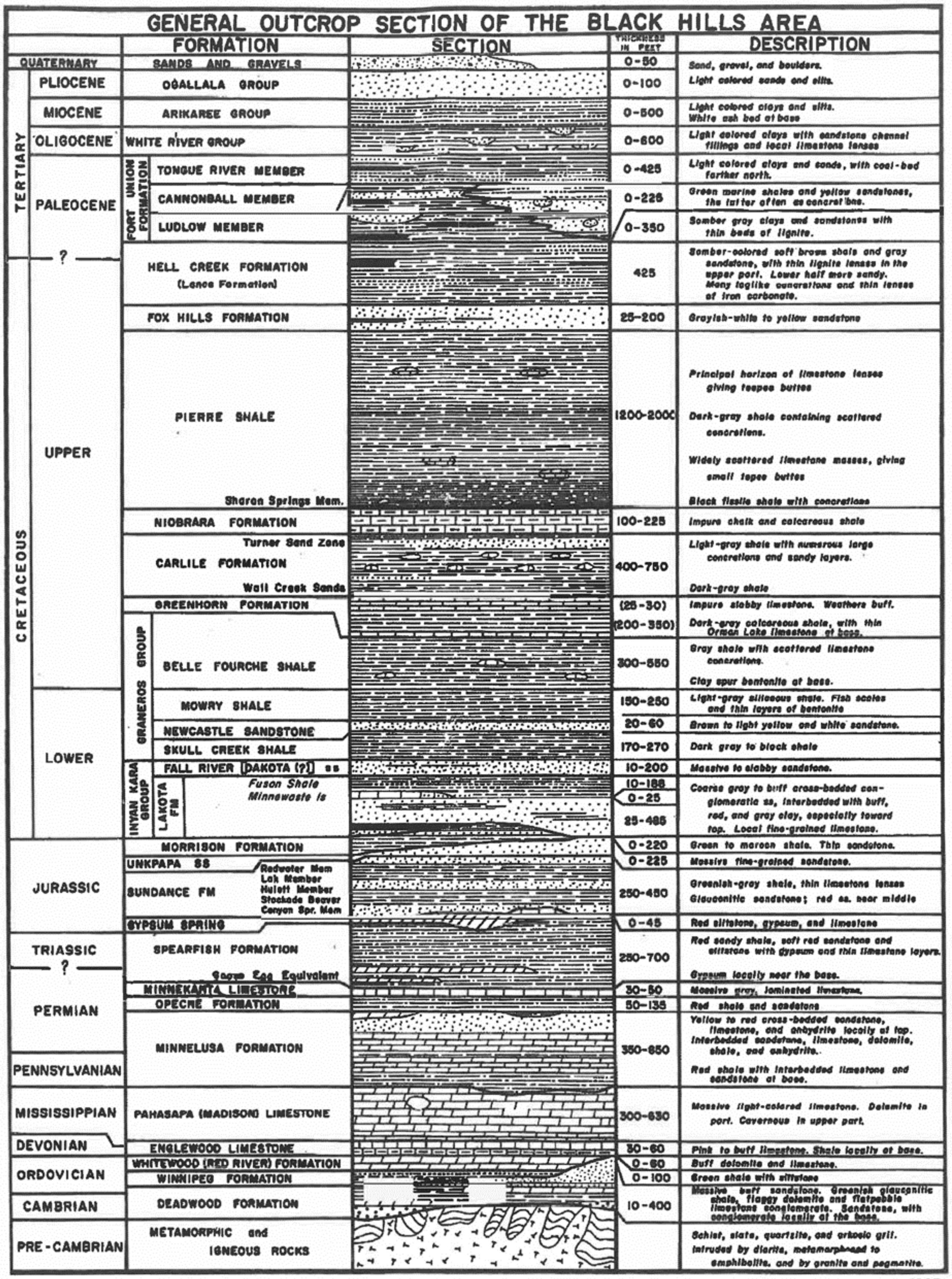
Slim Buttes Formation (Eocene) - White, grayish- to yellowish-orange, and pale-red to pink siltstone, clayey siltstone, bentonitic claystone, medium-to fine-grained sandstone, and conglomerate. Thickness up to 48 ft (15 m).

Wos – Older metasedimentary rocks (Upper Archean) - Gray phyllite, mica schist, and biotite- plagioclase schist. Approximately 500 ft (152 m) exposed.

CORRELATION OF MAP UNITS

(Map unit age ranges may not represent continuous deposition or emplacement)





DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
RAPID CITY, SOUTH DAKOTA

Geologic Time Scale

Era	Period	Epoch	Millions of Years
Cenozoic	Quaternary	Holocene	present
		Pleistocene	0.008
	Tertiary	Pliocene	1.8
		Miocene	5.3
		Oligocene	23.8
		Eocene	33.7
		Paleocene	55.5
Mesozoic	Cretaceous	Maestrichthian	65.5
		Campanian	71.3
		Santonian	83.5
		Coniacian	86.3
		Turonian	88.7
		Cenomanian	93.3
		Albian	98.5
		Aptian	112
		Barremaian	121
		Hauterivian	127
		Valanginian	130
		Berriasian	135
		Tithonian	142
	Jurassic		145
	Triassic		213
Paleozoic	Permian		248
	Pennsylvanian		286
	Mississippian		325
	Devonian		360
	Silurian		410
	Ordivician		440
	Cambrian		505
			544

Precambrian Time (4,500 to 544 million years ago)

Figure 4. Geologic-time scale.