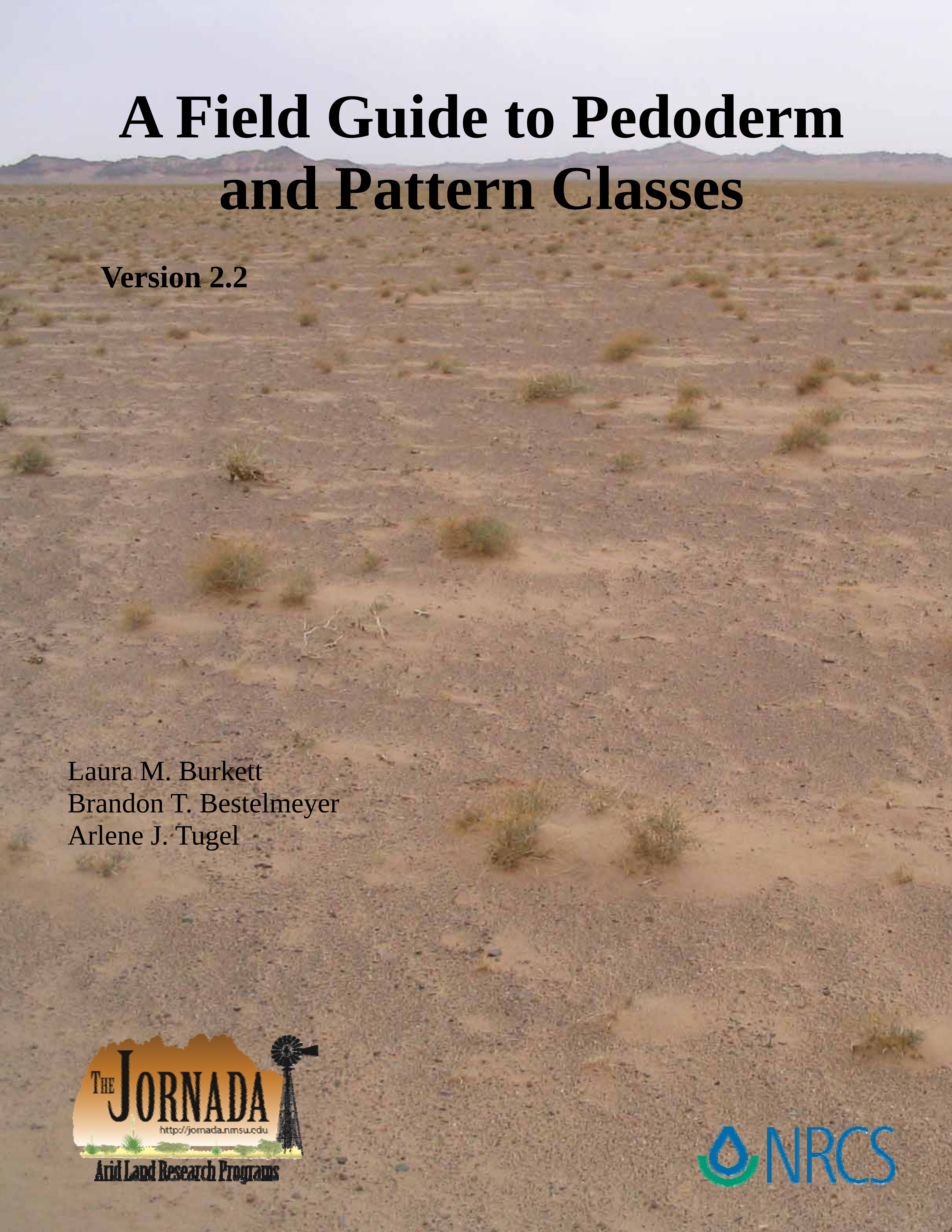

A Field Guide to Pedoderm and Pattern Classes

Version 2.2

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Cover photo: Desert steppe dominated by *Artemisia frigida* in southern Mongolia. Pedoderm Class = WP (So); Resource Retention Class = 6; Soil Redistribution Class = 3a.

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by
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A special thank you to David Trujillo for conceptual contributions during the early phases of the Pedoderm and Pattern Class development. We thank Jeff Herrick and Justin Van Zee for photo contributions. Skye Wills, Joe Chiaretti and Curtis Talbot improved the document.

USDA-ARS Jornada Experimental Range
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What are Pedoderm and Pattern Classes?

Pedoderm and Pattern Classes provide a simple language to describe soil surface features and plant patterns much in the same way we recognize plant communities or soil types using standardized names. Pedoderm and Pattern Classes (PPCs) describe the soil **pedoderm** (i.e., the air-soil interface), the spatial arrangement (pattern) of plants potentially influencing the soil pedoderm, and evidence of **soil redistribution**. PPCs provide a record of soil surface features and plant patterns that influence **ecosystem function**. PPCs complement observations of plant community **composition** and **soil profiles**.

PPCs have categorical or ordinal values and are designed to be assessed quickly within field **plots** during **inventory**, soil survey, or when characterizing site conditions of monitoring plots. The classes provide a record of soil surface features and plant patterns that affect the site's ability to respond to management actions, restoration, and natural drivers. To date, obtaining information about these types of attributes has required highly technical or time-intensive procedures, so soil surface and plant pattern data have not been regularly collected. We developed PPCs to help remedy this limitation.

PPCs closely correspond to several of the indicators described in Interpreting Indicators of Rangeland Health (IIRH; Pellant et al., 2005) and Landscape Function Analysis (LFA; Tongway and Hindley 2004). Unlike IIRH, PPCs are not based on deviation from **site potential**, but rather describe existing conditions. Furthermore, PPCs integrate observations of multiple attributes that are dealt with individually in IIRH and LFA (such as **pedestals**, **water flow patterns**, **rills** and coppicing) to arrive at a single class. Thus, a trained observer can evaluate a site quickly without rating and interpreting numerous individual indicators. PPCs are especially useful when multiple observations must be gathered quickly over extensive areas.

Where can Pedoderm and Pattern Classes be Applied?

Pedoderm and Pattern Classes can be applied anywhere that soil surface properties and the spatial arrangement of plants influence soil and **nutrient** redistribution, resource **retention**, water **infiltration** and plant establishment. In particular, PPCs are designed for use in arid, semi-arid and subhumid ecosystems. With additional testing and adaptation, they may be useful in humid systems. They can be applied to deserts, grasslands, savannas and some woodlands. PPCs have been developed and applied in various areas of the world, including United States, China, Mongolia, Australia, Israel, and Argentina (reflected in the photographs used in this document). Pedoderm and Pattern Classes can have utility in croplands, especially where fallow periods are employed in dryland farming.

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Pedoderm and Pattern Classes (PPCs) integrate observations of multiple features that vary in occurrence and appearance. Thus, the application of PPCs in the field involves a degree of subjectivity, and class assignments are sometimes fuzzy—that is, a plot can exhibit characteristics of more than one class. This is no different from a physician's diagnosis. Few would argue that qualitative observations, such as the redness of the throat or swelling of the lymph nodes, are not valuable indicators. Most would agree that color charts are not needed to assess throat redness, and calipers are unnecessary to detect swollen lymph nodes. PPCs represent a tool to aid in the diagnosis of ecosystem function. The field manual offered here attempts to present PPCs such that independent users arrive at the same, single classification for each of the three PPCs on the same piece of ground. This goal requires clear explanations based on a broad array of cases. We anticipate that this manual will be improved by user critique, particularly coming from geographic areas the authors have not directly experienced. Please do not hesitate to contact Laura or Brandon with questions or suggestions for improvement.

Overview of the Pedoderm and Pattern Classes

The **pedoderm class** describes the type of material that occurs at the air-soil interface (the pedoderm or 'skin of the soil'). Each class represents properties of the unvegetated surface that influence soil **erosion**, nutrient retention and addition, water infiltration and plant establishment.

The **resource retention class** describes the spatial patterning of persistent **vascular plant** patches and interpatches across a plot. The different patterns can influence how well a site can retain water and nutrient resources as well as prevent erosion.

The **soil redistribution class** describes the extent and severity of erosion and **deposition** on a plot. Soil redistribution (erosion and deposition by wind and water) affects plants directly via **disturbances** and indirectly via the addition or loss of nutrients. Soil redistribution also affects air quality, water quality, and other ecosystem functions.

These classes are typically used in conjunction with observations of the vegetation and soil profile in a plot (typically 1/10th acre or 20 x 20 m) to characterize the **state** or condition of an ecosystem at a location. The soil profile is used to understand the inherent potential of a site, especially its **ecological site**. The vegetation data are used to determine the plant **community phase** or state, including the varied ecosystem services and other organisms it supports. The pedoderm and resource retention classes describe the properties at the soil surface that influence plant community productivity and soil erosion. The soil redistribution class describes active and recent erosion and deposition that affect the soil surface and plant community. Each of these five elements (plant community, soil profile and three PPCs) is interrelated in numerous ways to influence what we perceive as ecosystem function or **rangeland health**. For example, evaluations based on PPCs can help to estimate the likelihood of successful recovery where extensive soil redistribution is taking place.

Pedoderm Class (PC)

The pedoderm class is a description of the thin layer of soil at the air/soil interface (the pedoderm) across a plot, including physical, chemical and **biological crusts**, rocks at the soil surface, duff, bare soil and the aggregation of **soil particles**. The features of each class influence water infiltration, soil erosion and retention, nutrient retention and addition, and plant establishment. Where multiple features occur on a plot, class selection is based on the feature of greatest influence.

Pedoderm classes are loosely arranged in order of their influence on ecosystem function. For example, the ability to protect the soil resource from erosion and physical disturbance for a subset of pedoderm classes would rank as follows: bare single grain soil < weak physical or biological crust < strong physical crust < erosion pavement < desert pavement. A pedoderm class can be temporary or long-lasting. Physical disturbance can transform a weak physical or biological crust to a bare single grain pedoderm. Raindrop impact following tillage can convert a soil aggregate pedoderm into a weak physical crust. Heavy rainfall can dislodge and transport rock fragments within an erosion pavement, but cannot displace rocks in a desert pavement.

Pedoderm Class (PC) Method

Walk around a 20 m x 20 m area (or another defined area representing a plot), typically centered on a soil pit. Observe the pedoderm (i.e., the lateral expanse of the top 0.5-3 cm of the soil surface at the air/soil interface; Fey et al. 2006).

If necessary, pull up several surface '**crusts**' throughout the plot and look for structural **aggregates**, **cyanobacterial sheaths**, biological crusts, **physical crusts**, etc. A soil knife, archeological pick, or trowel is useful to separate the pedoderm from the underlying soil without destroying pedoderm structure.

Consider only the pedoderm, and not the **plant bases**, when determining which class to select.

Start at the top of the pedoderm class list and work down (Table 1). Choose only one class. While there can be two or more pedoderm classes present, the interpretation of multiple classes is difficult. When more than one class is present, select the class that has the greatest influence on **soil stability**, water infiltration, and nutrient retention on the plot. The most influential pedoderm class usually has the greatest area on the plot.

If the pedoderm class selected on the data form (Table 1) is weak physical or biological crust, salt crust, poorly developed biological crust, cracking or curling, rubbery algal crust, or strongly developed biological crust record one or two dominant biological crust **functional/structural groups** codes under Dom Biol Crust from the list provided on the data form (Table 1).

Pedoderm Class Modifier

If patches of loose, **structureless** soil (recent **eolian** deposits) discontinuously cover a pedoderm class throughout the plot, enter So (Loose soil over another pedoderm class; Fig. 1) in the corresponding Pedoderm Class Modifier cell. So cannot be used as a modifier with S (bare single grain soil).

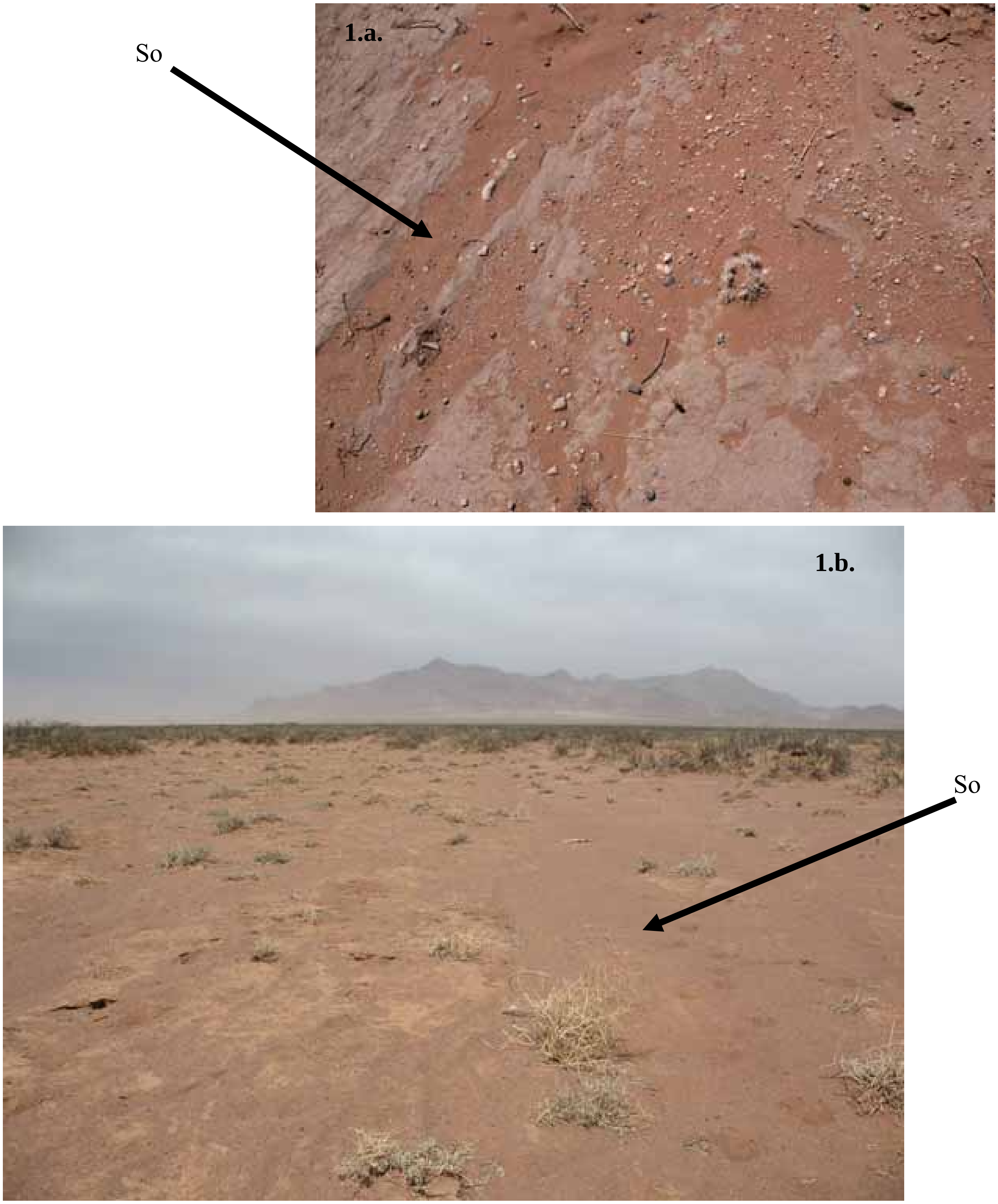


Figure 1. So - Loose soil over a pedoderm class. Arrows point to loose, structureless soil discontinuously covering the pedoderm. Note the difference in soil color between the loose soil (redder) and the soil it covers (grayer) in 1.a. In these examples, 'So' would be listed in the Pedoderm Class Modifier column to the far right of 'weak physical or biological crust' on the data form (the 'weak physical or biological crust' is the grayer soil in Fig. 1.a. and lighter/ yellower soil in Fig. 1.b.).

Table 1. Pedoderm Class (PC) Data Form. Begin at the top of the Pedoderm Class data form and work down the form. Place a check mark in the appropriate box under "select one" next to the PC that best describes the plot. Where biological crusts are a significant component of the selected PC, enter the code(s) for the dominant biological crust functional/structural group(s) in the appropriate cell under the Dom Biol Crust column (cell is blacked out if not applicable to a PC). These codes are listed as a footnote at the bottom of the form. Where patches of loose, structureless soil discontinuously cover a pedoderm class throughout the plot, enter So under the Pedoderm Class Modifier column (not to be used with bare single grain soil pedoderms). More detailed descriptions of how to use this data form and each class are found in the Pedoderm Class (PC) Method and Distinguishing Pedoderm Classes (PC). A complete Pedoderm and Pattern Class data form can be download from: http://jornada.nmsu.edu/esd/development-resources (accessed on July 22, 2011). Note to NRCS soil scientists: the PC data form requires modification to accommodate soil crust modifiers.

Pedoderm Class (v. 3.0)	select one	[1]Dom Biol Crust	[2]Pedoderm Class Modifier
S = Bare single grain soil; pedoderm is characterized by bare mineral soil and no other class.			
SA = Soil aggregates; well-formed or distinct structural aggregates at the soil surface and no other pedoderm class (well aggregated, but not platy, stable soils).			
RM = Rock mulch with stable soil; surface soil material is trapped and protected by closely spaced and partially embedded rock fragments (mostly cobbles and larger); can be associated with rock outcrops.			
WP = Weak physical or biological crust; none to few cyanobacterial sheaths dangling from ped, no darkening from cyanobacteria.			
SP = Strong physical crust; usually platy or massive, no substantial biological component.			
CEM = Cemented horizon exposed at surface.			
SC = Salt crust of fine to extremely coarse evaporite crystals or visible whitening on the soil surface; may include biological components.			
PDB = Poorly developed biological crust, dense cyanobacterial sheaths form a smooth or dimpled crust of variable darkness; can include other functional/structural groups (algae, lichen, moss).[1]			
SDB = Strongly developed biological crust, typically two or more functional/structural groups (cyanobacteria, algae, moss, lichen) form a rugose, pinnacled or rolling crust.[1]			
CB = Cracking or curling, rubbery algal crust, with or without lichen.[1]			
EP = Erosion pavement; a lag of rock fragments remaining after erosion and removal of finer soil material, forming a dense uniform pavement; individual fragments may be displaced during runoff events.			
DP = Desert pavement; a concentration of closely packed and varnished rock fragments at the soil surface, embedded in a vesicular crust.			
D = Duff; non-decomposed to fully decomposed plant and organic matter located above the A horizon (a patchy or continuous O horizon).			

[1] List 1-2 dominant biological crust functional/structural groups from this list: CY (Cyanobacteria), LC (Lichen Crust), M (Moss), LV (Liverwort), A (Algae).

[2] Pedoderm Class Modifier: So = Loose soil over a pedoderm class.

Pedoderm Class (PC) Descriptions

S - Bare single grain soil; pedoderm is characterized by bare mineral soil and no other class (Fig. 3). This pedoderm is distinguished by a lack of structural aggregates (i.e., **single grain**). Soil **peds** do not occur at the surface. Individual particles of soil less than 5 mm in diameter are visible in the hand. Physically disturbed soils tend to be in this class. This pedoderm is particularly susceptible to wind and **water erosion**.

SA - Soil aggregates; well-formed or distinct structural aggregates at the soil surface and no other pedoderm class (well aggregated, but not platy, stable soils; Fig. 4). The surface **soil structure** (peds) can be **angular** or **subangular blocky**, **granular** or **columnar**. Dig a small soil pit to view the soil structure and verify a soil aggregate pedoderm. Soil aggregate pedoderms are typically found in grassland communities and are darkened by **organic matter**. Soils with structural aggregates have high resistance to wind and water erosion and good infiltration.

RM - Rock mulch with stable soil; surface soil material is trapped and protected by closely spaced and partially embedded rock fragments (mostly cobbles and larger); can be associated with rock outcrops (Fig. 5). Soil tends to accumulate. Rock mulch pedoderms are usually fertile and productive. Rock mulch pedoderms tend to have a higher resistance to erosion than soil aggregate pedoderms. Rock mulch pedoderms consist predominantly of larger clasts that are not redistributed by water. Rock mulch pedoderms do not contain concentrations of **gravel**.

WP - Weak physical or biological crust; none to few cyanobacterial sheaths dangling from ped, no darkening from cyanobacteria (Fig. 6). The cyanobacterial sheaths appear as barely visible strands dangling from a fragment of the crust, with small soil aggregates adhering to them. The soil surface has a thin or medium **platy** structure, with a weak or moderate grade of expression, and may appear **smooth** (Fig. 2) or with shallow cracks. Weak crusts bind the soil together and have slightly increased resistance to wind and water erosion compared with bare single grain soil pedoderms. However, weak physical or biological crust pedoderms can be disrupted by **raindrop impact**, resulting in **splash erosion**. This can seal surface soil pores, which reduces infiltration relative to bare single grain soil and soil aggregate pedoderms.

SP - Strong physical crust; usually platy or massive, no substantial biological component (Fig 7). These crusts are medium to very thick platy, **prismatic**, columnar or **massive**. Dry strong physical crusts are usually hard and difficult to penetrate when a finger is pressed against the crust. There are no substantial biological crust components, although in some cases, biological or weak physical crusts can form on top of thick strong physical crusts. Thus, care should be taken to ensure that the entire pedoderm is observed by digging and lifting out surface peds that can be over 2 cm thick. **Vesicular pores** can be present. Strong physical crusts impart resistance to raindrop impact, reducing wind and water erosion relative to weak physical or biological crust pedoderms. Infiltration rates, however, are also low due to **surface sealing** and reduced pore space, and **interrill erosion** can occur.

CEM - Cemented horizon exposed at surface (Fig. 8). A **cemented horizon** forms through **pedogenesis** beneath the soil surface (i.e, it is a **B horizon**). Erosion exposes these cemented **horizons** at the soil surface. Remnants of the soil that once covered the cemented horizon are typically scattered throughout the area of this pedoderm. A brittle crust of gypsum formed at the soil surface is included in cemented horizon pedoderms. Cemented horizons are resistant to wind and water erosion but restrict water infiltration and especially plant establishment. **Bedrock** (R or Cr) horizons exposed through erosion are included in CEM pedoderm classes.

SC - Salt crust of fine to extremely coarse evaporite crystals or visible whitening on the soil surface; may include biological components (Fig. 9). Salt crusts can form on top of weak physical or biological crust pedoderms or strong physical crusts. Infiltration rates vary depending on the type of salts and presence of underlying physical crusts. Where salt crusts appear as a result of salinization in plant communities that lack a tolerance for soil salinity, salts can interfere with seedling establishment.

PDB - Poorly developed biological crust, dense cyanobacterial sheaths form a smooth or dimpled crust of variable darkness; can include other functional/structural groups (algae, lichen, moss; Fig. 10). Poorly developed biological crusts are recognized by the dense cyanobacterial sheaths compared to weak physical or biological crusts. They resist raindrop impact and erosion better than weak physical or biological crusts, but are insufficiently rough or continuous to trap **sediment** or to slow **runoff**. Poorly developed biological crust pedoderms can include areas with evidence of disruption of the biological crust that has lead to the formation of small, weak physical crust patches.

SDB - Strongly developed biological crust, typically two or more functional/structural groups (cyanobacteria, algae, moss, lichen) form a rugose, pinnacled or rolling crust (Fig. 2, 11). Two or more functional/structural groups are typically common in contrast to poorly developed biological crusts. Compared to poorly developed biological crust pedoderms, strongly developed biological crust pedoderms are sufficiently rough and continuous to trap sediment, slow runoff and protect against erosion.

CB - Cracking or curling, rubbery algal crust, with or without lichen (Fig. 12). These crusts are composed of thin, typically cracked surface peds that may curl upward at the edges. When wet, the crust is rubbery to the touch and the underside of individual peds commonly appears green. Cracking or curling, rubbery algal crust pedoderms can have **lichens** associated with them. The cracking or curling, rubbery algal crusts stabilize the soil surface by binding soil particles together, however, the curled crusts can become detached and be carried away by wind or water. The ability of cracking/curling crusts to resist erosion depends upon their moisture status, size, thickness and anchor strength. In general, dry cracking or curling, rubbery algal crusts are less resistant to **wind erosion** than poorly developed biological crusts and strongly developed biological crusts. Cracking or curling, rubbery algal crusts stabilize the soil surface and trap sediments and **resources** better than weak physical or biological crust and bare single grain soil pedoderms.

EP - Erosion pavement; a lag of rock fragments remaining after erosion and removal of finer soil material, forming a dense uniform pavement; individual fragments may be displaced during runoff events (Fig. 13). The density, cover and size of **rock fragments** can vary, but gravel-sized rock fragments are the dominant soil surface feature in the plant interspaces. In contrast to desert pavements (below), rocks do not appear **varnished** or polished. Erosion pavements protect the soil surface from erosion by raindrop impact, **overland water flow** and wind. Unlike rock mulch and desert pavement pedoderms, rock fragments comprising erosion pavement pedoderms are not embedded in accumulating soil material. Erosion pavements include eroded rock mulch pedoderms with concentrations of surface gravel.

DP - Desert pavement; a concentration of closely packed and varnished rock fragments at the soil surface, embedded in a vesicular crust (Fig. 14). The **desert varnish** imparts a darkened and shiny appearance to the exposed surface of the rocks and the soil in which the rocks are embedded has vesicular pores. The high cover, concentration, and embedded nature of rock fragments in desert pavements resists wind and water erosion slightly more than erosion pavements. The embedded rock fragments in the soil surface, along with the presence of well-developed vesicular layers, significantly reduces water infiltration relative to erosion pavements. Individual rock fragments are not displaced during runoff events. Desert pavements occur on relatively stable surfaces and do not indicate recent or active erosion .

D - Duff; non-decomposed to fully decomposed plant and organic matter located above the A horizon (a patchy or continuous O horizon; Fig. 15). Individual leaves and plant parts are recognizable in the upper part of the duff layer, but become less discernable with depth. Individual plant parts are not readily distinguished at the boundary with the **A horizon**. Duff stabilizes the soil surface, protecting it from erosion by raindrop impact, overland water flow, and wind. The effect of duff on water infiltration depends upon its thickness, water content, and the water repellency of the duff and **mineral soil**. The presence of pores and wet areas in the duff and underlying mineral soil can promote **preferential flow** into and through the mineral soil.

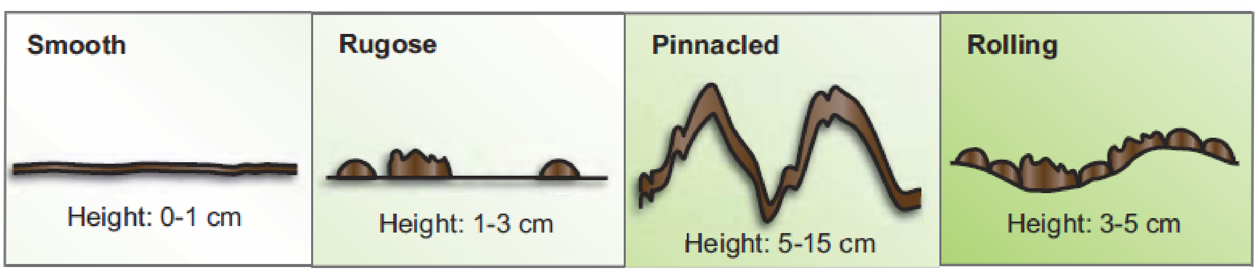


Figure 2. Biological crust morphology following Rosentreter et al. (2007). Smooth biological crusts typically occur in hot, hyper-arid deserts and in recently disturbed deserts. Smooth biological crusts have the least vertical relief with heights between 0 and 1 cm and are usually dominated by **cyanobacteria**. **Rugose** biological crusts occur in slightly less arid deserts. Rugose biological crusts have more vertical relief than smooth crusts, with heights between 1 and 3 cm and contain gaps of smooth crusts or mineral soil between them. **Pinnacled** biological crusts commonly occur in mid-latitude cool deserts. Pinnacled biological crusts have the greatest vertical relief with heights between 5 and 15 cm. **Rolling** biological crusts exist only where frost-heaving occurs in the winter. Rolling biological crusts have more vertical relief than smooth crusts, but less than pinnacled crusts, with heights between 3 and 5 cm; rolling crusts typically do not include gaps of mineral soil surface or smooth crusts.

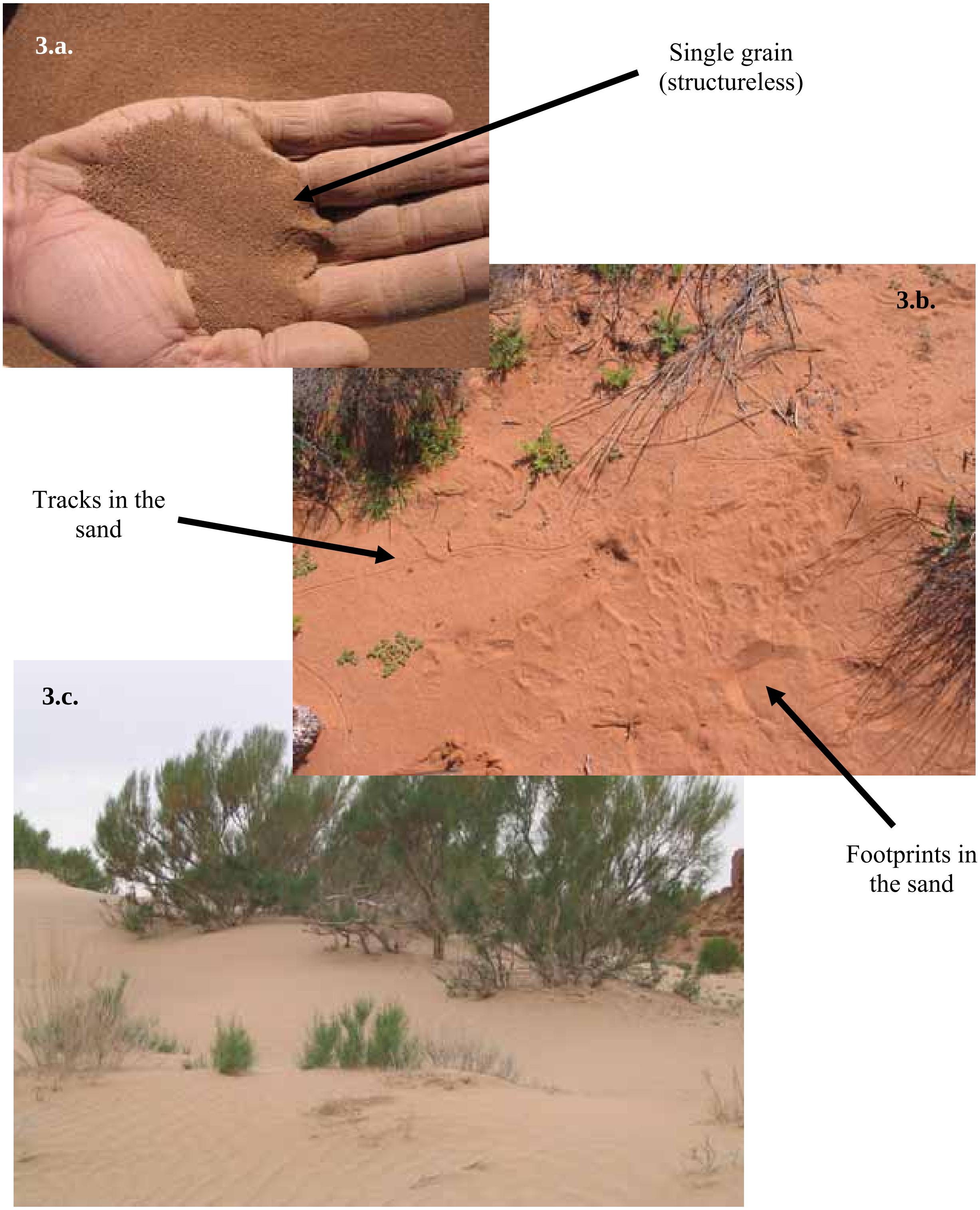


Figure 3. S - Bare single grain soil; pedoderm is characterized by bare mineral soil and no other class. Individual particles of soil less than 5 mm in diameter are visible in the hand (Fig. 3.a.). Animal tracks are frequently observed in a bare single grain soil pedoderm (left arrow of Fig 3.b.). The edges of human footprints look like tracks in sand and there are no structural aggregates broken up by footprints (bottom right arrow in Fig. 3.b.).

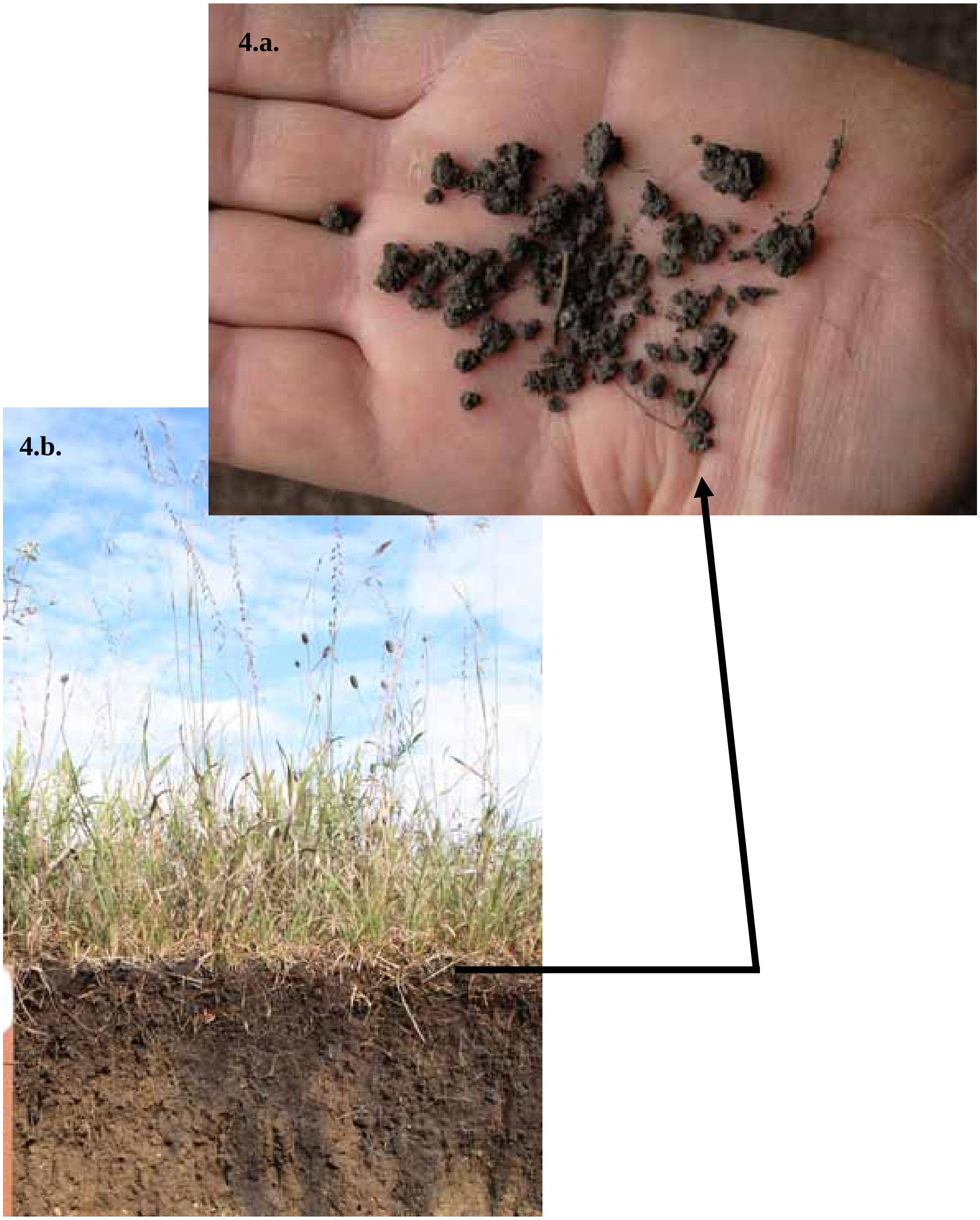


Figure 4. SA - Soil aggregates; well-formed or distinct structural aggregates at the soil surface and no other pedoderm class (well aggregated, but not platy, stable soils; Fig. 4.a.). Soil aggregate pedoderms are typically found in grassland communities (Fig. 4.b.) and are darkened by organic matter. Photos provided by Bruce Kunze, Area Resource Soil Scientist, NRCS.

Figure 5. RM - Rock mulch with stable soil; surface soil material is trapped and protected by closely spaced and partially embedded rock fragments (mostly **cobbles** and larger; Fig 5.a.–c.); can be associated with rock outcrops. Rock mulch pedoderms are usually fertile and productive (Fig 5.d.-e.).

Figure 6. WP - Weak physical or biological crust; none to few cyanobacterial sheaths dangling from ped, no darkening from cyanobacteria. The cyanobacterial sheaths appear as barely visible strands dangling from a fragment of the crust, with small soil aggregates adhering to them (circled area in Fig. 6.a.). The soil surface has thin or medium platy structure (Fig. 6.b.). The soil surface can appear smooth or with shallow cracks (Fig. 6.c.-d.).

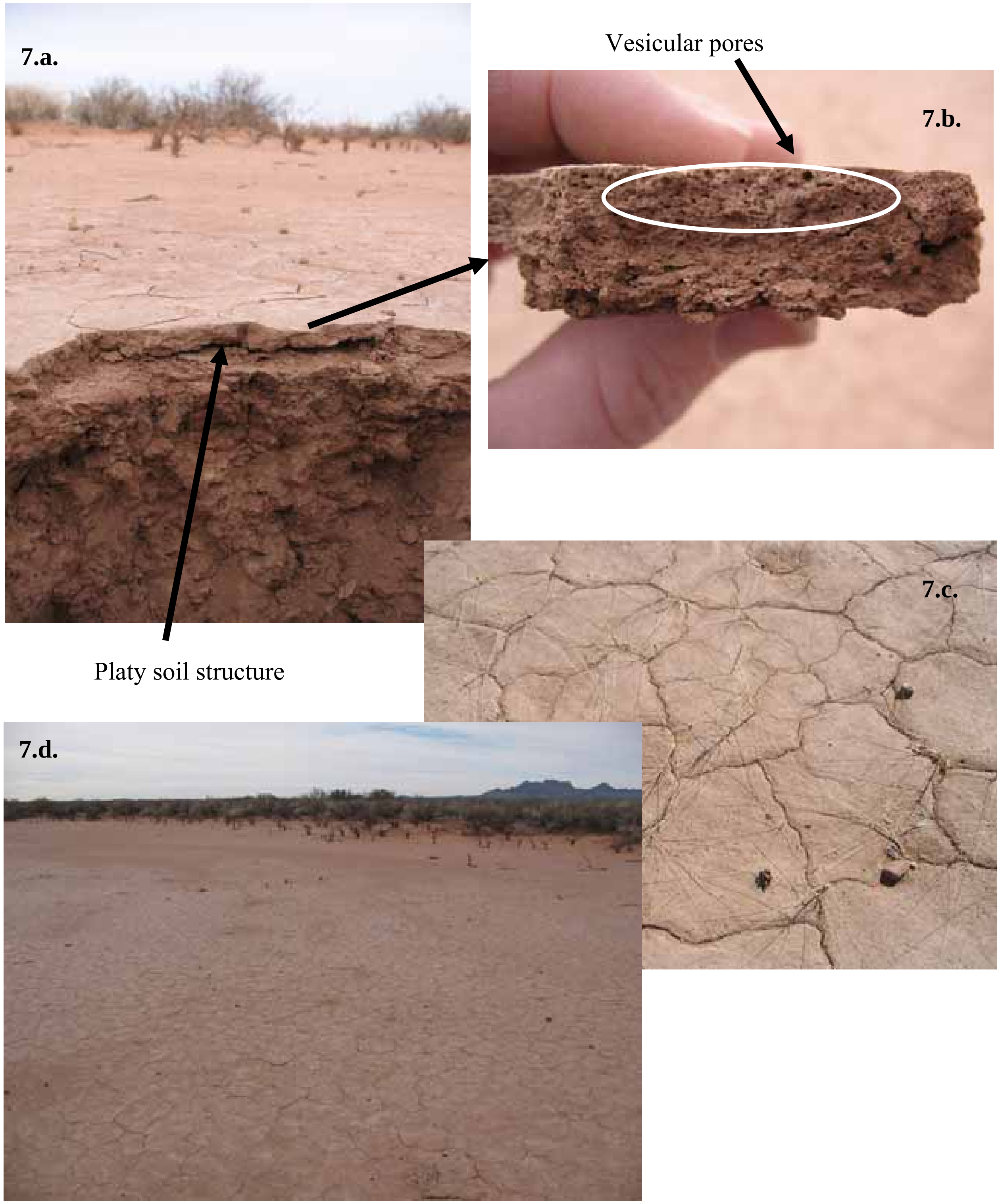


Figure 7. SP - Strong physical crust; usually platy or massive, no substantial biological component (Fig. 7.a.-d.). In some cases, biological or weak physical crusts can form on top of thick strong physical crusts. Thus, care should be taken to ensure that the entire pedoderm is observed by digging and lifting out surface peds that can be over 2 cm thick (Fig. 7.a.-b.). Vesicular pores can be present (Fig. 7.b.).

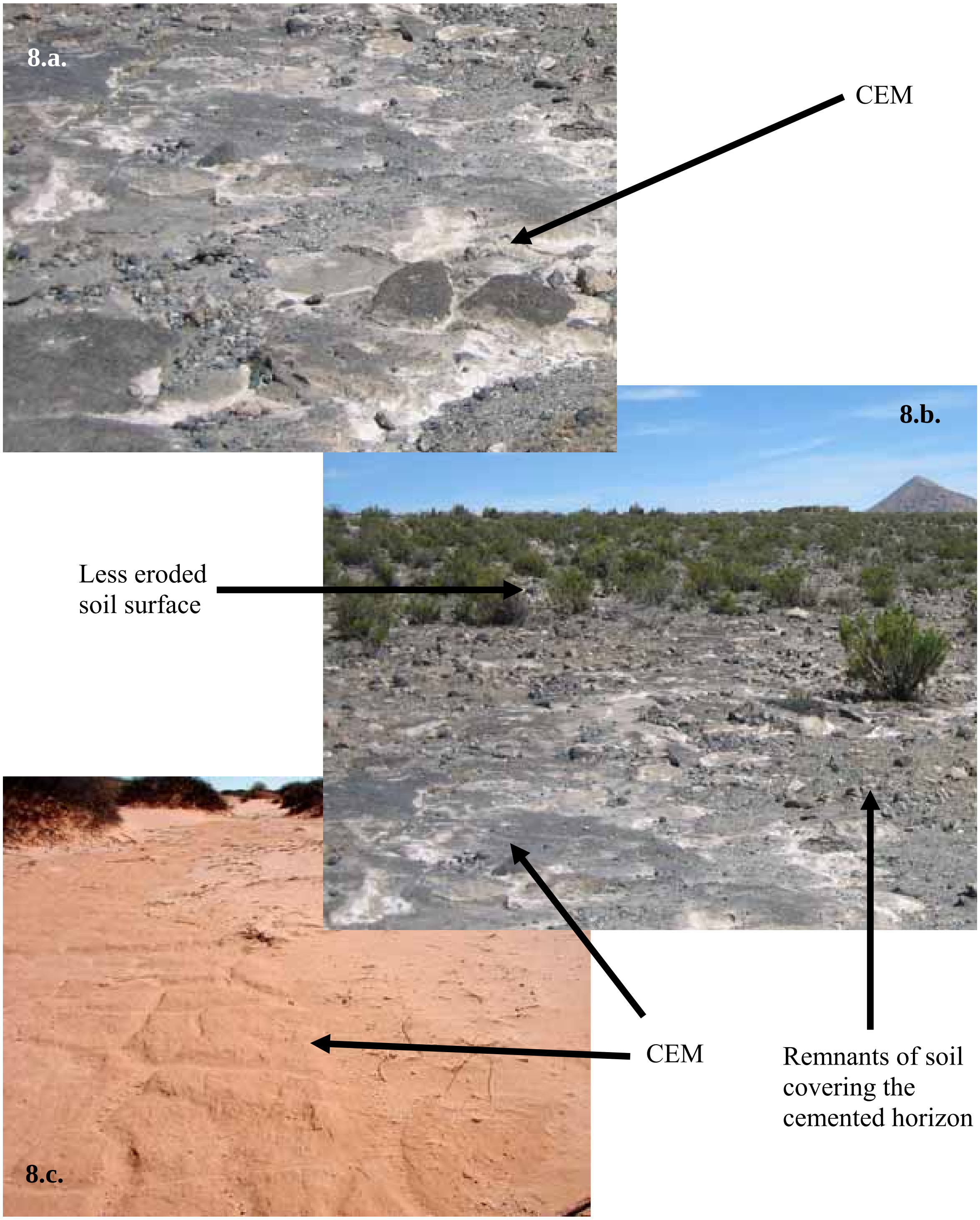


Figure 8. CEM - Cemented horizon exposed at surface. A cemented horizon forms through pedogenesis beneath the soil surface and erosion exposes these horizons at the soil surface (Fig. 8.a.-c.). Remnants of the soil that once covered the cemented horizon are typically scattered throughout the area of this pedoderm (Fig. 8.b.).

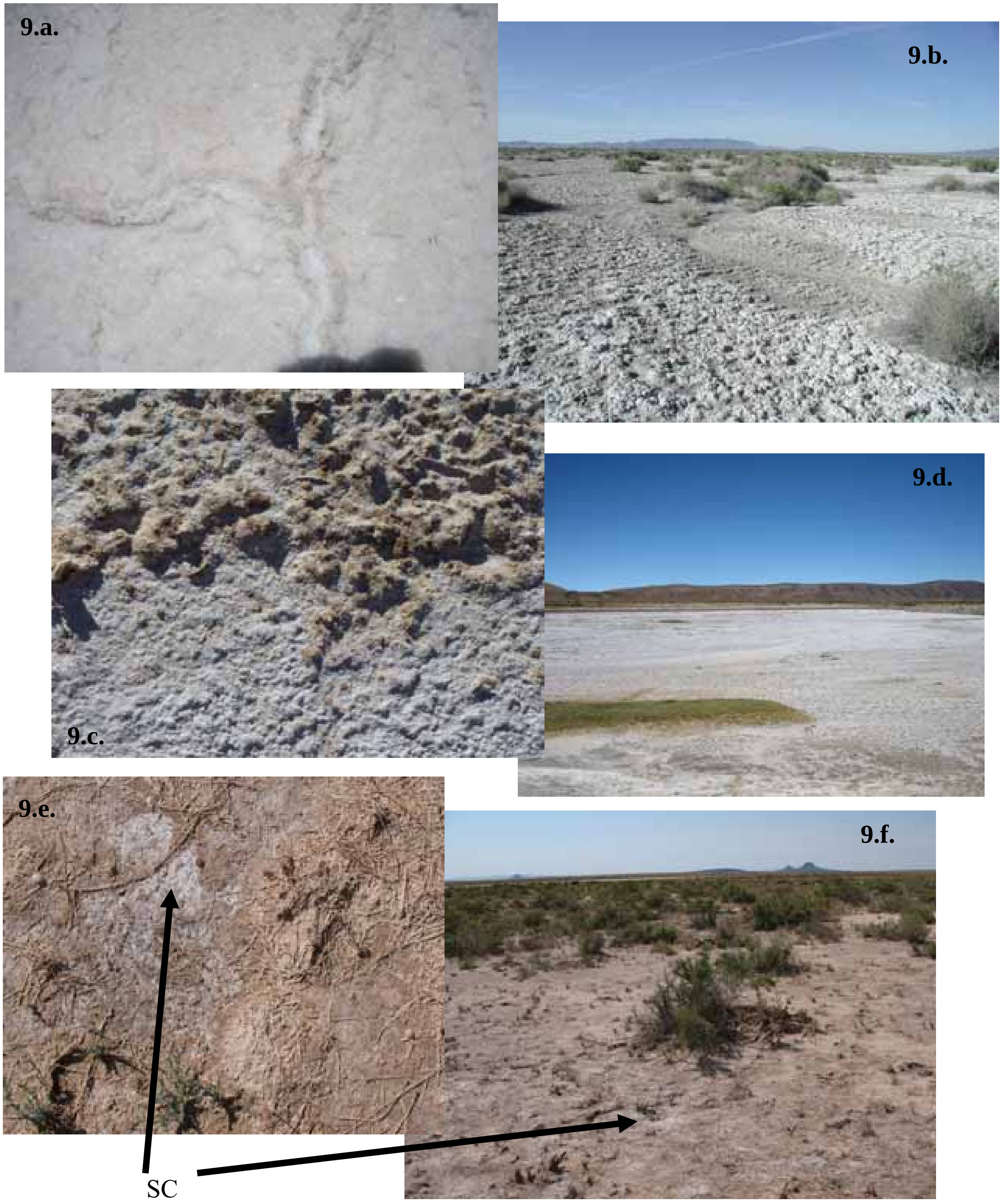


Figure 9. SC - Salt crust of fine to extremely coarse evaporate crystals (Fig. 9.a.-d.) or visible whitening (arrows on Fig. 9.e.-f.) on the soil surface; may include biological components. Photo 9.b. provided by Joe Chiaretti, Soil Scientist, NRCS.

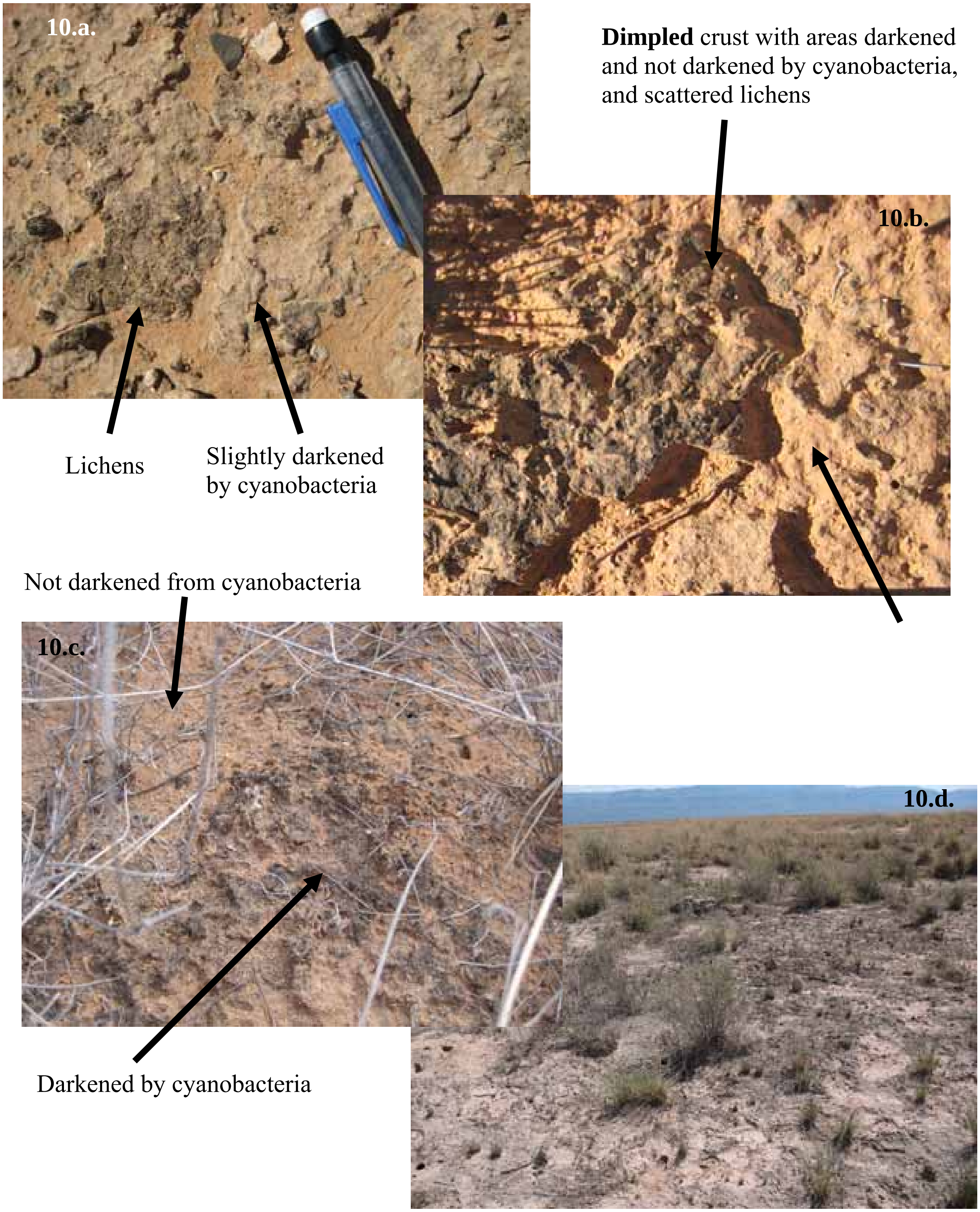


Figure 10. PDB - Poorly developed biological crust, dense cyanobacterial sheaths form a smooth or **dimpled** crust of variable darkness; can include other functional/structural groups (**algae**, lichen, **moss**; Fig. 10.a.). Poorly developed biological crusts are recognized by the dense cyanobacterial sheaths (Fig. 10.a.-d.) compared to weak physical or biological crusts.

Figure 11. SDB - Strongly developed biological crust, typically two or more functional/ structural groups (cyanobacteria, algae, moss, lichen) form a rugose, pinnacled or rolling crust (Fig. 11.a.-f.). Two or more functional groups are typically common in contrast to poorly developed biological crusts (Fig. 11.d.-f.). Photo 11.c. was provided by Tom Reedy, retired soil scientist, NRCS.

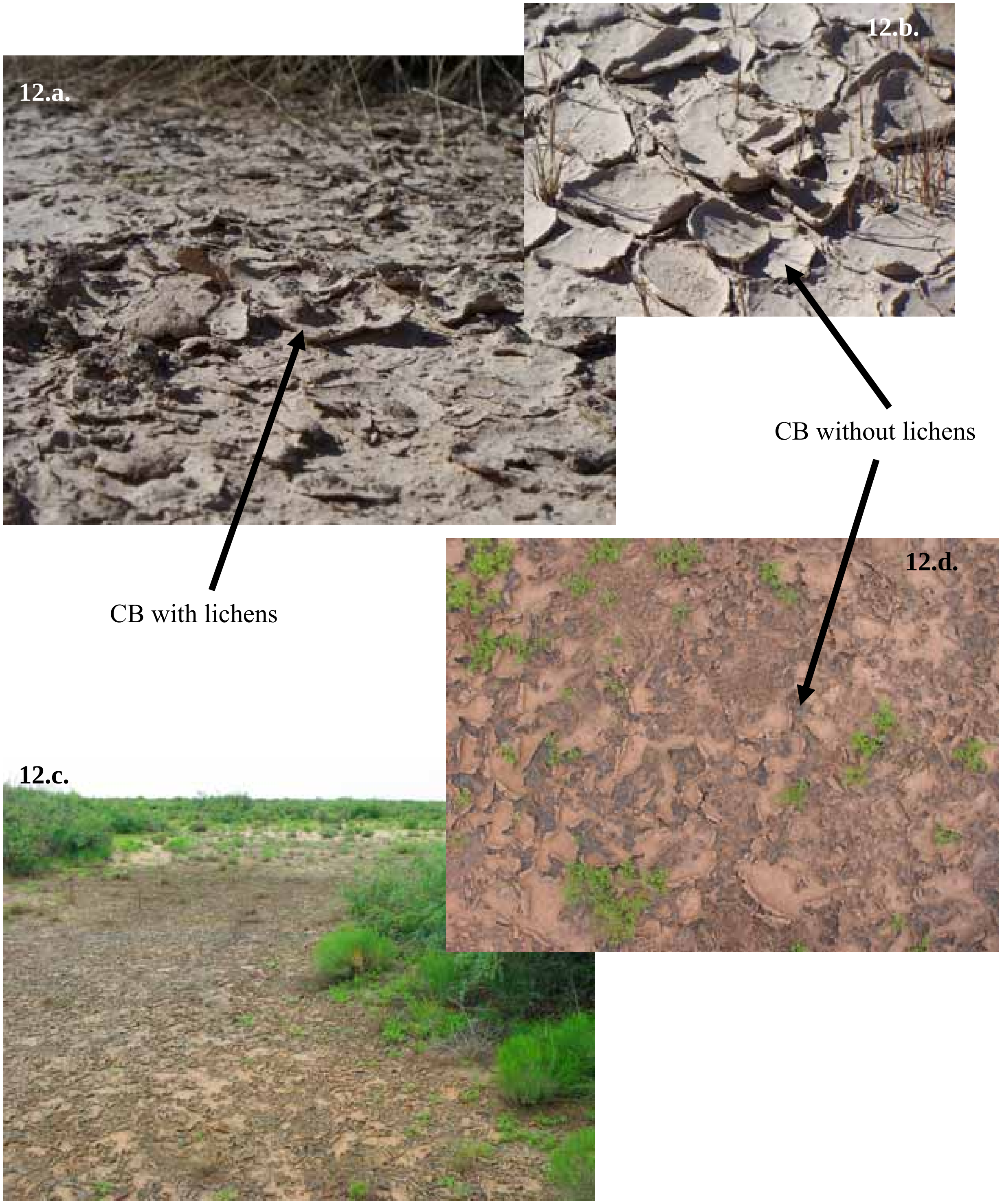


Figure 12. CB - Cracking or curling, rubbery algal crust, with or without lichen. These crusts are composed of thin, typically cracked surface peds that may curl upward at the edges (Fig. 12.a.-d.). Cracking or curling, rubbery algal crusts can have lichens associated with them (Fig. 12.a.).

Figure 13. EP - Erosion pavement; a lag of rock fragments remaining after erosion and removal of finer soil material, forming a dense uniform pavement; individual fragments may be displaced during runoff events. The density, cover and size of rock fragments can vary (Fig. 13.a.-c.), but gravel-sized rock fragments are the dominant soil surface feature in the plant interspaces (Fig. 13.d.). In contrast to desert pavements, rocks do not appear varnished or polished (compare to next page) and fragments are not fully embedded within the soil surface (Fig. 13.a.-c.).

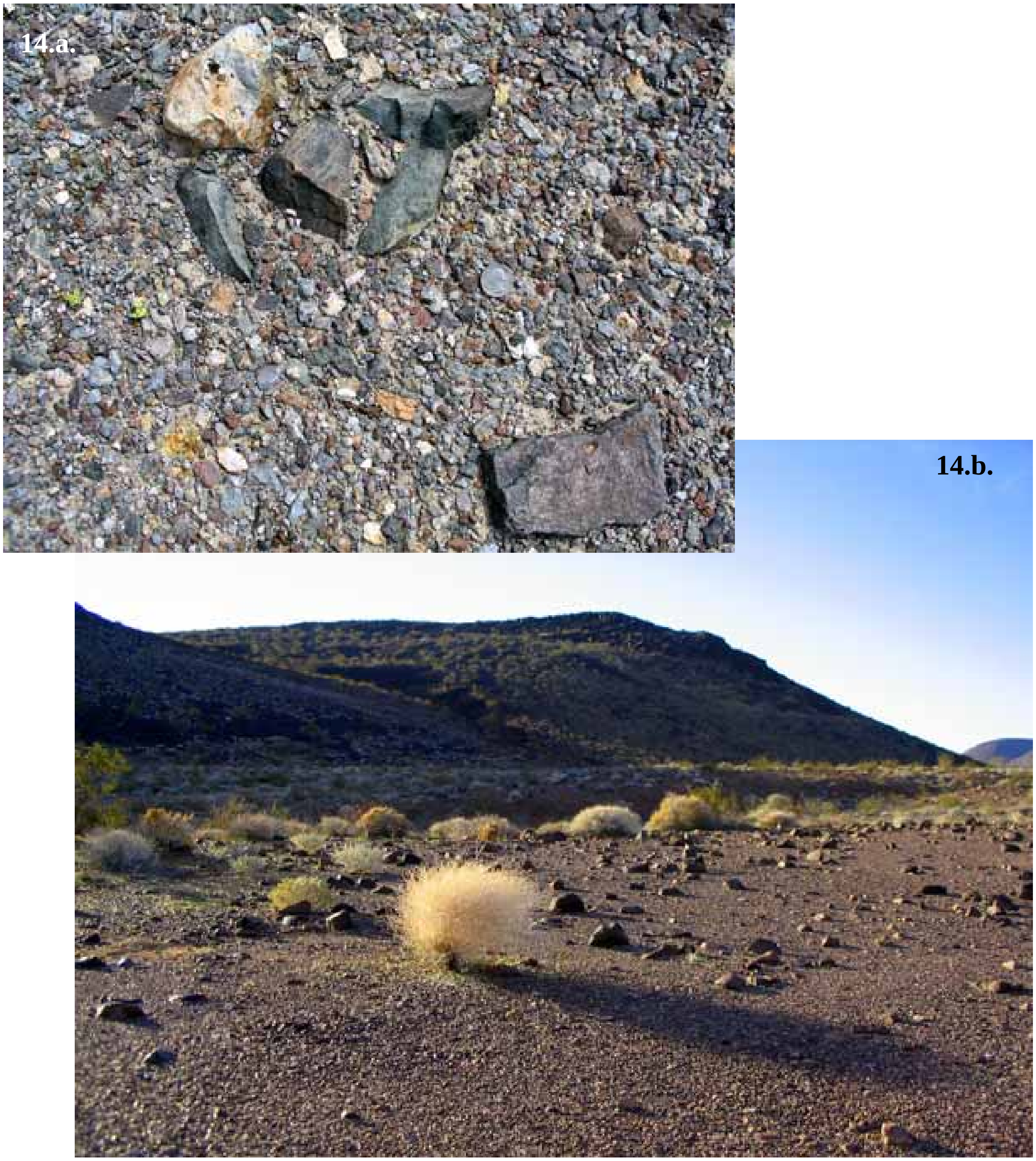


Figure 14. DP - Desert pavement; a concentration of closely packed and varnished rock fragments at the soil surface, embedded in a **vesicular crust**. In contrast to erosion pavements, gravel-sized rock fragments are fully embedded in the soil surface and are not displaced during runoff events (Fig. 14.a. & b.). The shiny appearance of the rocks indicates a desert varnish that formed on a relatively stable surface (Fig. 14.a. & b.). Desert pavements do not indicate recent or active erosion. Photos provided by Joe Cook, AZGS Geologist.

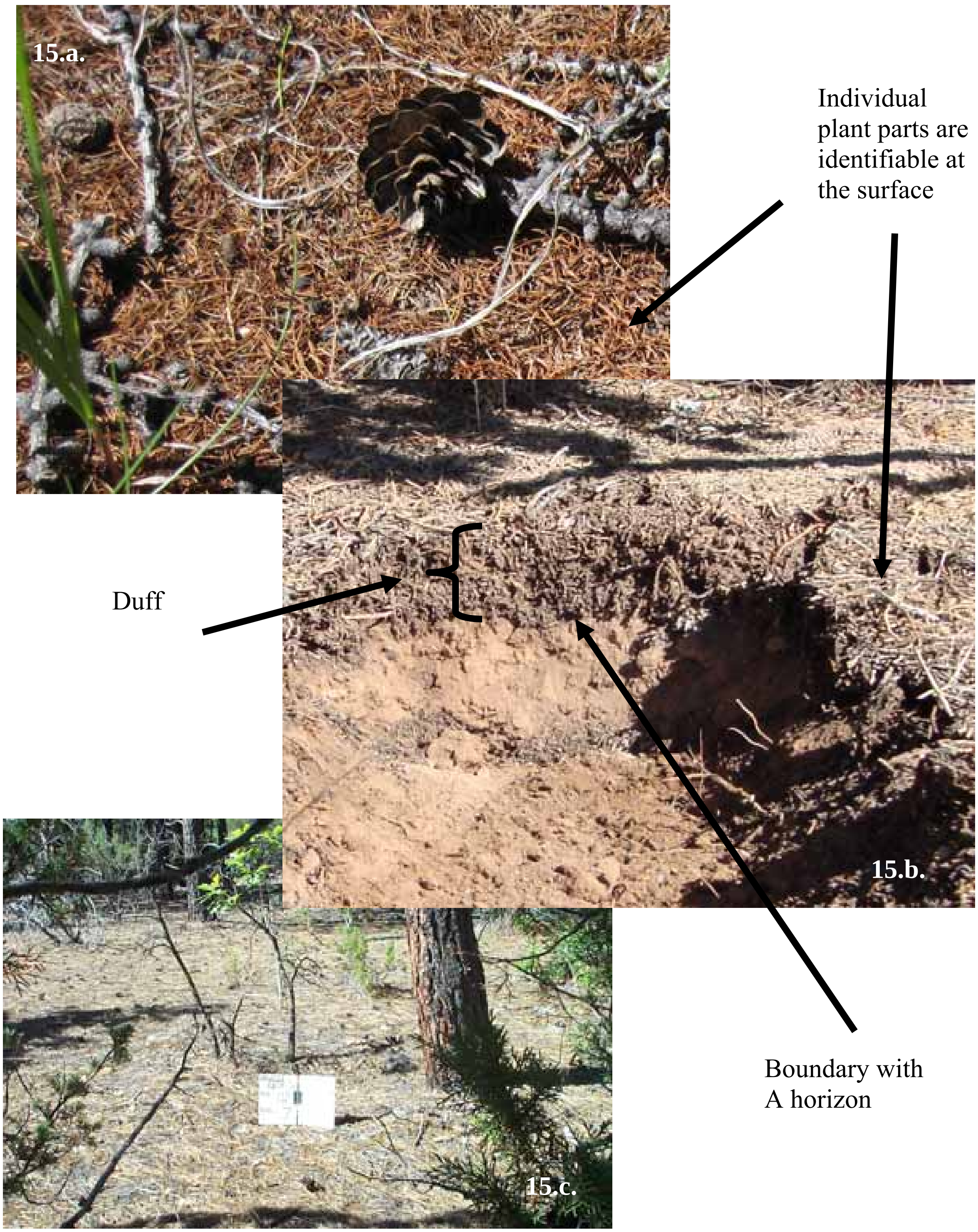


Figure 15. D - Duff; non-decomposed to fully decomposed plant and organic matter located above the A horizon (a patchy or continuous **O horizon**). Individual leaves and plant parts are recognizable in the upper part of the duff layer, but become less discernable with depth (Fig. 15.a. & b.). Individual plant parts are not readily distinguished at the boundary with the A horizon (Fig. 15.b.).

Resource Retention Class (RRC)

The resource retention class is a description of the size and connectivity of persistent vascular plant patches and **interpatch areas** across a plot. The features of each class reflect the ability of the persistent plant community to retain water, nutrients, soil, and other resources (**litter**, seeds). These resources have a greater potential to be retained at lower classes. Figure 16 provides a conceptual overview of the plant – interpatch patterns described using the resource retention classes. Unlike the gap intercept method that measures interpatches (gaps) in one dimension along a transect line (Herrick et al. 2009), the RRC considers interpatch size and shape in two dimensions and, therefore, patch connectivity.

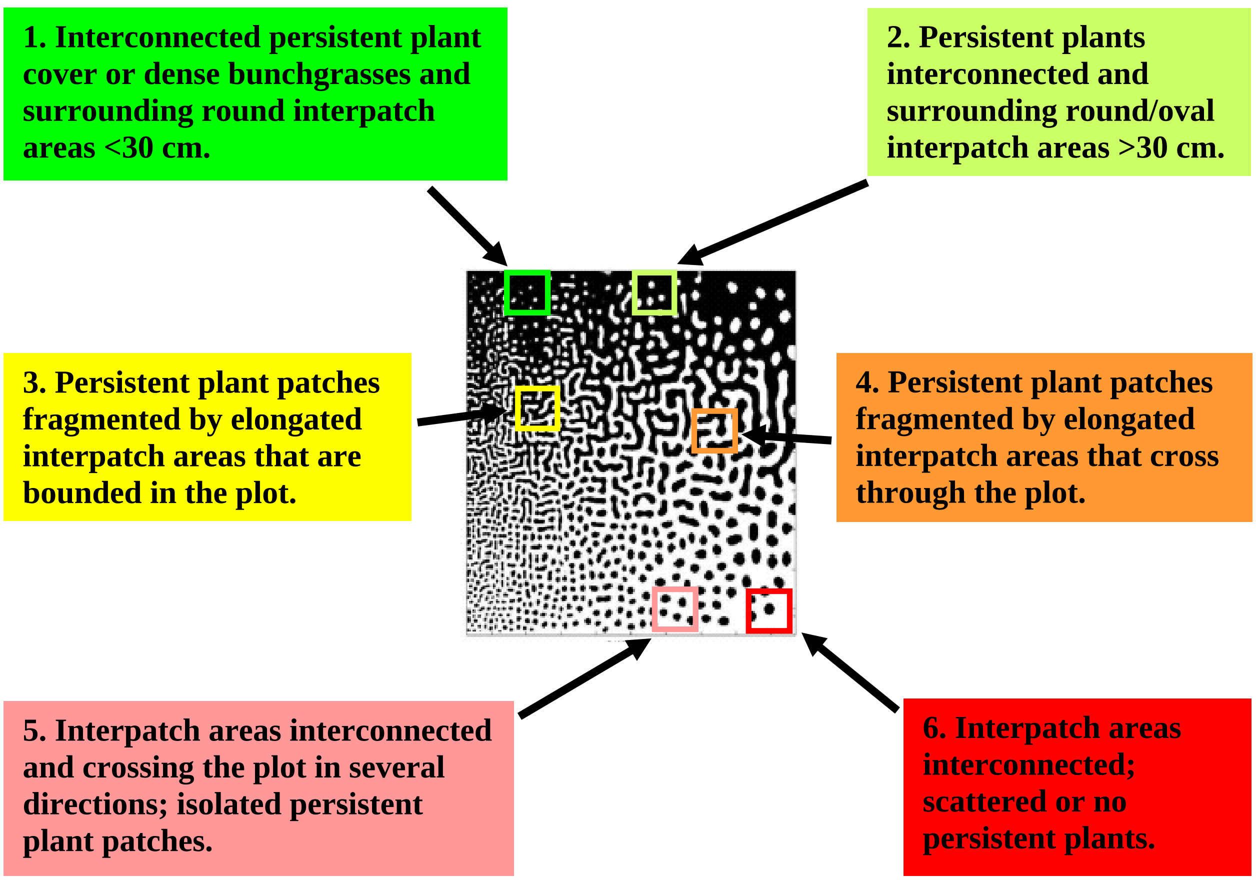


Figure 16. A schematic overview of resource retention classes (RRC) comparing the patterns described by each class. The image shows a continuum of patterns of vegetation fragmentation produced by a simulation model, where the dark areas represent **persistent plant patches** and the white areas are interpatch areas. The colored squares represent plots and the patch-interpatch patterns within each plot correspond to the associated RRC class. The figure was adapted from Reitkerk et al. (2004).

Resource Retention Class (RRC) Terminology

Persistent vascular plant: a long-lived, vascular plant species that remains on the site for multiple years, or a short-lived species that consistently replaces itself in the same location year after year.

Persistent plant patch: a discrete group of individuals of one or more persistent vascular plant species separated from other such patches by an interpatch area. Persistent plant patches do not include **annuals** and short-lived plants that are usually absent from the site during wind or water erosion events, or non-vascular plants that are considered part of the pedoderm. The area of a persistent plant patch is defined by plant parts that are at or near the soil surface. For example, shrub canopies high above the soil surface do not define the dimensions of the patch because they trap few resources moving laterally across the soil surface. Rather, patch dimensions would be defined by plant bases and portions of the canopy at the soil surface (white arrows in Figures 17 and 18). Persistent plant patches trap and retain water, nutrients and soil due to their persistent physical structures. There is usually evidence of sediment accumulation within a persistent plant patch.

As a general guideline, a persistent plant patch consists of multiple plants whose plant bases are within 20 cm of one another. A separate patch is recognized when the spacing between adjacent plants in a given direction is greater than 20 cm.

If necessary, define different rules for what constitutes a persistent plant patch in the study area, given assumptions about how plants intercept resources moving laterally across the soil surface. These rules should be common within a set of related **Major Land Resource Areas**, sections, or **ecoregions** and reflect how plant structures and patches affect resource retention.

Interpatch area: an area without **perennial**, long-lived vascular plants; effectively the soil pedoderm or the soil pedoderm with short-lived, non-persistent plants. Interpatch areas are generally recognized when plant spacing exceeds 20 cm. Areas covered by rock fragments, mineral soil, litter, duff, biological/physical crusts, and annual/non-persistent plants are considered interpatch areas. Animal disturbances (such as ant and rodent mounds) that meet these requirements are included as interpatch areas. Note that the RRC focuses on the role of persistent vascular plant cover and the arrangement of that cover in stabilizing the soil surface and capturing resources. Interpatch areas can be sources of water runoff and bare or disturbed soil pedoderms are typically sources of sediment during runoff events.

Resources: water, soil, litter, seeds, and nutrients considered in the context of ecosystem or landscape function.

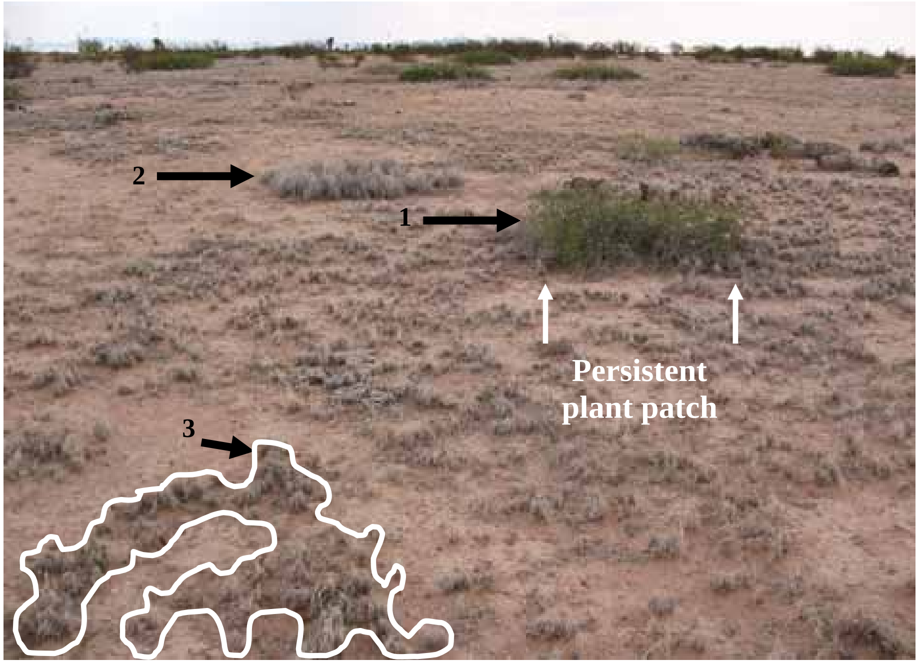


Figure 17. Three discrete patch types occur in this system. Patch composition is described on the data form (Table 2) by the plant codes (1) PRGL2 (*Prosopis glandulosa*), (2) PLMU3 (*Pleuraphis mutica*), and (3) SCBR2 (*Scleropogon brevifolius;* plant codes can be obtained at http://plants.usda.gov/java/). Or, patches can simply be described as (1) shrub, (2) perennial mid-grass and (3) perennial short grass. Codes can be used for lifeforms (e.g., SH, mid PG, short PG). The white arrows show the width of the PRGL2 patch. The white lines indicate the SCBR2 patch.

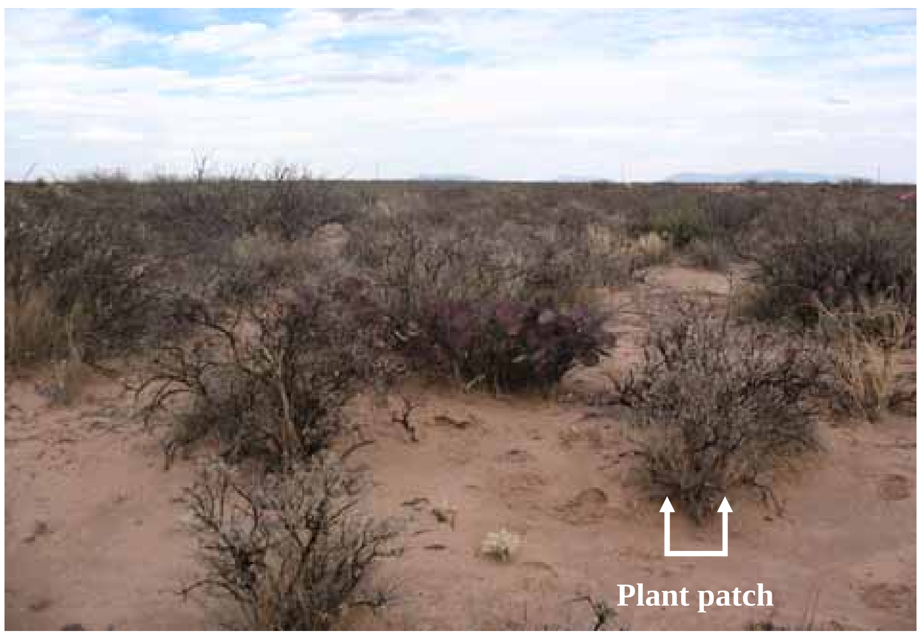


Figure 18. Plant patches here always include tarbush (*Flourensia cernua*; FLCE) accompanied by one or more additional species, almost always including a long-lived perennial mid-grass species. These plant patches can be described on the data form (Table 2) as FLCE mixed with perennial grasses and other species (SH w/ mid PG, etc). The width of a patch is shown with white arrows. Note that the patch width is smaller than the width of the canopy.

Resource Retention Class (RRC) Method

Walk around a 20 m x 20 m area (or other defined area representing a plot), typically centered on the soil pit. Observe the size and shape of interpatch areas (>20 cm across or as defined for your region) as well as the size and connectivity of persistent vascular plants.

Consider how the persistent plants are influencing lateral resource movement on the site.

Evaluate overland water flow paths from the uphill side of the plot to the downhill side of the plot. How far can water travel before encountering a persistent plant patch that would slow water flow and trap sediments (i.e., what is the length of the interpatch area?).

Beginning at the prevailing **windward** side of the plot, assess the likely paths wind would travel as moving **leeward**. How far can wind travel in interpatch areas before encountering a persistent plant patch that would intercept wind-born sediment (i.e., what is the length of the interpatch area or **fetch**)?

Now, keeping their lengths in mind, how wide are these interpatch areas?

After observing the size and shape of interpatch areas throughout the plot, consider the following questions when selecting a resource retention class from those listed on the data from (Table 2):

Are the interpatch areas small (<30 cm in diameter) and oval or round in shape? Or are the interpatch areas distinctly longer than they are wide? Do the interpatch areas create pathways for wind or water that are bounded within the plot? Or, that extend across the plot? Are the interpatch areas roughly as long as they are wide and interconnected in several directions?

Is the plot characterized by a **matrix** of interconnected persistent plants, possibly including scattered interpatch areas (e.g., RRC 1 or 2; Figures 19 and 20)? Or, is the site better described as a matrix of interconnected interpatch areas surrounding isolated, scattered or no persistent plant patches (e.g., RRC 5 or 6; Figures 23 and 24)? If the plot falls somewhere in between the two previous conditions, consider SRCs 3 and 4 (Figures 21 and 22).

Different areas of the plot can be best described by more than one class (e.g., small round interpatch areas on one side and elongated interpatch areas that cross through the plot on the other), but the goal is to assign the plot to a single class. In general, choose the class that is likely to have the greatest influence on the site or is of greatest concern.

If resource retention classes 3 through 5 are selected, describe the composition of the persistent plant patches on the data form in Table 2 (e.g., grass or shrub species composing patches as demonstrated on the previous page in Figures 17 and 18).

Table 2. Resource Retention Class (RRC) Data Form. Select the RRC that best describes the persistent plant patches or interpatch areas. Choose the class that has the most influence on soil, water and nutrient retention on the site. For RRCs 3 through 5, describe the composition of the persistent plant patches at the bottom of the data form. More detailed information on how to use this data form can be found under Resource Retention Class (RRC) Method and Resource Retention Class (RRC) Descriptions. A complete Pedoderm and Pattern Class data form can be download from: http://jornada.nmsu.edu/esd/development-resources (accessed on July 22, 2011).

Resource Retention Class (v. 3.0)

	select one	
1. Interconnected persistent plant cover or dense bunchgrasses and surrounding round interpatch areas <30 cm.		**Notes**
2. Persistent plants interconnected and surrounding round/oval interpatch areas >30 cm.		
3. Persistent plant patches fragmented by elongated interpatch areas that are bounded in the plot.		
4. Persistent plant patches fragmented by elongated interpatch areas that cross through the plot.		
5. Interpatch areas interconnected and crossing the plot in several directions; isolated persistent plant patches.		
6. Interpatch areas interconnected; scattered or no persistent plants.		
Describe persistent plant patch composition:		

Resource Retention Class (RRC) Descriptions

Figure 19. Resource Retention Class 1: Interconnected persistent plant cover or dense bunchgrasses and surrounding round interpatch areas <30 cm. Interpatch areas among the persistent plants are less than 30 cm in size throughout the plot. In order to select this class, interconnected persistent plants must be the prevalent feature on the plot (not interpatch areas or ephemeral, short-lived grasses or forbs).

Figure 20. Resource Retention Class 2: Persistent plants interconnected and surrounding round/oval interpatch areas >30 cm. Interpatch areas are larger than 30 cm throughout the plot, and persistent plants are connected throughout the plot. In order to select this class, persistent plants must characterize the plot (not interpatch areas or ephemeral, short-lived grasses or forbs).

Figure 21. Resource Retention Class 3: Persistent plant patches fragmented by elongated interpatch areas that are bounded in the plot. Persistent plant patches are separated by elongated interpatch areas, but those interpatch areas do not cross the entire width of the plot (are bounded within the plot).

Figure 22. Resource Retention Class 4: Persistent plant patches fragmented by elongated interpatch areas that cross through the plot. Persistent plant patches are separated by elongated interpatch areas and those interpatch areas repeatedly cross the entire width of the plot or extend beyond the plot's dimensions (are not bounded within the plot).

Figure 23. Resource Retention Class 5: Interpatch areas interconnected and crossing the plot in several directions; isolated persistent plant patches. Persistent plants are not the dominant feature on the plot and those that are present are found in scattered, isolated patches.

Figure 24. Resource Retention Class 6: Interpatch areas interconnected; scattered or no persistent plants. There are no persistent plants on the plot, or only a few individual plants exist.

Soil Redistribution Class (SRC)

The SRC describes the extent and severity of soil redistribution processes (erosion and deposition by wind and water) across a plot. **Redistribution** processes are indicated by multiple features that include, but are not limited to, pedestals, water flow patterns, **depositional mounds** and **carbonate coats** or **soil lines on rock fragments**. The features of each class influence the ability of the soil to support plant communities and other functions. The extent and severity of soil redistribution and its effects on plants are greater at higher classes (Fig. 25).

The focus of SRC is on evidence of active and recent erosion and deposition processes. Evidence from historical processes can also be observed (typically in soil profiles), but SRC focuses on how soil redistribution influences the current plant communities and soil movement rates. It can be difficult to disentangle recent from historical soil redistribution processes, therefore SRC should be interpreted with caution. Furthermore, at a given point in time, either erosion or deposition can be most apparent, or both can be equally apparent. Care must be taken to determine whether only one or both are affecting a site.

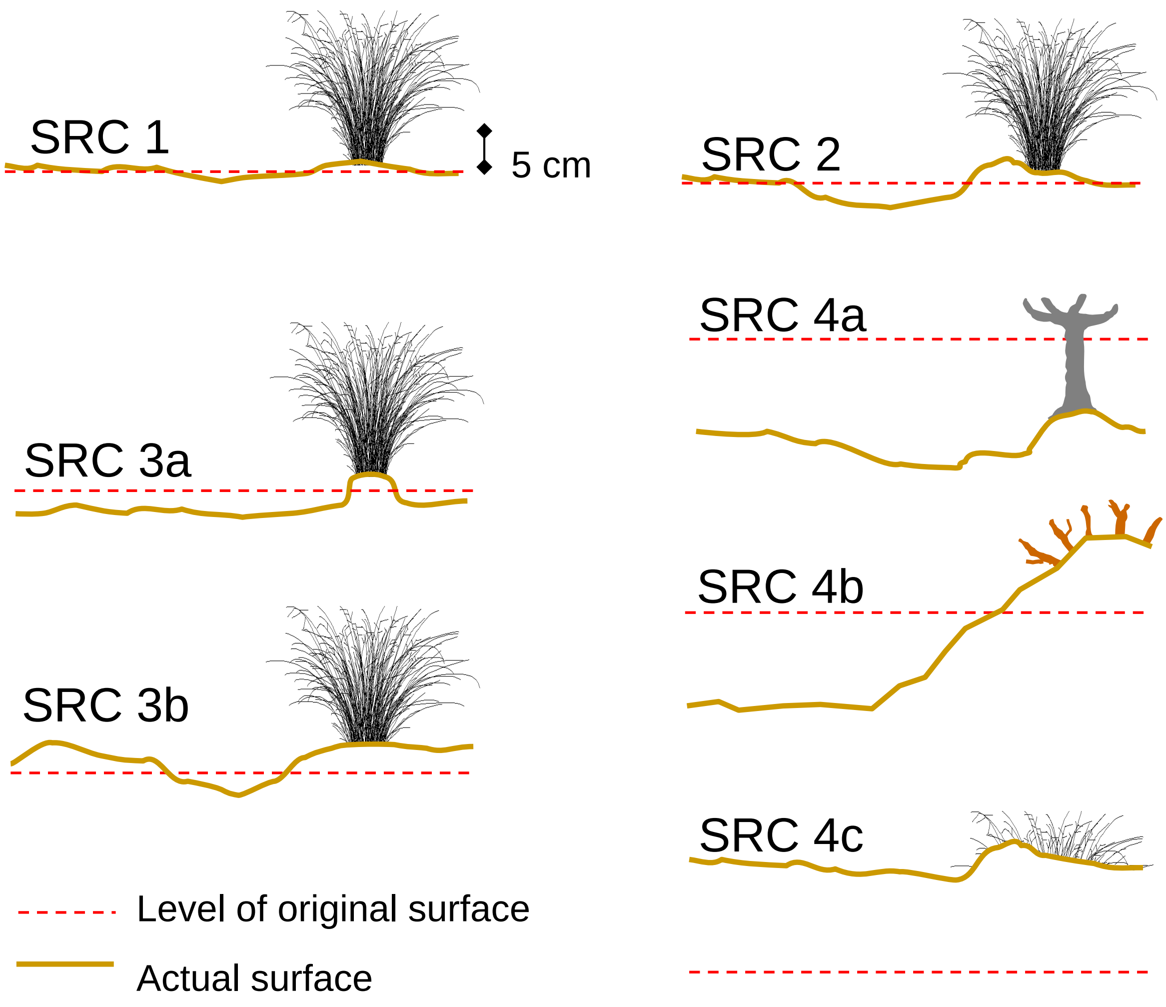


Figure 25. Depiction of increasing severity of soil redistribution with greater soil redistribution classes. Lateral extent of soil redistribution increases at higher classes.

Soil Redistribution Class (SRC) Method

There are two steps to the SRC method: (1) evaluate the spatial extent of soil redistribution and (2) determine its severity. Walk around a 20 m x 20 m area (or other defined area representing a plot), typically centered on the soil pit, and observe evidence of erosional and depositional processes occurring on the site. Evidence of soil redistribution can include one or more indicators. Refer to the class definitions in “Soil Redistribution Classes Descriptions” for a description of indicators commonly found in each SRC. Appendix A reviews soil redistribution indicators and the processes they represent.

Step 1. Spatial extent of soil redistribution
The spatial extent of soil redistribution spans the following continuum: no redistribution (SRC 0); very slight soil redistribution within a matrix of vegetated soil (SRC 1); patchy erosion or deposition (SRC 2); extensive redistribution occurring across most or all of the plot (SRCs 3a-4c). The spatial extent of soil redistribution increases as the evidence of erosion or deposition becomes more common throughout a plot.

Answer the following questions and review Figure 25 to select the correct class:

> *Is soil loss or deposition extensive and occurring throughout most of the plot?*
> If the answer is yes, the plot is in class 3a, 3b, 4a, 4b, or 4c. In this situation, the plot contains widespread evidence of soil redistribution as evidenced by numerous, repeating indicators of erosion or deposition. Proceed to Step 2 to evaluate the severity of soil redistribution.
>
> If the answer is no (soil loss or deposition is not extensive) the plot is in SRC class 0, 1 or 2. Continue with the following questions to assign the class:
>
> *Is there evidence of erosion or deposition?* NO; Select SRC ‘0’ on the data form (Table 3).
>
> *Is there very slight soil movement within a vegetated matrix?* YES; Select SRC ‘1’.
>
> *Do indicators of soil redistribution occur in patches surrounded by a matrix of stable vegetated soil?* YES; Select SRC ‘2’.

Step 2. Severity of soil redistribution
Severity is evaluated for plots with extensive soil loss or deposition to select the correct class from 3a, 3b, 4a, 4b, or 4c. Severity of soil redistribution is determined by the difference in elevation between the plant base and the soil surface (is the depth of erosion and thickness of deposition more or less than 10 cm). SRCs 3a and 3b have a moderate level (<10 cm) of redistribution. SRCs 4a, 4b and 4c have a severe level (>10 cm) of redistribution. Determine whether the difference in elevation is due to erosion, deposition, or both by digging a small pit at the bases of plants (Appendix A provides more detailed information).

If the plant base is elevated above the soil surface (pedestalled), there is evidence of erosion. For soil loss, differentiate between moderate (<10 cm; SRC 3a) loss of the soil surface (A horizon) and severe (>10 cm; SRC 4a or 4b) loss of the soil surface.

If plant bases lie below the soil surface, there is evidence of deposition. Deposition is also indicated by partial plant burial and recent deposits. Recent deposits (usually <100 ya) can appear as a thin or finely **stratified soil** surface with platy layers alternating with layers lacking structure, or deposits can be structureless and a different color from the underlying surface (e.g., loose sand). For soil deposition, distinguish between moderate soil deposits (<10 cm thick; SRC 3b) and severe (>10 cm thick; SRC 4b or 4c) or continuous deposition (SRC 4c).

Soil mounds formed through both erosion and deposition appear as soil with a different color or texture (frequently finely stratified) that sits on top of an eroded soil surface.

The dominance or co dominance of erosion and deposition is determined by their areal coverage relative to one another within the plot.

Answer the following questions and review Figure 25 to select the correct class:

> *Is the plot dominated by <10 cm of soil loss?* YES; Select SRC '3a' on the data form (Table 3).
>
> > Note: If soil loss is <10 cm deep and qualified personnel determine the A horizon is completely eroded exposing the **subsoil**, select either SRC '4a' or '4b' depending on absence or presence of deposition.
>
> *Is the plot dominated by sediment deposits <10 cm thick from a sediment source off the plot?* YES; Select SRC '3b'.
>
> *Is the plot dominated by >10 cm of soil loss or an **exposed subsoil** throughout the majority of the plot AND soil deposition is not codominant?* YES; Select SRC '4a'.
>
> *Are patchy sediment deposits codominant with soil loss >10 cm thick, or an exposed subsoil, across the plot?* YES; Select SRC '4b'.
>
> *Is the plot dominated by continuous or >10 cm thick sediment deposits?* YES; Select SRC '4c'.

Step 3. Review class descriptions and select a class.
Refer to the class definitions in "Distinguishing Soil Redistribution Classes" to verify the correct class selection. If the description does not match the initial class selection, re-evaluate the plot and select another class.

Table 3. Soil Redistribution Class (RRC) Data Form. Select one SRC class from the list. The soil redistribution class name is boldfaced within the soil redistribution class definitions. The key concept for each class is italicized. Use the italicized concepts when determining which class to select. Evidence for each class follows the italicized concept. Use these attributes to assist with class selection. A complete Pedoderm and Pattern Class data form can be download from: http://jornada.nmsu.edu/esd/development-resources (accessed on July 22, 2011).

Soil Redistribution Class (v. 3.0)

Soil Redistribution Class	select one	Notes:
0. No evidence of erosion or deposition.		
1. Very slight soil redistribution.		
2. Patchy, slight (<5 cm) soil loss and deposition[3,4].		
3a. Extensive, moderate soil loss (<10 cm)[3,4].		
3b. Extensive, moderate soil redistribution (<10 cm)[3,4].		
4a. Extensive, severe erosion (>10 cm); little deposition.		
4b. Extensive, severe erosion (>10 cm) with patchy sediment deposition[3,4].		
4c. Extensive, severe sediment deposition (>10 cm)[3,4].		

[3]Depositional mounds are formed by the settling of sediment transported by wind and water movement; mounds can occur on or behind obstructions or where wind/water velocity is reduced.

[4]Confirm deposition within a soil pit. Recently deposited material is usually seen as a thinly or finely stratified soil surface with alternating thin layers of varying textures; lacks structure.

Soil Redistribution Class Definitions

0. **No evidence of erosion or deposition**.

1. **Very slight soil redistribution**. *No noticeable thinning of the soil surface and soil movement occurs within a matrix of vegetated/stable soil.* Evidence includes narrow, elongate, sometimes tortuous, water flow patterns and litter movement with entrained soil, indicating loss or deposits of 1 mm to several centimeters of soil from wind or water.

2. **Patchy, slight (<5 cm) soil loss and deposition[3,4]**. *The soil surface is thinned in discrete patches within a matrix of vegetated/stable soil. Sediment source may be on or off the plot.* Evidence includes pedestals, soil lines on rock fragments, terracettes, water flow patterns, litter dams with entrained soil, wind scouring, soil mounds.

3a. **Extensive, moderate soil loss (<10 cm)[3,4]**. *Noticeable thinning of the soil surface across the plot, with or without patches of stable soil or sediment accumulation. Patches of stable soil and sediment deposits are typically associated with persistent plants.* Evidence includes soil mounds, pedestals throughout the plot, soil lines on rock fragments, scarplets, gravel lag, water flow patterns, and rills suggesting the loss of several centimeters of surface soil across most of the plot.

3b. **Extensive, moderate soil redistribution (<10 cm)[3,4]**. *Sediment deposits (<10 cm thick) common across the plot from a sediment source off the plot. Sediment accumulation can be associated with erosion or redistribution of sediments suggesting that soil is currently moving into and out of the plot.* Evidence includes depositional mounds throughout the plot, partial burial of plants or stones, terracettes and discontinuous sheet deposits. These features are sometimes associated with scattered pedestals, water flow patterns and rills indicating erosion or local redistribution of the sediment deposits.

4a. **Extensive, severe erosion (>10 cm); little deposition**. *Plot is embedded in an extensive area of erosion.* Evidence includes scarplets, scarps, gravel lag, soil lines on rock fragments, prominent pedestals (often with decadent or dead plants), rills, gullies, exposed roots and exposed subsoil. A site with a SRC of 4a is an eroding site, usually caused by fluvial processes.

4b. **Extensive, severe erosion (>10 cm) with patchy sediment deposition[3,4]**. *Plot is embedded in an extensive area of erosion and deposition.* Evidence includes scarplets, scarps, gravel lag, soil lines on rock fragments, prominent pedestals often with decadent or dead plants, rills, gullies, exposed roots, exposed subsoil, extensive wind scouring, soil mounds, terracettes and buried plants indicating substantial deposition. Usually associated with a mix of fluvial and eolian processes.

4c. **Extensive, severe sediment deposition (>10 cm)[3,4]**. *Sedimentation continuous across plot. May be hard to detect without excavation. Sediments originate from off the plot.* Evidence includes depositional mounds or continuous sediment deposits, buried plants or stones, coppicing and hummocky surface. Rills may be present. Deposition can be caused by fluvial or eolian processes.

Soil Redistribution Class (SRC) Descriptions

The extent and severity of erosion and deposition increases as the soil redistribution class increases. For each class below, the boldfaced class name and the italicized class definition are followed by a description of evidence. The descriptions reference useful indicators but not all indicators mentioned are needed for a particular class. The quantitative distinctions among classes (e.g., <5 cm, <10 cm, >10 cm) apply to the indicators listed as evidence.

0. No evidence of erosion or deposition (Fig. 26). There is no evidence of active or recent erosion or deposition on the plot. A plot with a SRC = 0 is a stable site. It is able to resist erosion, is not receiving any offsite deposition and soil is not being redistributed within the site.

It is possible to select this class when a plot has an erosion pavement pedoderm if no other signs of soil redistribution are present. In this situation, significant erosion occurred historically and left behind a dense **gravel lag** that stabilized the soil surface. The soil surface appears as a smooth, continuous erosion pavement with no mounding under persistent plants, no water flow patterns and no other indicators of erosion or deposition besides a gravel lag.

1. Very slight soil redistribution (Fig. 27). *No noticeable thinning of the soil surface and soil movement occurs within a matrix of vegetated/stable soil.* Evidence includes narrow, elongate, sometimes tortuous water flow patterns and litter movement with entrained soil, indicating loss or deposits of 1 mm to several centimeters of soil from wind or water. A plot with SRC = 1 is a stable site, but differs from SRC 0 in that some soil and resources are redistributed within the interspaces of the plot. Compared to the remaining classes (2-4c), SRC 1 has no noticeable **thinning** of the soil surface, nor any offsite deposits.

2. Patchy, slight (<5 cm) soil loss and deposition (Fig. 28). *The soil surface is thinned in discrete patches within a matrix of vegetated/stable soil. Sediment source may be on or off the plot.* Evidence includes pedestals, soil lines on rock fragments, **terracettes**, water flow patterns, **litter dams** with entrained soil, **wind scouring** and soil mounds. The majority of a plot with a SRC of 2 is stable/vegetated. Unlike SRCs 0 and 1, SRC 2 has patches where the soil surface is thinning, as well as patchy deposits. Soil deposits can be from on or off the plot. Soil erosion/ deposition is not extensive or deep/thick (compare to SRC 3a-4c).

3a. Extensive, moderate soil loss (<10 cm) (Fig. 29). *Noticeable thinning of the soil surface across the plot, with or without patches of stable soil or sediment accumulation. Patches of stable soil and sediment deposits are typically associated with persistent plants.* Evidence includes soil mounds, pedestals throughout the plot, soil lines on rock fragments, **scarplets**, gravel lag, water flow patterns and rills suggesting the loss of several centimeters of surface soil across most of the plot. Sediment source can be on or off of the plot. Unlike SRC 0 - 2, the majority of a plot with SRC 3a is not stable. The primary processes on a site with SRC 3a result in the loss of soil and other resources throughout the plot. SRC 3a differs from 4a-c in that soil loss is not deep and deposition is not thick.

A plot with an erosion pavement (gravel lag) would fit into SRC 3a if there is additional evidence of active erosion and a thinned soil surface (A horizon) is located directly under the erosion pavement.

3b. Extensive, moderate soil redistribution (<10 cm) (Fig. 30). *Sediment deposits (<10 cm thick) common across the plot from a sediment source off the plot. Sediment accumulation can be associated with erosion or redistribution of sediments suggesting that soil is currently moving into and out of the plot.* Evidence includes depositional mounds throughout the plot, partial **burial of plants** or **stones**, terracettes and discontinuous **sheet deposits**. These features are sometimes associated with scattered pedestals, water flow patterns and rills indicating erosion or local redistribution of the sediment deposits. SRC 3b is not dominated by stable soil. In contrast to SRC 3a, SRC 3b has thin sediment deposits throughout most of the plot (aggrading landscape). Class 3b differs from 4b-c in that soil deposition is not thick and is interrupted.

4a. Extensive, severe erosion (>10 cm); little deposition (Fig. 31). *Plot is embedded in an extensive area of erosion.* Evidence includes scarplets, **scarps**, gravel lag, soil lines on rock fragments, prominent pedestals (often with decadent or dead plants), rills, **gullies**, exposed roots and exposed subsoil. A site with a SRC of 4a is an eroding site, usually caused by **fluvial** processes. The soil surface has been removed throughout the majority or the entire plot (in contrast to SRC 0 to 3b). Small litter or soil dams (sediment from on the site) can be scattered throughout the plot at obstacles to flow, but soil deposition does not characterize the site (compare to 4b and 4c).

A plot with an erosion pavement (gravel lag) would fit into this class if there is evidence of active erosion with at least 10 cm of recent soil loss. Typically the subsoil (B or C horizon) is located directly under the erosion pavement.

4b. Extensive, severe erosion (>10 cm) with patchy sediment deposition (Fig. 32). *Plot is embedded in an extensive area of erosion and deposition.* Evidence includes scarplets, scarps, gravel lag, soil lines on rock fragments, prominent pedestals often with decadent or dead plants, rills, gullies, exposed roots, exposed subsoil, extensive wind scouring, soil mounds, terracettes and buried plants indicating substantial deposition. Usually associated with a mix of fluvial and eolian processes. A site with a SRC of 4b shares characteristics of both 4a and 4c; it is both actively eroding and receiving deposits.

A plot with an erosion pavement (gravel lag) would fit into this class if there is evidence of active erosion and deposition, and the subsoil is located directly under the erosion pavement.

4c. Extensive, severe sediment deposition (>10 cm) (Fig. 33). ***Sedimentation*** *continuous across plot. May be hard to detect without excavation. Sediments originate from off the plot.* Evidence includes depositional mounds or continuous sediment deposits, buried plants or stones, coppicing and **hummocky** surface. Rills may be present. Deposition can be caused by fluvial or eolian processes. A plot with a SRC of 4c is situated within an aggrading landscape. In contrast with classes 0-4a, SRC 4c is receiving thick or continuous sediment deposits, burying plants and stones. Recent deposits can be redistributed throughout the plot but the dominant process is deposition.

Figure 26. Soil Redistribution Class 0: No evidence of erosion or deposition. There is no evidence of active or recent erosion or deposition on the plot. The following are not present on the plot: water flow patterns, litter dams with entrained soil, pedestals, soil lines on rock fragments, wind scouring, rills, gullies, gravel lag, scarps, scarplets, exposed roots, terracettes, sediment deposits, depositional mounds, burial of plants or stones, sheet deposits, coppicing or hummocky surface. The soil surface (usually A or O horizon) is intact, stable, and has not been recently thinned or received any recent deposits.

Figure 27. Soil Redistribution Class 1: Very slight soil redistribution. *No noticeable thinning of the soil surface and soil movement occurs within a matrix of vegetated/stable soil.* Evidence here shows narrow, elongate, sometimes tortuous, water flow patterns, indicating loss or deposits of 1 mm to several centimeters of soil from wind or water. Most of this plot (SRC = 1) consists of stable/vegetated soil. During strong flow events, thin sediments shift around within the plot. However, there is no net loss or gain within the plot, and the soil surface is intact.

Figure 28. Soil Redistribution Class 2: Patchy, slight (<5 cm) soil loss and deposition. *The soil surface is thinned in discrete patches within a matrix of vegetated/stable soil. Sediment source may be on or off the plot.* Evidence on this plot includes pedestals, soil lines on rock fragments, water flow patterns, wind scouring and soil mounds. The majority of this plot is stable/vegetated. Unlike SRCs 0 and 1, this plot (SRC of 2) has patches where the soil surface is thinning, as well as patchy deposits. Deposits can be from soil or resources that originated on the plot, as well as from off-site sources.

Figure 29. Soil Redistribution Class 3a: Extensive, moderate soil loss (<10 cm). *Noticeable thinning of the soil surface across the plot, with or without patches of stable soil or sediment accumulation. Patches of stable soil and sediment deposits are typically associated with persistent plants.* Evidence depicted above includes soil mounds, pedestals throughout the plot, gravel lag and water flow patterns suggesting the loss of several centimeters of surface soil across most of both plots. Unlike SRCs 0, 1 or 2, the majority of the area on a plot with an SRC of 3a is not stable, but has active/recent soil redistribution throughout with patches of stable or vegetated soil (remnants of the intact, non-eroded soil surface with or without small deposits). The primary processes on this type of site (SRC = 3a) result in the overall loss of soil and other resources. This site differs from those with SRCs of 4a-c in that soil loss is not deep and deposition is not thick. Plots with SRC 3a can have areas with discontinuous sheet deposits and few depositional mounds, but plants and stones are only partially buried and deposits are not thick or continuous.

Figure 30 Soil Redistribution Class 3b: Extensive, moderate soil redistribution (<10 cm). *Sediment deposits (<10 cm thick) common across the plot from a sediment source off the plot. Sediment accumulation can be associated with erosion or redistribution of sediments suggesting that soil is currently moving into and out of the plot.* Evidence depicted here includes depositional mounds throughout the plot and partial burial of plants. Deposition must be confirmed with a small soil pit. This site (SRC = 3b) is not dominated by stable soil. In contrast to SRC 3a, it has thin sediment deposits throughout most of the plot (aggrading landscape). This class differs from 4b-c in that soil deposition is not thick and is interrupted.

Figure 31. Soil Redistribution Class 4a: Extensive, severe erosion (>10 cm); little deposition. *Plot is embedded in an extensive area of erosion.* Evidence on this plot includes scarplets, gravel lag, prominent pedestals with decadent or dead plants, rills, exposed roots and exposed subsoil. This is an eroding site, caused by fluvial processes. The soil surface has been removed throughout the majority of the plot (in contrast to SRC 0 to 3b). Small litter or soil dams (sediment from on the site) can be seen scattered throughout the plot at obstacles to flow, but soil deposition does not characterize this plot (compare to 4b and 4c).

Figure 32. Soil Redistribution Class 4b: Extensive, severe erosion (>10 cm) with patchy sediment deposition. *Plot is embedded in an extensive area of erosion and deposition.* Evidence on this plot includes prominent pedestals with decadent plants, exposed roots, exposed subsoil, extensive wind scouring, soil mounds and buried plants indicating substantial deposition. This is associated with a mix of fluvial and eolian processes. This site shares characteristics of both 4a and 4c; it is both actively eroding and receiving deposits. At least 10 cm of the soil surface has been lost throughout the majority of the plot (in contrast with SRCs 0-3b) and thick deposition is occurring (in contrast with 4a).

Figure 33. Soil Redistribution Class 4c: Extensive, severe sediment deposition (>10 cm). *Sedimentation continuous across plot. May be hard to detect without excavation. Sediments originate from off the plot.* Evidence on this site includes depositional mounds, continuous sediment deposits, buried plants or stones, coppicing and hummocky surface. A plot with an SRC of 4c is situated within an aggrading landscape. In contrast with classes 0-4a, it is receiving thick (>10 cm) and continuous sediment deposits, burying plants and stones.

Tips for Pedoderm and Pattern Class Determinations

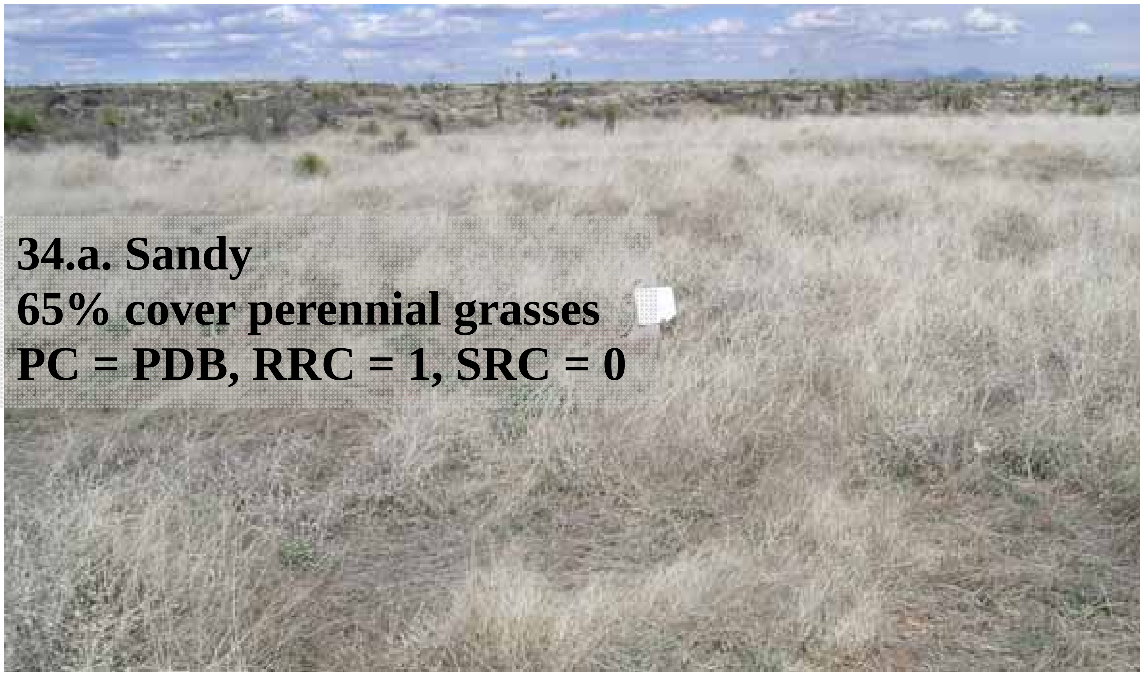
Although the pedoderm, resource retention and soil redistribution classes are interrelated, they must be determined separately; one class does not determine another. Soil erosion and deposition are affected by the pedoderm (PC), the plant and interpatch patterns (RRC), **soil texture**, and disturbance processes on and off site.

Pedoderm and Pattern Class Interpretation and Use

Collectively, the Pedoderm and Pattern Classes (PPCs) provide a record of current soil and plant community features that affect resources for plant growth, and ultimately, ecosystem function. Specifically, the PPCs describe a site using observable features that reflect processes involved in the protection of the soil resource from erosion, the capture and retention of nutrients and water, and the erosion and deposition of soil. Together with information about the plant community and soil profile, the PPCs provide a rapid **assessment** of ecosystem function (Figures 34 and 35).

This information can be used in the inventory and evaluation of soil and plant community properties primarily in deserts, grasslands, savannas, and woodlands. Suggested uses include the following:

1. **Extrapolate rangeland health assessments to broader scales:** Records of PPCs along with information about the soil profile and vegetation at plots can be linked to spatial data (e.g., soil survey, ecological site, or state maps) to assist with extrapolating rangeland health assessments to broader scales (e.g., a pasture or allotment).
2. **Develop ecological site descriptions:** Records of PPCs alongside soil profile and vegetation data from multiple sites can facilitate the development of **ecological site descriptions**.
3. **Differentiate ecological states and community phases:** PPCs can be used to help describe and distinguish the properties of **ecological states** or community phases.
4. **Describe and interpret dynamic soil properties:** PPCs can be used to help describe and interpret dynamic soil properties associated with community phases.
5. **Predict responses to management, restoration and natural drivers:** Records of PPCs alongside descriptions of ecological sites and states can help understand the responses of a site to management actions, restoration, and natural drivers.
6. **Communication tools:** PPCs can also be used to communicate soil surface features related to ecosystem function in a relatively simple way to land users.



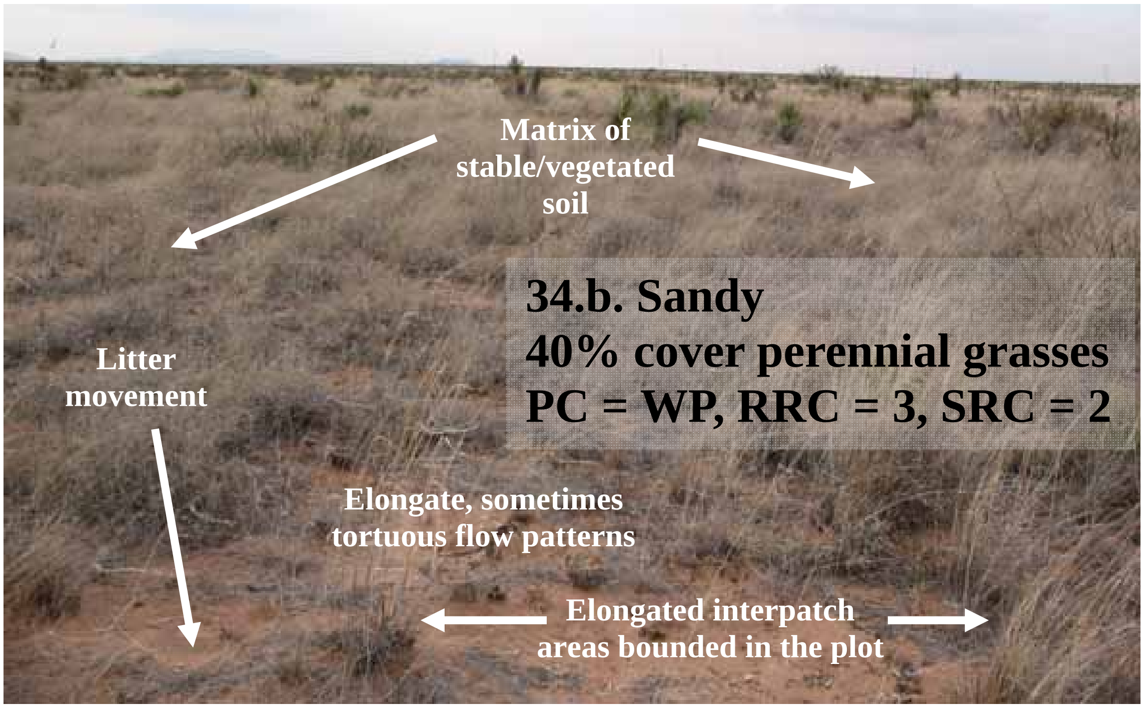
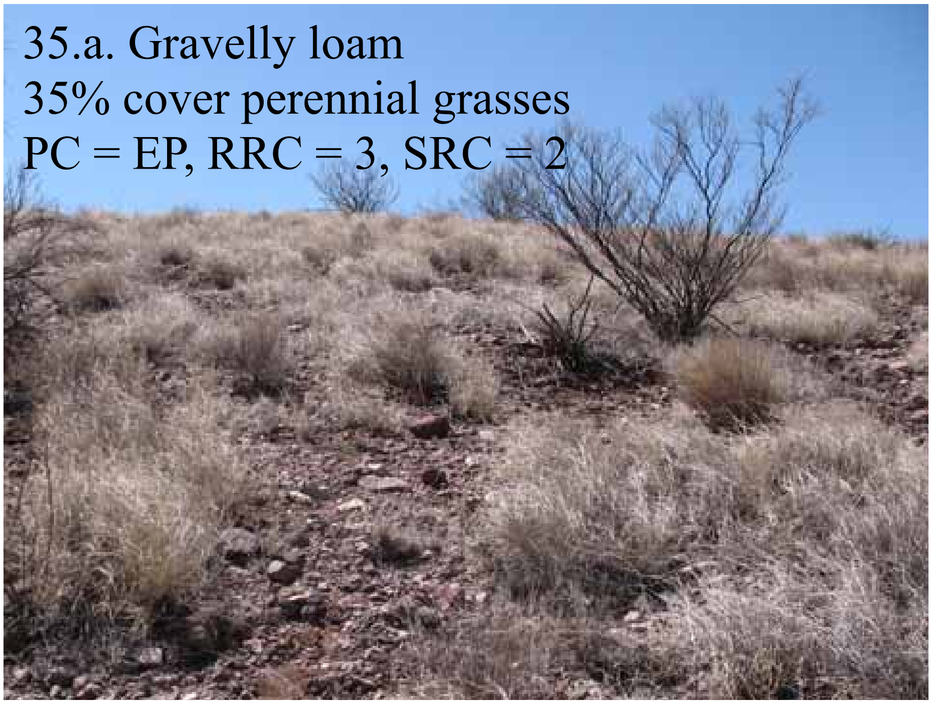


Figure 34. Both plots are in Sandy ecological sites and dominated by perennial grasses. The pedoderm (poorly developed biological crust), the small interpatches, and the stable soil (SRC = 0) of 34.a. convey that this plot has a better potential for plant establishment, growth and survival as well as retaining soil and site resources compared to that of 34.b. The weak physical or biological crust coupled with the larger interpatches of 34.b. suggest a reduced resistance to wind and water erosion and disturbance (physical or introduction of weedy/invasive species). The SRC of 2 in 34.b. indicates reduced soil stability of the site. The site in 34.b. would be considered at greater risk of soil erosion and subsequent grass loss when compared to 34.a.



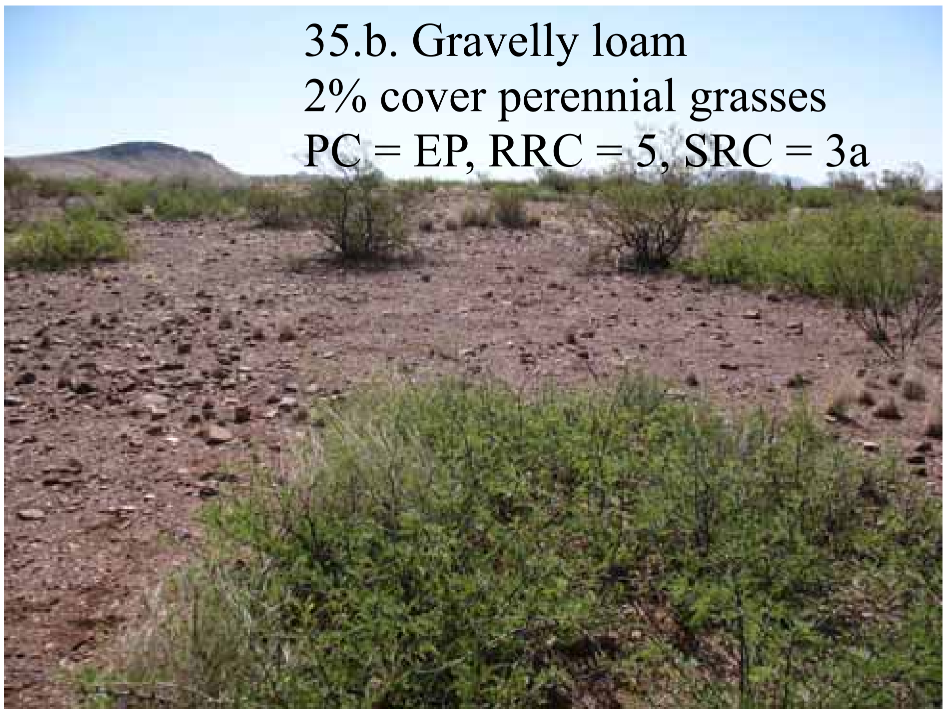


Figure 35. The plot pictured in Figure 35.a. is a Gravelly loam ecological site dominated by grasses with some honey mesquite (*Prosopis glandulosa*) and other woody species. The plot in 35.b. is the same ecological site, but is dominated by honey mesquite with perennial grasses occurring mainly in the shrubs. Both sites have an erosion pavement protecting the soil from erosion. However, 35.a. has a much greater potential to sustain soil resources and plant productivity due to its larger and more connected persistent plants and fewer indicators of soil redistribution. The site pictured in 35.a. has a greater potential to respond favorably to management and manipulation than that in 35.b.

Appendix: Resource and Soil Redistribution Indicators

This appendix provides an overview of soil redistribution processes and indicators that reflect these processes. Soil redistribution results from two primary processes: erosion and deposition caused by wind and water. The soil redistribution classes discussed on pages 30-43 are designed to reflect (1) the spatial extent of soil redistribution, that is, how much of a plot is affected by erosion or deposition and (2) the severity of soil redistribution, defined here as the depth of erosion and thickness of deposition.

Erosion
Water erosion can occur in several ways. Splash erosion occurs when raindrop impact dislodges soil as it collides with the bare mineral soil surface, causing erosion of thin layers of soil (<5 mm). As rainfall rates exceed soil infiltration rates, water begins to collect on the soil surface. Eventually water will begin to move down slope. As water velocity and volume increase, small particles of litter become entrained in the moving water, resulting in litter movement (Fig. A1). Litter movement is easiest to see when litter is moved from under plant canopies and concentrates in interspaces. With a further increase in water momentum more and larger pieces of litter are transported by water. When water encounters an obstacle, the rate of flow is reduced or stopped, and the litter is deposited, usually in the form of a litter dam (Fig. A1). Litter movement and litter dams are evidence of soil redistribution when soil is entrained within the litter.

With increasing water flow and increasing plant interspace size and area, soil particles become dislodged and move within interpatch areas within a plot. As interpatch size increases and elongates, soil and water are transported down slope in slightly channeled areas (**concentrated flow)**, which are water flow patterns (Fig. A2). The depth of soil erosion in water flow patterns varies from one millimeter to at most a few centimeters and is deepest at the center. **Sheet erosion** occurs when these slightly channeled flows become interconnected, resulting in un-channeled surface water flow (sheet flow) and uniform removal of thin layers of soil (Fig. A2). With higher water flow rates, water flow patterns or sheet erosion can develop into concentrated flow. As water flow becomes more concentrated and channelized, more soil is displaced and rills are formed through **rill erosion** that are several cm deep (Fig. A3). The most severe form of concentrated water erosion takes the form of gully erosion; gullies are steep sided and usually ≥50 cm deep (Fig. A3).

Wind erosion also begins by first entraining and transporting small pieces of litter. Again, this can be seen as litter movement (Fig. A1). With a further increase in wind speed, larger and more pieces of litter can be moved, litter falls out of the wind column and forms litter dams at obstacles to flow (Fig. A1).

The ability of soil to resist wind erosion decreases as wind speeds increase, interpatch areas expand, plant stature decreases, and as soil textures become finer. Wind erosion usually begins with saltation in plant interspaces: a soil particle is dislodged by wind, but is too heavy to be carried more than a few centimeters. As it falls back to the soil surface it causes the movement of additional soil particles (Lyles 1977). The erosive forces of saltation increase with increasing wind speed. Within an interpatch area, erosion from saltation increases from the windward side, is greatest in the middle of an interpatch area, and decreases as it nears an obstacle to flow (leeward side of interpatch). As this becomes more severe, wind scouring occurs (Fig. A4). Wind scouring appears as a concave or platter-shaped bare area with as little as 1 mm of soil loss at the outer edges of the interpatch and up to several centimeters in the center. Wind scouring begins as patchy soil loss where interpatch areas are relatively small and not connected, and can increase to large areas encompassing most or all of the plot.

As severity of soil erosion increases, patches of stable soil or soil mounds of the remnant, less-eroded soil surface remain only where persistent plants or biological crusts stabilize the soil (Fig. A5). The elevated position of these soil mounds above the surrounding interpatch soil surface is evidence of soil loss. With continued erosion, soil is removed from directly around the plant bases, forming plant pedestals (Fig. A6). Pedestals <5 cm tall can be detected only by close observation of the height of persistent plant bases relative to the non-mounded soil surface. Continued erosion reveals exposed roots of the pedestalled plants. These are prominent pedestals with decadent or dead plants, with ≥10 cm soil loss or ≥10 cm tall pedestals (Fig. A6).

A gravel lag is formed when wind and water erosion removes small soil particles (<5 mm in diameter) and the remaining rock fragments (>5 mm) are left behind to accumulate on the soil surface (Fig. A7). Rock fragments within the soil can become coated with clay, **carbonates**, silica or mineral stains. When soil material erodes away from the rocks, the coats and stains are exposed as soil lines on rock fragments, roughly parallel to the soil surface (Fig. A8). Scarplets are formed when highly erosive events or prolonged wind or water erosion removes 3-20 cm of soil within small areas (Fig. A9). Scarps are formed in the same manner as scarplets, but are more expansive and appear as escarpments or benches 20-50 cm in height (Fig. A9). Severe erosion, including gully erosion, deep wind scouring and deep sheet erosion completely removes the soil surface (O and A horizons) and results in exposed subsoil, typically featuring exposed roots (Fig. A9).

Deposition

Soil deposition occurs when the force of wind or water transporting the soil material is reduced. Deposition can initially appear as patchy soil deposits (usually of a different color, 1 mm to several centimeters thick; Fig. A10). As erosion increases, greater volumes of soil are moved. When water erosion is slowed or stopped, often at persistent plants, terracettes can form, typically <10 cm thick. When wind or water erosion is slowed or stopped, discontinuous sheet deposits and depositional mounds are formed (Fig. A10 & A11). Depositional mounds are soil mounds formed via sediment deposition. Terracettes, discontinuous sheet deposits, and depositional mounds can be formed from soil originating on or off site.

Because persistent plants are obstacles to wind and water flow, deposition results initially in partial burial of plants or stones (<10 cm thick; Fig. A11). As the severity of erosion increases, and offsite sediment sources increase, continuous sheet deposits accumulate in low-lying, level positions. Depositional mounds increase in size due to prolonged deposition of material, typically from offsite sources. This results in burial of plants or stones (>10 cm thick) and selection for persistent plants that are tolerant of thick deposition (Fig. A11). **Coppices** form at persistent plants through thick deposition, forming a hummocky surface appearing as numerous dunes (typically much greater than 10 cm tall; see Fig. A11).

Appendix: Resource and Soil Redistribution Indicators
Litter movement and litter dams

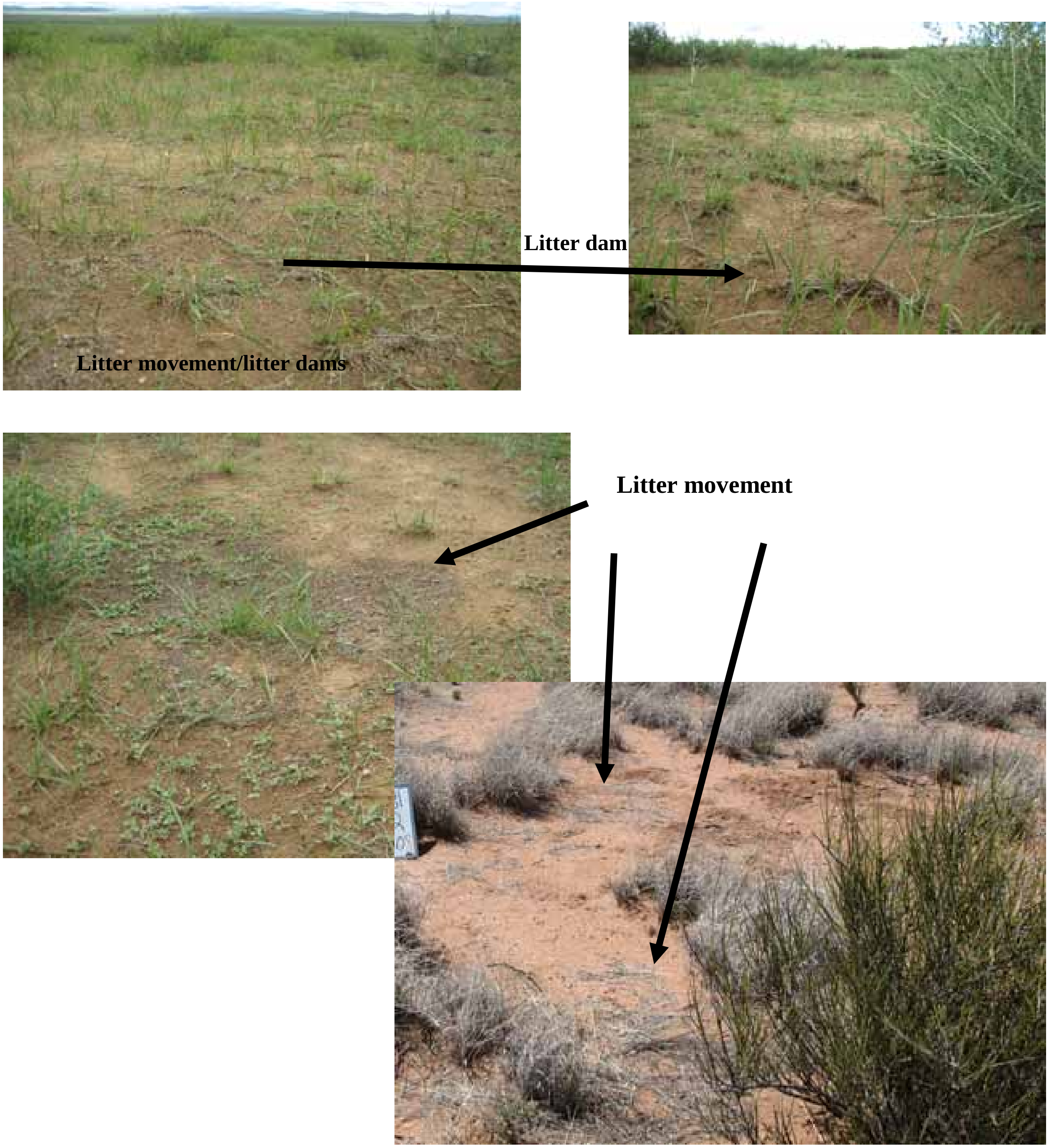
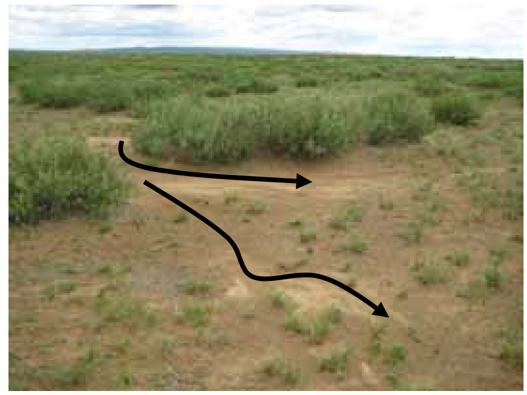


Figure A1. Litter movement is evidence of resource redistribution (transportation of litter from under plant canopies to plant interspaces by wind or water). As water flow increases it becomes sufficiently high to entrap larger and greater pieces of litter. Once water reaches an obstacle that slows or stops flow, litter is deposited behind these obstacles as litter dams. When soil is entrained within litter, there is evidence of soil redistribution.

Appendix: Resource and Soil Redistribution Indicators
Water flow patterns and sheet flow

Water flow patterns



Sheet flow

Figure A2. Water erosion: when water flow increases sufficiently to dislodge and transport soil particles, water flow patterns form. These can occur as narrow, elongate, sometimes tortuous water flow patterns through and around persistent plants. Water flow patterns are shallow and have gentle slopes to their edges. When water flow becomes continuous and interconnected, sheet flow occurs and sheet erosion removes thin layers of soil in wide expanses throughout a plot.

Appendix: Resource and Soil Redistribution Indicators
Rills and gullies

Rills

Gullies

Figure A3. Water erosion: as water flow becomes increasingly concentrated, rills are formed. Rills are deeper than water flow patterns, and have steeper edges. Rill erosion removes between 1 mm and several centimeters of soil. Increased water erosion and concentration of flow causes the formation of gullies**.** Gully erosion results in steep-sided or sheer-faced channels, typically >50 cm deep.

Appendix: Resource and Soil Redistribution Indicators
Wind scouring

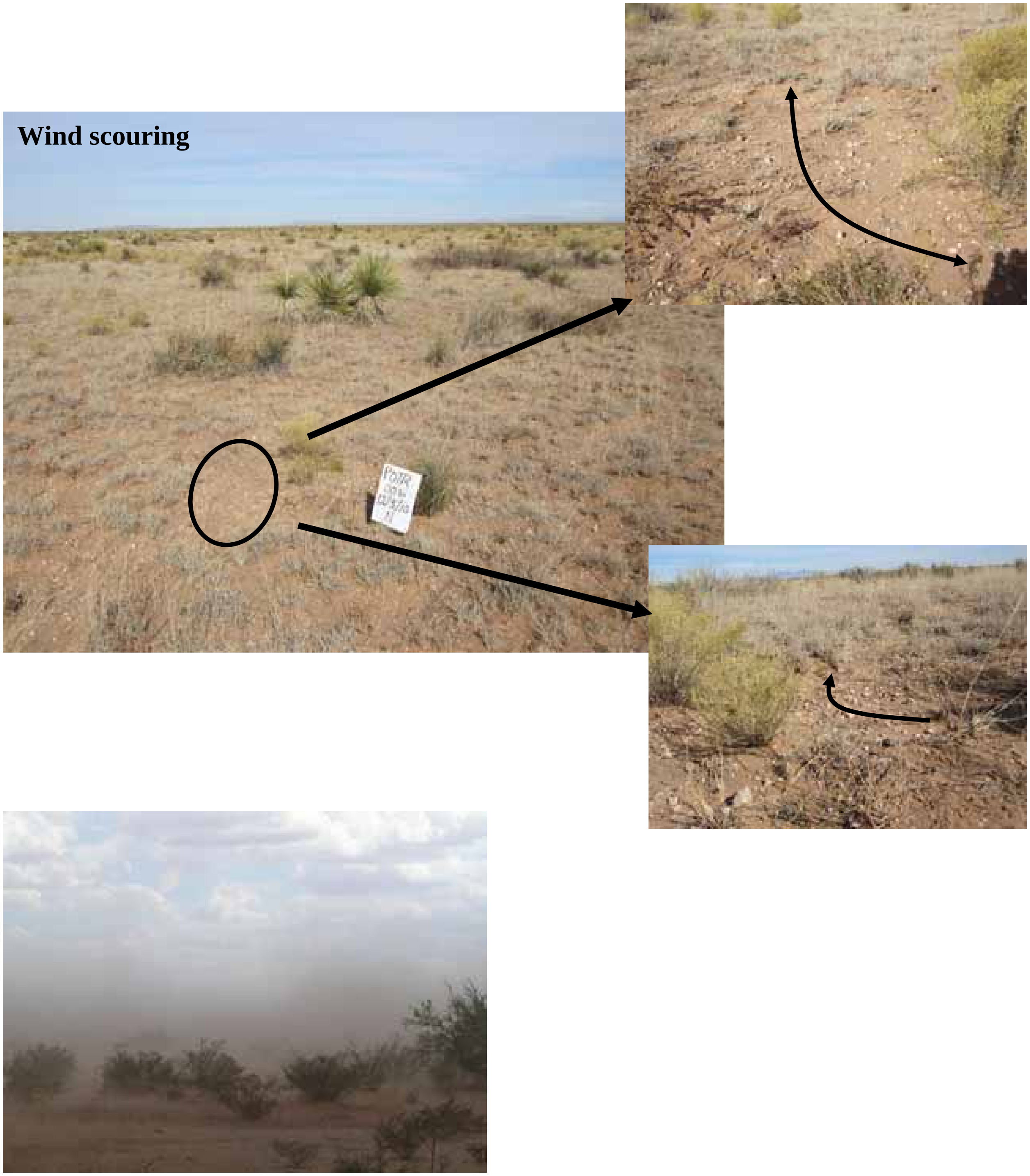
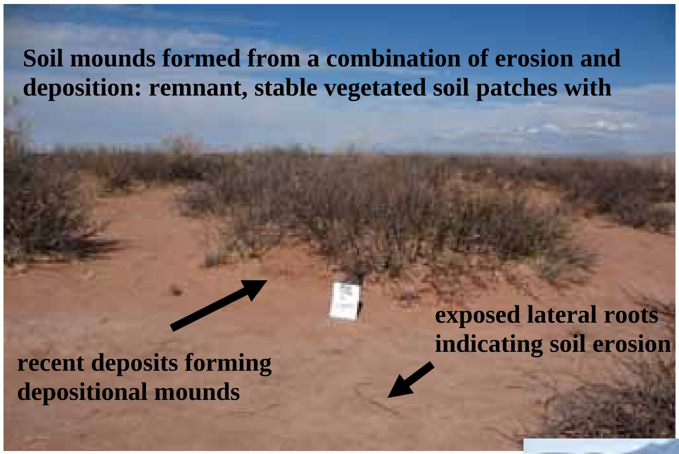
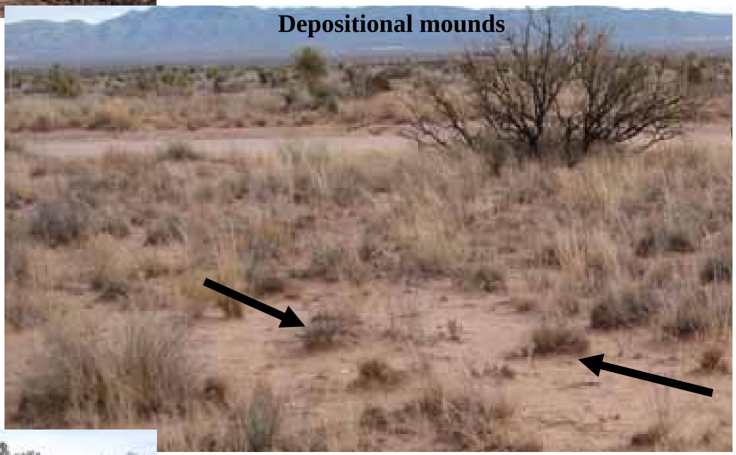
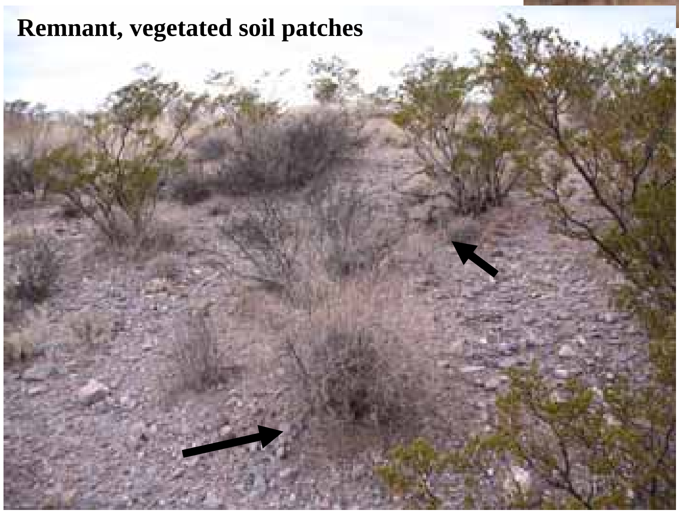


Figure A4. Wind erosion: wind scouring occurs when wind erosion removes finer soil particles from plant interspaces, forming elongated and slightly concaved depressions.

Appendix: Resource and Soil Redistribution Indicators
Soil mounds: formed by erosion, deposition or both



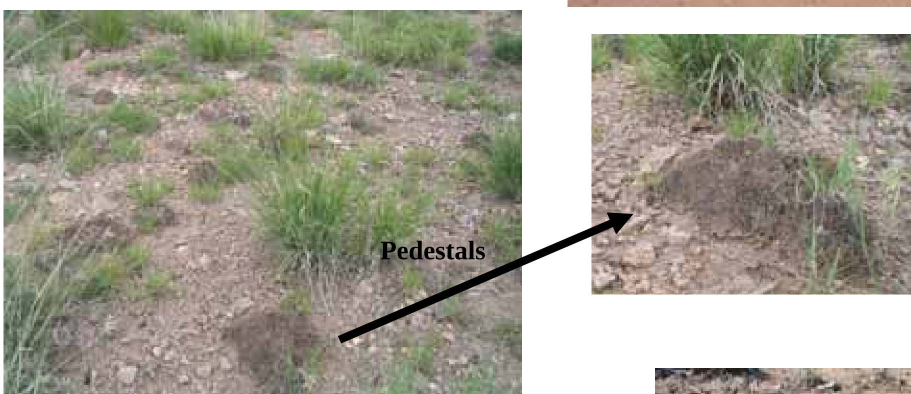




Placeholder for soil mound excavation example(s)

Figure A5. Soil mounds: are they remnant, stable/vegetated soil patches (soil remaining in place after erosion, stabilized by persistent plant patches), depositional mounds (soil deposited at persistent plant patches that form obstacles to erosion and slow wind), or have they formed through a combination of erosion and deposition? <u>Excavate</u> to the persistent plant base and determine whether the plant base occurs above the non-mounded soil surface (evidence of erosion), below the soil surface (evidence of deposition), or above the non-mounded soil surface but below recent deposits (evidence of both). Recent soil deposits can appear as different-colored, loose or finely stratified soil.

Appendix: Resource and Soil Redistribution Indicators
Pedestals



Prominent pedestals with dead/decadent plants:

Figure A6. Wind and water erosion: pedestals are formed through the thinning of the A horizon, exposing and elevating the plant base above the surrounding (non-mounded) soil surface. With increased erosion, plant pedestals appear 'taller' or more elevated above the non-mounded soil surface. Increased erosion leads to prominent pedestals with dead/decadent plants, typically with exposed roots. Note, if soil mounds are present, excavate back to the plant base to determine whether or not pedestalling has occurred.

Appendix: Resource and Soil Redistribution Indicators
Gravel lag

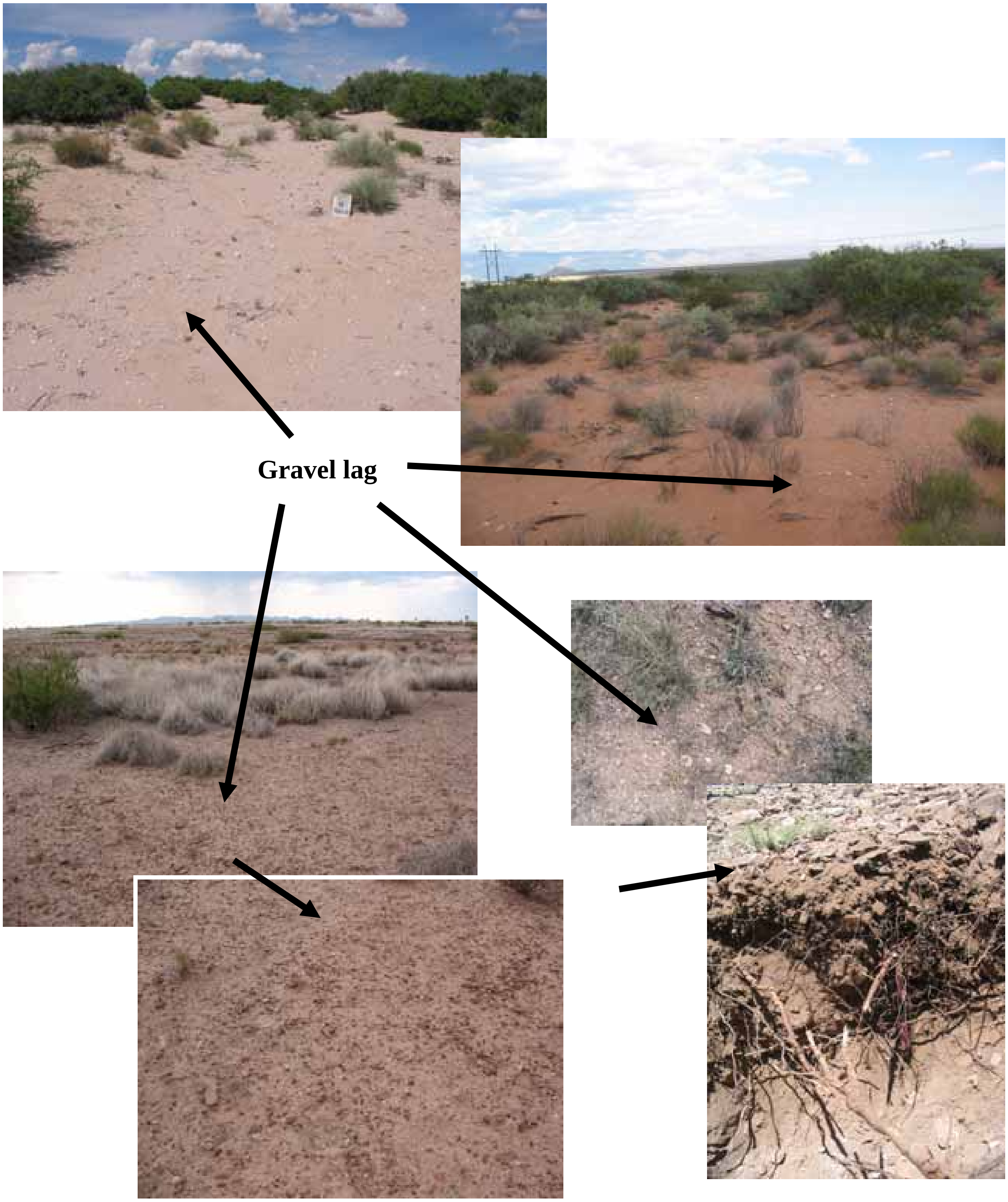


Figure A7. Wind and water erosion: A gravel lag is formed as rock fragments accumulate and remain at the soil surface after the removal of finer soil particles by wind or water erosion.

Appendix: Resource and Soil Redistribution Indicators
Soil lines on rock fragments

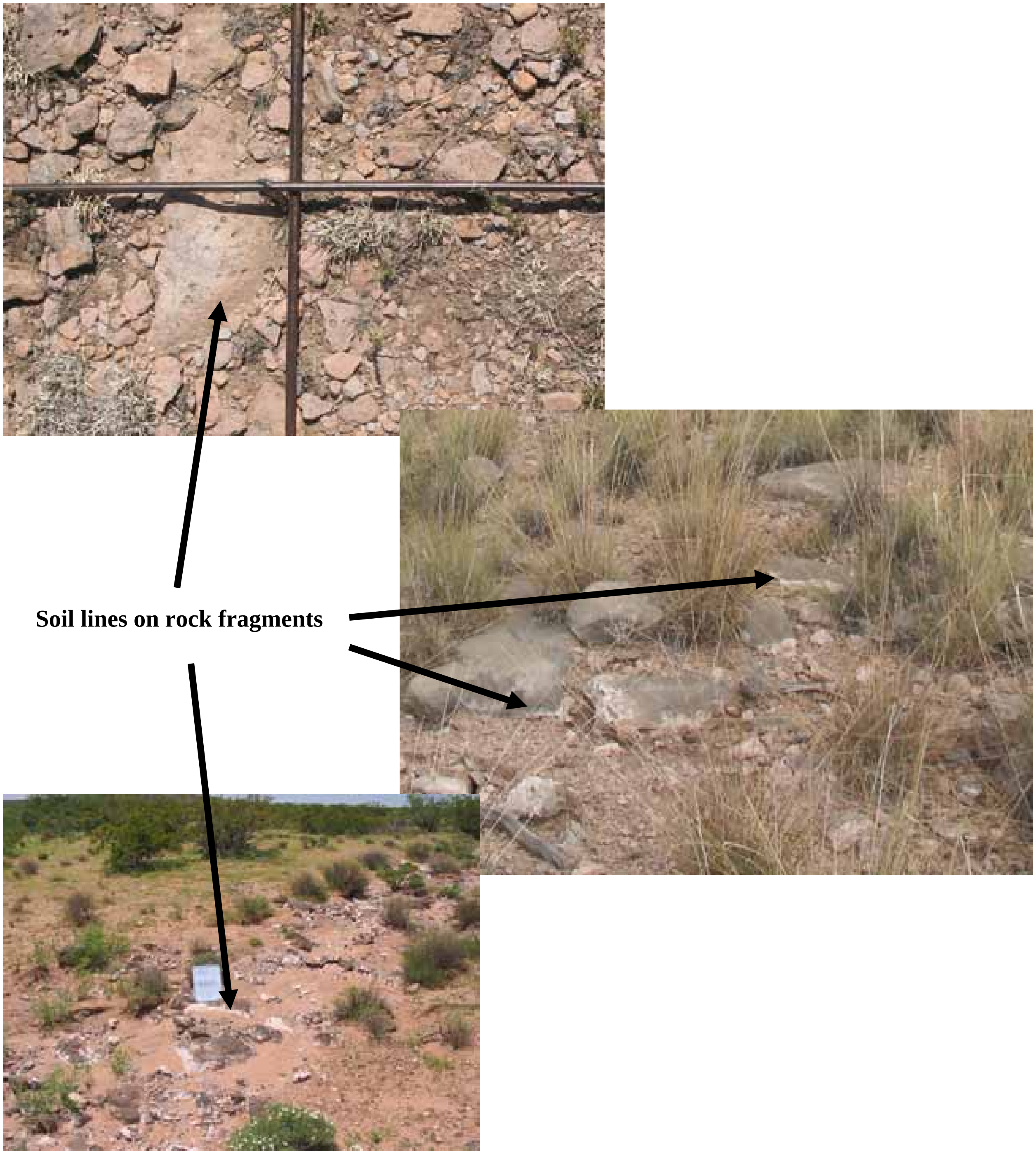


Figure A8. Wind and water erosion: soil lines on rock fragments appear as coatings of clay, carbonates, or silica, or mineral stains on the underside and sides of rock fragments; formed during pedogenesis and appearing as a line around individual rock fragments where erosion has removed soil adjacent to the rock or exhumed the rock. Lines are roughly parallel to the soil surface unless the rock has been displaced. Clay coatings, carbonates, and silica are formed in B horizons. Clay coatings and mineral stains are red to brown; carbonates and silica are whitish. Carbonate collars around rocks in A horizons (e.g., desert pavement; McFadden et al. 1998) are evidence of erosion only where exposed by soil loss; see also carbonate coats on rock fragments.

Appendix: Resource and Soil Redistribution Indicators
Exposed roots, scarplets and scarps

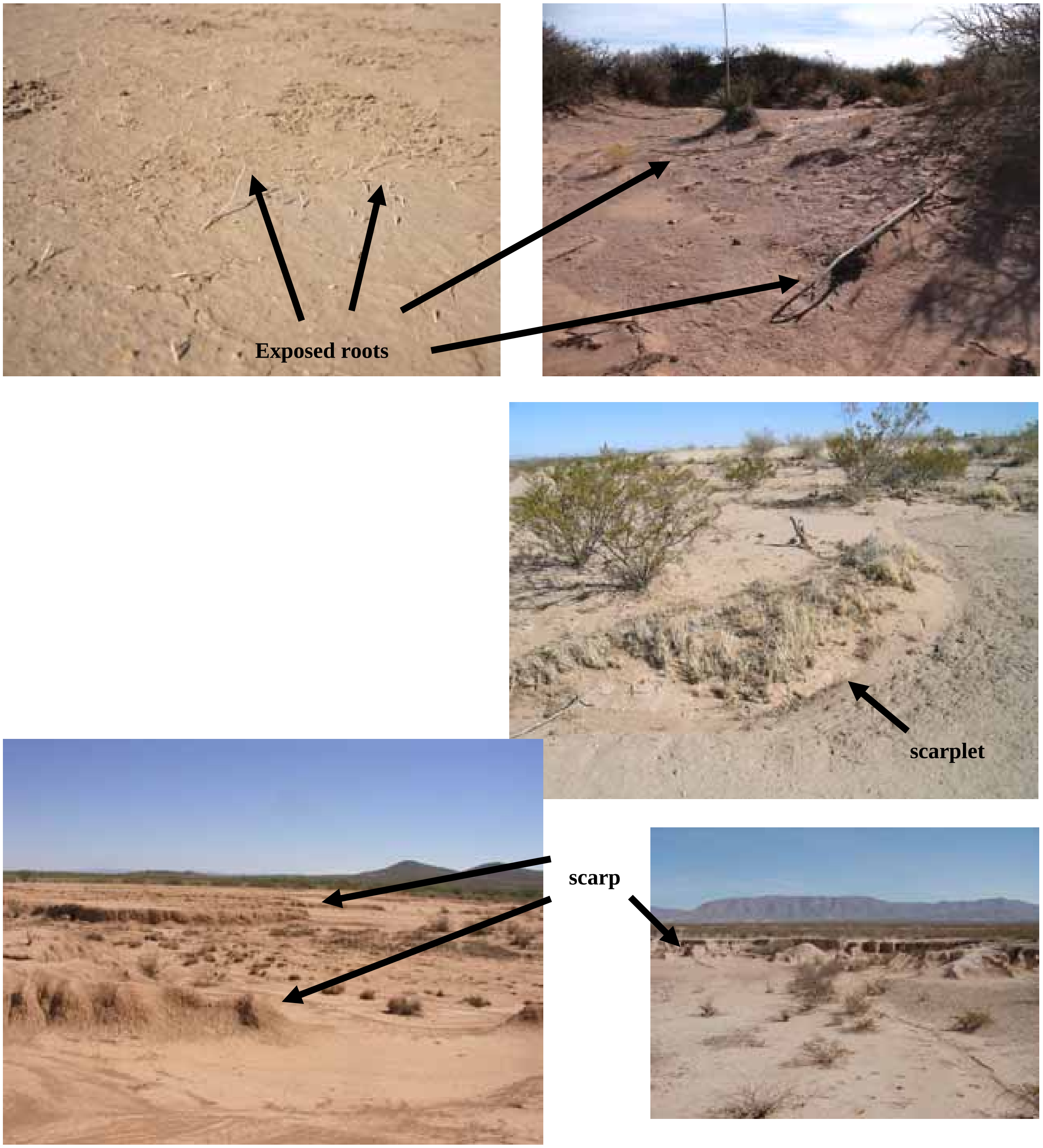


Figure A9. Wind and water erosion: exposed roots are a result of the thinning or loss of the soil surface. Vertical exposed roots include roots exposed below the plant base on plant pedestals and roots no longer attached to a plant stem or plant base (commonly seen as remnant grass roots). Vertical exposed roots indicate thinning of the surface horizon, at a minimum. Lateral exposed roots appear as lateral roots at the soil surface (typically occur with exposed subsoil/B horizon). A scarp is an escarpment, steep slope or structural bench of some extent at the soil surface resulting from erosion; can be of any height, but typically less than 50 cm tall (adapted from SSSA 2008). A scarplet is a miniature scarp extending only a short distance laterally and typically less than 20 cm tall.

Appendix: Resource and Soil Redistribution Indicators
Thin deposits and thin, discontinuous sheet deposits

Thin (soil) deposits

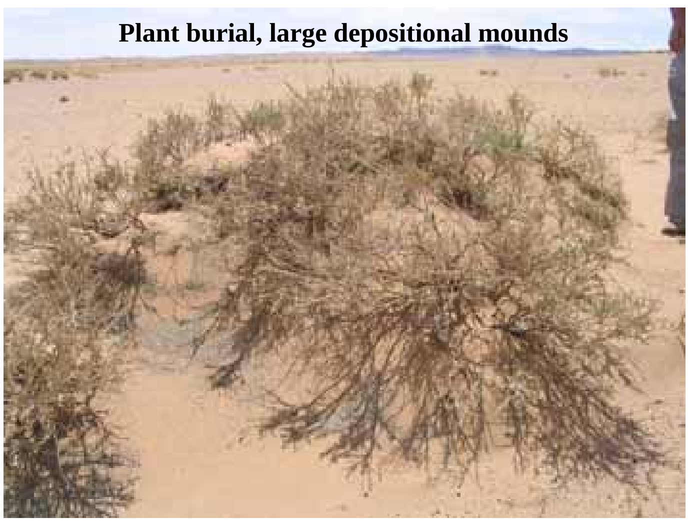
Thin, discontinuous sheet deposits

Figure A10. Deposition: thin deposits occur when wind or water flow slows and soil is deposited from the flow. Thin, discontinuous sheet deposits form when minor to medium wind or water erosion is slowed or stopped and soil is deposited.

Appendix: Resource and Soil Redistribution Indicators
Plant burial, depositional mounds, coppicing

Partial plant burial, small depositional mounds

Plant burial, depositional mounds



Plant burial, large depositional mounds

Coppicing

Figure A11. Deposition: with increased wind-borne sediment sources, small depositional mounds are formed at persistent plants, usually resulting in partial plant burial. Depositional mounds increase in size as deposition becomes more thick. This can result in coppicing and a hummocky landscape.

Glossary

A horizon - "Mineral horizons that have formed at the surface or below an O horizon. They exhibit obliteration of all or much of the original rock structure1 and show one or both of the following: (1) an accumulation of humified organic matter closely mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons (defined below) or (2) properties resulting from cultivation, pasturing, or similar kinds of disturbance" (Soil Survey Staff 2010).

Aggregate (soil) - "A group of primary soil particles that cohere to each other more strongly than to other surrounding particles" (SSSA 2008).

Algae - "A simple plant composed of a single cell or string of cells" (Rosentreter et al. 2007); "a large and diverse group of simple, typically autotrophic organisms ranging from unicellular to multicellular forms....They are photosynthetic like plants, and 'simple' because their tissues are not organized into the many distinct organs found in [vascular] plants" (Wikipedia contributors, 2011).

Angular blocky - Soil structure. "Units are blocklike or polyhedral with flat or slightly rounded surfaces that are casts of faces of surrounding peds; nearly equidimensional. Faces intersect at relatively sharp angles" (SSSA 2008); see also ped.

Annual plant (annual) - "A plant that completes its life cycle and dies in one year or less" (SRM 1999).

Assessment - "The process of estimating or judging the value or functional status of ecological processes (e.g., rangeland health)" (Herrick et al. 2009).

B horizon - "Horizons that formed below an A, E, or O horizon. They are dominated by the obliteration of all or much of the original rock structure and show one or more of the following:

1. Illuvial concentration of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica, alone or in combination;
2. Evidence of removal, addition, or transformation of carbonates and/or gypsum;
3. Residual concentration of oxides;
4. Coatings of sesquioxides that make the horizon conspicuously lower in color value, higher in chroma, or redder in hue, without apparent illuviation of iron;
5. Alteration that forms silicate clay or liberates oxides, or both, and that forms granular, blocky, or prismatic structure if volume changes accompany changes in moisture content;
6. Brittleness; or
7. Strong gleying…" (Soil Survey Staff 2010).

Bedrock - "A general term for the solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface" (SSSA 2008).

Biological crust - "Microorganisms (e.g., algae, cyanobacteria, microfungi) and non-vascular plants (e.g., mosses, lichens) that grow on or just below the soil surface" (Herrick et al. 2009).

Boulder - "Rock or mineral fragments >600 mm in diameter" (SSSA 2008); see also rock fragments.

Bunchgrass – "A grass having the characteristic growth habit of forming a bunch; lacking stolens or rhizomes" (SRM 1999); examples of bunchgrasses include dropseeds (*Sporobolus* species), three awns (*Aristida purpurea* and *A. ternipes*) and bluebunch wheatgrass (*Pseudoroegneria spicata*).

Burial of plants - Erosion and soil redistribution deposits sediments that accumulate around persistent plants, burying them from the base up.

Carbonate - Naturally occurring, nearly white, chalky precipitate of calcium carbonate in soil. Forms of carbonate include finely disseminated (discrete bodies not visible), filaments, masses, nodules, or soil horizons engulfed in or cemented by calcium carbonate.

Carbonate coats on rock fragments – During soil formation (pedogenesis), chalky white deposits of calcium carbonate coat the underside, sides and in some cases, entire rock fragments, or create a ring (collar) around each rock. Carbonate-coated rocks on the soil surface are indicative of erosion. Degree of erosion (thinning of A versus exposure of subsoil) is determined by observing a soil pit. Disregard carbonate collars as evidence of erosion if they are embedded in undisturbed A horizons (e.g., desert pavement; McFadden et al. 1998); see also soil lines on rock fragments.

Cemented horizon - (1) A cemented B horizon; (2) "having a hard, brittle consistency because the soil particles are held together by cementing substances such as humus, calcium carbonate, or the oxides of silicon, iron and aluminum. The hardness and brittleness persist even when wet; (3) [Pan] Genetic - a natural subsurface soil layer with low or very low hydraulic conductivity and differing in certain physical and chemical properties from the soil immediately above or below the pan" (SSSA 2008).

Clay color stains on rock fragments – see soil lines on rock fragments.

Columnar - Soil structure. "Units are prismlike and bounded by flat to rounded vertical faces. Units are distinctly longer vertically than horizontally; vertices angular. Tops of units are very distinct and normally rounded" (SSSA 2008); see also ped.

Cobble - "Rounded or partially rounded rock or mineral fragments between 75 and 250 mm in diameter" (SSSA 2008); see also rock fragments.

Community phase (plant) - A plant community that occurs on a particular ecological site and in a particular state. Community phases within a given state are typically similar in plant functional groups, soil properties and ecosystem processes and, consequently, in vegetation structure, biodiversity and management requirements. They can be distinguished by their responses to disturbance, and are often connected by traditionally defined successional pathways (modified from Herrick et al. 2009); see also ecological state.

Composition (plant) - "The proportions of various plant species in relation to the total on a given area; it may be expressed in terms of cover, density, weight, etc." (SRM 1999).

Concentrated flow - "A relatively large water flow over or through a relatively narrow course" (SSSA 2008).

Coppice - "A small, streamlined dune that forms around desert, brush-and-clump vegetation" (SSSA 2008).

Crust - "A transient soil-surface layer, ranging in thickness from a few millimeters to a few centimeters, that is either denser, structurally different or more cemented than the material immediately beneath it, resulting in greater soil strength when dry as measured by penetration resistance or other indices of soil strength" (SSSA 2008); see also biological crust and physical crust.

Cyanobacteria - "Simple photosynthesizing organisms that can fix atmospheric nitrogen and serve as a photobiont in lichen associations (also called blue-green algae)" (Rosentreter et al. 2007).

Cyanobacterial sheath – Sticky polysaccharide sleeves exuded from filaments of cyanobacteria. Sheaths (1) adhere to and bind soil particles together, resisting wind and water erosion; (2) absorb water; (3) contribute nitrogen and carbon to the soil; and (4) are visible without magnification (Durrell and Shields 1961, Belnap and Gardner 1993 and Belnap 2003).

Deposition - The process of leaving soil "material ...in a new position by a natural transporting agent such as water, wind, ice, or gravity, or by the activity of man" (SSSA 2008).

Depositional mound – see soil mound.

Desert varnish - "A thin, dark, shiny film or coating of iron oxide and lesser amounts of manganese oxide and silica formed on the surfaces of pebbles, **boulders**, rock fragments, and rock outcrops in arid regions" (SSSA 2008).

Dimpled - Natural, smooth undulations in a poorly developed biological crust (PDB) seen as small (<5 mm), gentle bumps and depressions; a dimpled surface is comprised of cyanobacterial sheaths and has slightly more roughness than a smooth surface, but less than a rugose, pinnacled or rolling surface.

Disturbance - Ecosystem context: "Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett 1985); Soil context: "Any relatively discrete event that alters the capacity of soil to function and changes soil morphology, composition or processes" (Tugel et al. 2008).

Ecological site - (syn. rangeland ecological site) "a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation, and in its ability to respond to management actions and natural disturbances" (draft Interagency Ecological Site Handbook for Rangelands). Ecological sites are associated with soil map unit components of the National Cooperative Soil Survey. They are classes of land defined by recurring soil, landform, geological, and climate characteristics.

Ecological sites recur on similar soil components within either a Major Land Resource Area (MLRA) or **Land Resource Unit** (LRU).

Ecological site description (ESD) – (1) Reports that describe: (a) the biophysical properties of ecological sites; (b) the vegetation and surface soil properties of reference conditions representing either pre-European vegetation and historical range of variation (in the United States), proper functioning condition, or potential natural vegetation; (c) state-and-transition model graphics and text; and (d) the ecosystem services provided by the ecological site and other interpretations; (2) "Reports with associated data that contain the body of information associated with each ecological site (Bestelmeyer and Brown 2010); refer to National Range and Pasture Handbook (USDA NRCS 2003); see also **state and transition model**.

Ecological state - "A state includes one or more biological (including soil) communities that occur on a particular ecological site and that are functionally similar with respect to the three attributes (soil and site stability, hydrologic function and biotic integrity). States are distinguished by relatively large differences in plant functional groups, soil properties and ecosystem processes and, consequently, in vegetation structure, biodiversity and management requirements. They are also distinguished by their responses to disturbance. A number of different plant communities may be included in a state and the communities are often connected by traditionally defined successional pathways" (In Herrick et al. 2009).

Ecosystem function - The ability of an ecosystem to capture and use resources to produce goods and services.

Ecoregion - Ecological region; a geographic area with a specific suite of plant communities and unique climate, landforms, geology, and soils.

Eolian - "Pertaining to earth material transported and deposited by the wind including dune sands, sand sheets, loess, and parna" (SSSA 2008).

Erosion - (i) The wearing away of the land surface by rain or irrigation water, wind, ice, or other natural or anthropogenic agents that abrade, detach and remove geologic parent material or soil from one point on the earth's surface and deposit it elsewhere, including such processes as gravitational creep and so-called tillage erosion; (ii) The detachment and movement of soil or rock by water, wind, ice, or gravity......" (SSSA 2008).

Exposed subsoil - An E, B, C or other subsurface horizon observed at the surface after erosion and complete loss of the surface horizon.

Fetch - The distance between plants; the maximum distance that wind or water can flow before reaching an obstruction.

Fluvial - Pertaining to earth material transported and deposited by water.

Functional/structural group - "A suite or group of species that, because of similar shoot or root structure, photosynthetic pathways, nitrogen-fixing ability, life cycle, etc., are grouped together" (Herrick et al. 2009).

Granular - Soil structure. “Units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds" (SSSA 2008); see also ped.

Gravel - “A collection of pebbles (rounded, subrounded, or angular but not flat rock fragments) that have diameters ranging from 2 to 75 mm” (Soil Survey Division Staff 1993); see also rock fragments.

Gravel lag - An accumulation of rock fragments remaining at the soil surface after the removal of finer soil particles by water or wind erosion.

Gully - "A channel resulting from erosion and caused by the concentrated but intermittent flow of water usually during and immediately following heavy rains. Deep enough (usually >0.5 m) to interfere with, and not to be obliterated by, normal tillage operations" (SSSA 2008).

Horizon (soil) - "A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as color, structure, texture, consistency, kinds and number of organisms present, degree of acidity or alkalinity, etc." (SSSA 2008).

Hummocky - An undulating soil surface consisting of repeating coppices or depositional mounds.

Infiltration - "The entry of water into soil" (SSSA 2008).

Interpatch area - An area without perennial, long-lived vascular plants; effectively the soil pedoderm or the soil pedoderm with short-lived, non-persistent plants. Interpatch areas are recognized when plant spacing exceeds 20 cm. Areas covered by rock fragments, mineral soil, litter, duff, biological/physical crusts, and annual/non-persistent plants are considered interpatch areas because the RRC focuses on the role of persistent vascular plant cover and the arrangement of that cover in stabilizing the soil surface and capturing resources. Interpatch areas can be sources of water runoff and bare or disturbed soil pedoderms are typically sources of sediment during runoff events.

Interrill erosion - "The removal of a fairly uniform layer of soil on a multitude of relatively small areas by splash due to raindrop impact and by sheet flow" (SSSA 2008); see also rill erosion.

Inventory (rangeland inventory) - "(1) The systematic acquisition and analysis of resource information needed for planning and management of rangeland; (2) the information acquired through rangeland inventory" (SRM 1999).

Land Resource Unit (LRU) - Subdivisons of MRLAs that distinguish areas of different regional climate and/or geomorphology” (Bestelmeyer and Brown 2010).

Leeward - The downwind direction; the direction the prevailing wind travels.

Lichen - "Composite organism made up of a fungus and an alga, a cyanobacterium, or all three" (Rosentreter et al. 2007).

Litter - "The uppermost layer of organic debris on the soil surface; essentially, the freshly fallen or slightly decomposed plant matter" (SRM 1999). "Includes persistent and non-persistent organic [material] that is in contact with the soil surface (i.e., not rooted in the soil)"; (Herrick et al. 2009).

Litter dam - a collection of pieces of plant litter (leaves, small twigs, seeds, flowers) deposited along the soil surface, at obstacles to wind and water flow.

Liverwort - "A bryophyte belonging to the class Hepaticae, with flattened bodies that have distinct upper and lower surfaces" (Rosentreter et al. 2007).

Major Land Resource Area (MLRA) - "Geographically associated land resource units delineated by the NRCS and characterized by a particular pattern that combines soils, water, climate, vegetation, land use, and type of farming. There are 278 MLRAs in the United States, ranging in size from less than 500,000 acres to more than 60 million acres" (USDA NRCS 2006). "MLRAs are regional divisions of the United States based on strong differences in climate, physiography, plant geography and general land uses" (Bestelmeyer and Brown 2010).

Massive – Structureless soil; coherent; soil particles are not arranged into secondary units or peds (SSSA 2008); see also ped, soil structure, structureless.

Matrix - the formative part, prevailing condition or surrounding substance that constitutes the majority environment of a given area.

Mineral soil - "A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter. Usually contains <200 g kg^{-1}organic carbon (<120-180 g kg^{-1} if saturated with water), but may contain an organic surface layer up to 30 cm thick" (SSSA 2008).

Moss – Low growing, non-vascular plant in the division Bryophyta that has leaves attached in a whorl about the stem (Rosentreter et al. 2007).

Nutrient - "Elements or compounds essential as raw materials for organism growth and development" (SSSA 2008).

O horizon - "Horizons or layers dominated by organic soil materials. Some are saturated with water for long periods or were once saturated but are now artificially drained; others have never been saturated" (Soil Survey Staff 2010).

Organic matter - "The organic fraction of the soil exclusive of undecayed plant and animal residues...." (SSSA 2008).

Overland water flow - "Surface runoff of water following a precipitation event" (SRM 1999).

Ped - "A unit of soil structure such as a block, column, granule, plate, or prism, formed by natural processes (in contrast with a clod, which is formed artificially;" SSSA 2008); discrete, natural unit of soil.

Pedestal - "Plants or rocks that appear elevated as a result of soil loss by wind or water erosion (does not include plant or rock elevation as a result of non-erosional processes such as frost heaving" (Herrick et al. 2009); the root crown of a pedestalled plant occurs above the soil's surface, with or without exposed roots. See also soil mound.

Pedoderm - the lateral expanse of the top 0.5- 3 cm of the soil surface; the soil-air interface (Fey et al. 2006).

Pedoderm class (PC) - A description of the thin layer of soil at the air/soil interface (the pedoderm) across a plot, including physical, chemical and biological crusts, rocks at the soil surface, duff, bare soil and the aggregation of soil particles. The features of each class influence water infiltration, soil erosion and retention, nutrient retention and addition, and plant establishment. Where multiple features occur on a plot, class selection is based on the feature of greatest influence.

Pedogenesis (soil genesis) - "The mode of origin of the soil with special reference to the processes or soil-forming factors responsible for development of the solum, or true soil, from unconsolidated parent material..." (SSSA 2008).

Perennial plant (perennial) - "A plant that has a life span of three or more years" (USDA NRCS 2003).

Persistent (vascular) plant patch - a discrete group of multiple individuals of one or more persistent vascular plant species separated from other such patches by an interpatch area. Persistent plant patches do not include annuals and short-lived plants that are usually absent from the site during wind or water erosion events, nor non-vascular plants that are considered part of the pedoderm. Persistent plant patches trap and retain water, nutrients, and soil due to their persistent physical structures. There is often (but not always) evidence of sediment accumulation within a persistent plant patch. As a rule of thumb, a persistent plant patch consists of multiple plants whose plant bases are within 20 cm of one another. A separate patch is recognized when the spacing between adjacent plants in a given direction is greater than 20 cm.

Physical crust – A crust formed by impact of raindrops on bare soil that causes the soil surface to seal and form a thin surface layer that inhibits water absorption (Herrick et al. 2009).

Pinnacled - Pertaining to biological crust morphology; "pinnacled biological crusts occur in mid-latitude cool deserts, such as the Colorado Plateau;" pinnacled biological crusts have the greatest vertical relief with heights between 5 and 15 cm (Rosentreter et al. 2007); see also smooth, rolling and rugose.

Plant base - The morphological feature on a plant where the roots (below-ground biomass) and the stem(s) (above-ground biomass) of a plant meet; located at and just above the soil surface.

Platy - Soil structure. "Units are flat and platelike. They are generally oriented horizontally and faces are mostly horizontal" (SSSA 2008); see also ped.

Plot - a defined area that represents a portion of the landscape (typically 20 m x 20 m for

Pedoderm and Pattern Classes); a plot is located completely within, and represents, one soil type (except where placed in an intermingled complex of differing soils), ecological site, state and community phase.

Preferential flow - The process whereby free water and its constituents move by preferred pathways through a porous medium" (SSSA 2008); where patchy duff occurs under woody plants in pinyon-juniper communities, water movement into and through the duff and mineral soil occurs via preferential flow influenced by hydrophobic areas, roots, pores and wetted patches (Madsen et al. 2008).

Prismatic - Soil structure. "Units are prismlike and bounded by flat to rounded vertical faces. Units are distinctly longer vertically than horizontally; vertices angular. Tops of units are indistinct and normally flat" (SSSA 2008); see also ped.

Raindrop impact - The energy transferred when a drop of rain collides with the soil surface; depending upon the size and velocity of the raindrop this impact can dislodge soil particles and small gravel leading to erosion; see also splash erosion.

Rangeland health - The degree to which ecological processes acting in rangelands sustain the capacity to recover desired species during favorable periods, and sustain the varied ecosystem services expected from rangelands.

Redistribution - See soil redistribution.

Resource - Nutrients, water, minerals, soil, litter, seeds, organic matter and biota that exist on a plot or site and support living organisms.

Resource retention class (RRC) - A description of the size and connectivity of persistent vascular plant patches and interpatch areas across a plot. The features of each class reflect the ability of the persistent plant community to retain water, nutrients, soil, and other resources (litter, seeds). These resources have a greater potential to be retained at lower classes.

Retention - The ability to keep resources on a plot or site.

Rill - "A small, intermittent water course with steep sides; usually only several centimeters deep" (SSSA 2008).

Rill erosion - "An erosion process ... in which numerous and randomly occurring small channels of only several centimeters in depth are formed..." (SSSA 2008).

Rock fragments - "...Unattached pieces of geologic or pedogenic material 2 mm in diameter or larger that are strongly cemented or more resistant to rupture..." (USDA NRCS accessed 7/22/2011).

Rolling - Pertaining to biological crust morphology; "rolling biological crusts exist only where frost-heaving occurs in the winter, such as the Great Basin;" rolling biological crusts have more vertical relief than smooth crusts, but less than pinnacled crusts, with heights between 3 and 5 cm; rolling crusts typically do not include gaps of mineral soil surface or smooth crusts

(Rosentreter et al. 2007); see also pinnacled, rugose and smooth.

Rugose - Pertaining to biological crust morphology; "rugose biological crusts occur in slightly less arid deserts, such as the Mojave Desert;" rugose biological crusts have more vertical relief than smooth crusts, with heights between 1 and 3 cm and contain gaps of smooth crusts or mineral soil between them (Rosentreter et al. 2007); see also pinnacled, rolling and smooth.

Runoff - "That portion of precipitation or irrigation on an area which does not infiltrate, but instead is discharged from the area. That which is lost without entering the soil is called surface runoff. That which enters the soil before reaching a stream channel is called ground water runoff or seepage flow from ground water. (In soil science runoff usually refers to the water lost by surface flow; in geology and hydraulics runoff usually includes both surface and subsurface flow.)" (SSSA 2008).

Scarp - An escarpment, steep slope or structural bench of some extent at the soil surface resulting from erosion; may be of any height, but typically less than 50 cm tall (adapted from SSSA 2008).

Scarplet - A miniature scarp extending only a short distance laterally and typically less than 20 cm tall.

Sediment - "Transported and deposited particles or aggregates derived from rocks, soil, or biological material" (SSSA 2008).

Sedimentation - "The process of sediment deposition" (SSSA 2008).

Sheet erosion - "The removal of a relatively uniform thin layer of soil from the land surface by rainfall and largely unchanneled surface runoff (sheet flow)" (SSSA 2008); see also interrill erosion.

Sheet deposit - A thin, relatively uniform layer of soil deposits; occurs either continuously across the plot or in patches.

Single grain - Structureless soil; noncoherent; individual soil particles are visible and are not arranged into secondary structural units or peds (SSSA 2008); see also ped, soil structure, structureless.

Site potential (reference state) - Historical or natural state for an ecological site including its range of variation. Reference states have been identified according to varying criteria, but they most often designate the historical range of variation at the time of European settlement. It is often implicitly assumed that historically observed states are those that provide the maximum options for management and ecosystem services. This is because they were relatively unaltered by modern human extractive activities (Bestelmeyer et al., 2010).

Smooth - Pertaining to biological crust morphology; "smooth biological crusts occur in hot, hyper-arid deserts, such as the Colorado Desert, and in recently disturbed deserts;" smooth biological crusts have the least vertical relief with heights between 0 and 1 cm and are often dominated by cyanobacteria (Rosentreter et al. 2007); see also pinnacled, rolling and rugose.

Soil lines on rock fragments – Coatings of clay, carbonates, or silica, or mineral stains on the underside and sides of rock fragments; formed during pedogenesis and appearing as a line around individual rock fragments where erosion has removed soil adjacent to the rock or exhumed the rock. Lines are roughly parallel to the soil surface unless the rock has been displaced. Clay coatings, carbonates, and silica are formed in B horizons. Clay coatings and mineral stains are red to brown; carbonates and silica are whitish. Carbonate collars around rocks in A horizons (e.g., desert pavement; McFadden et al. 1998) are evidence of erosion only where exposed by soil loss; see also carbonate coats on rock fragments.

Soil mound - A general term for a patch of soil elevated above the surrounding soil surface. Soil mounds typically appear at persistent plants. A soil mound can be formed through erosion and deposition. As erosion occurs, areas of soil remain where persistent plants or biological crusts stabilize the soil. These soil mounds are more specifically referred to as pedestals and provide evidence of erosion. Sediment deposition can also form soil mounds (see depositional soil mound below). Excavation of soil mounds formed through a combination of erosion and deposition exhibit: (1) plant bases above the surrounding, non-mounded, interpatch soil surface (pedestalled plants), and (2) burial of the remnant soil by finely stratified or different colored or textured deposits. See also pedestal.

Depositional soil mound - An accumulation of sediment deposited by wind or water, typically at or behind a plant or woody litter. When excavated, a depositional mound features thin or finely stratified soil surface with platy layers alternating with layers lacking structure, or deposits can be structureless and a different color from the underlying surface (e.g., loose sand). These deposits are continuous down to, and rest directly on top of, the non-mounded soil surface.

Soil particle - "Mineral particles, <2.0 mm in equivalent diameter, ranging between specified size limits. The names and size limits of separates recognized by the USDA are: very coarse sand (1-2 mm); coarse sand (0.5-1 mm); medium sand (0.25-0.5 mm); fine sand (0.1-0.25 mm); very fine sand (0.05-0.5 mm); silt (0.002-0.05 mm); and clay (<0.002 mm)" (SSSA 2008).

Soil profile - "A vertical section of the soil through all its horizons and extending into the C horizon" (SSSA 2008).

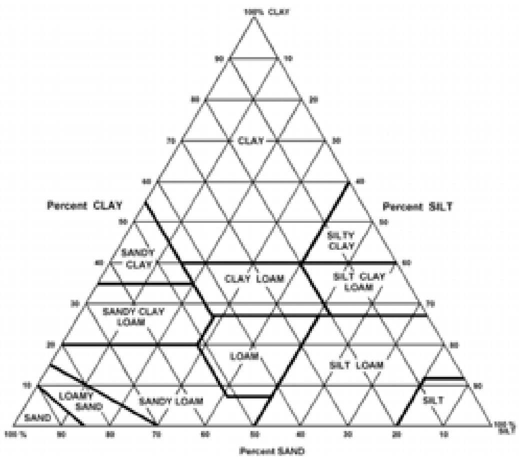
Soil redistribution - The movement of soil by wind and water; includes erosion and / or deposition.

Soil redistribution class (SRC) - A description of the extent and severity of soil redistribution processes (erosion and deposition by wind and water) across a plot. Redistribution processes are indicated by multiple features that include, but are not limited to, pedestals, water flow patterns, depositional mounds and carbonate coats or **clay color stains on rock fragments**. The features of each class influence the ability of the soil to support plant communities and other functions. The extent and severity of soil redistribution and its effects on plants are greater at higher classes.

Soil stability - The ability of the soil to retain it structure and resist wind and water erosion.

Soil structure - "The combination or arrangement of primary soil particles into secondary units or peds. The secondary units are characterized on the basis of size, shape, and grade (degree of distinctness)...." (SSSA 2008); see also: angular blocky, columnar, granular, ped, platy, prismatic, structureless, subangular blocky, **wedge**.

Soil texture - "The relative proportions of the various soil separates in a soil as described by the classes of soil texture shown in [the soil textural triangle below]. The textural classes may be modified by the addition of suitable adjectives when rock fragments are present in substantial amounts; for example, 'stony silt loam'. The sand, loamy sand, and sandy loam are further subdivided on the basis of the proportions of the various sand separates present. The limits of the various classes and subclasses are as follows:" (SSSA 2008).



Splash erosion - "The detachment and airborne movement of small soil particles caused by the impact of raindrops on soils" (SSSA 2008).

State - see ecological state; see also state and transition model.

State and transition model (STM) – Synthetic descriptions of the dynamics of the vegetation and surface soils occurring within specific ecological sites. STMs consist of a diagram and narratives that describe these dynamics and evidence for the causes. STMs are developed using a broad array of evidence including historical information, local and professional knowledge, general ecological knowledge, and monitoring and experimental data from a specific ecological site or similar sites. (Bestelmeyer et al. 2010).

Stratified (soil) - "Arranged in or composed of strata or layers" (SSSA 2008).

Stone - "Rock or mineral fragment between 250 and 600 mm in diameter if rounded, and 380 to 600 mm if flat. See also rock fragments" (SSSA 2008).

Structureless - "No observable aggregation or no definite and orderly arrangement of natural lines of weakness....primary soil particles [do not combine or arrange] into secondary structural units or peds...." (SSSA 2008); see also single grain and massive.

Subangular blocky - Soil structure. "Units are blocklike or polyhedral with flat or slightly rounded surfaces that are casts of faces of surrounding peds; nearly equidimensional. Mixture of rounded and plane faces and the vertices are mostly rounded" (SSSA 2008); see also ped.

Subsoil - Soil horizon(s) located under the A or surface horizon, technically B horizons. Can include E and C horizons for the purposes of this document.

Surface seal(ing) - "The deposition by water, orientation and/or packing of a thin layer of fine soil particles on the immediate surface of the soil, greatly reducing its water permeability" (SSSA 2008).

Terracette - "Benches of soil deposition behind obstacles causes by water, not wind, erosion" (Pellant et al. 2005).

Thinning (of the surface horizon) - Erosion of thin layers of the surface horizon in patches or throughout the plot. Subsoil is not exposed.

Varnish - see desert varnish.

Vascular plant - "Higher plants with vessels that conduct sap throughout the plant" (Pellant et al. 2005); e.g., grasses, shrubs and trees.

Vesicular crust - A crust consisting of vesicular pores (unconnected, nearly spherical voids with smooth walls; SSSA 2008).

Vesicular pore - "Unconnected voids with smooth walls" (SSSA 2008).

Water erosion - (1) The wearing away of land surface by rain or overland water flow; the process by which water detaches and removes soil from one point on the earth's surface and deposits it elsewhere; (2) The detachment and movement of soil by water. Includes gully erosion, interrill erosion, rill erosion, sheet erosion, and splash erosion.

Water flow pattern - "The path water takes (i.e., accumulates) as it moves across the soil surface during overland flow" (Herrick et al. 2009).

Wedge – Soil structure. “Elliptical, interlocking lenses that terminate in acute angles, bounded by slickensides; not limited to vertic materials" (Schoeneberger et al. 2002); formed in the subsoil.

Wind erosion - (1) The wearing away of land surface by wind; the process by which water detaches and removes soil from one point on the earth's surface and deposits it elsewhere; (2) The detachment and movement of soil by wind. See also wind scouring.

Wind scouring - The act of wind erosion removing finer soil particles from interspaces and leaving behind residual gravel, rock or exposed roots on the soil surface (Pellant et al. 2005); wind scoured areas are typically elongated and slightly concave in shape (slight depressions).

Windward - The upwind direction; the direction from which the prevailing wind originates.

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