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Geologic Natural Features Classification System for Missouri
Missouri Department of Natural Resources

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MISSOURI DEPARTMENT OF NATURAL RESOURCES

MISSOURI GEOLOGICAL SURVEY
Joe Gillman, Director and State Geologist

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Table of Contents

List of Figures

THE GEOLOGIC NATURAL FEATURES CLASSIFICATION SYSTEM

HISTORICAL BACKGROUND

In March 1978 a group of ten geologists representing private, academic, and government institutions met in Denver, Colorado, under the auspices of the U.S. Department of the Interior, Heritage Conservation and Recreation Service to develop guidelines and a general format for geological classification systems (Heritage Conservation and Recreation Service, 1978). Jerry D. Vineyard, Assistant State Geologist of Missouri and a Department of Natural Resources member of the Missouri Natural Areas Committee, was a member of that panel. In 1979 Mr. Vineyard initiated work on a geological classification system tailored specifically to Missouri. In May 1983, the Missouri Natural Areas Committee (MONAC) adopted a Geologic Natural Features Classification System (GNFCS) designed specifically for Missouri. It is one of a trilogy of classification systems, along with a terrestrial natural communities classification (Nelson, 1985) and an aquatic communities classification (Pflieger, 1985), used by MONAC as a framework for selecting sites that comprise the Missouri Natural Areas System. (Hebrank, 1989)

INTRODUCTION

Building on the framework of the unpublished manuscript, which developed the original classification system (Hebrank, 1983), it is the author's intention to update the system to incorporate the 30+ years of additional knowledge and understanding of Missouri’s geologic environment. This revision includes a more precise discussion of the major geologic divisions, greater descriptive detail for individual geologic features, an update of the many references and definitions used in the framework of the natural area classification system and a more in-depth description of Missouri’s karst environments. Where possible the definitions were adjusted to remain consistent with the Glossary of Geology published by Neuendorf, (2011). Additionally, to assist with referencing the revision will be officially published as an open file report from the Missouri Department of Natural Resources, Missouri Geological Survey.

The 2019 Geologic Natural Features Classification System for Missouri has been updated to include an expansion of two sections. The first section is a general summary of the major geologic divisions of Missouri, including a description of the major karst areas within the state. The second section attempts to classify all geologic features located within the state of Missouri based on the genesis of the feature. A third section in the MONAC document titled “Checklist” was included in the original document, but was not part of the original classification system. This section has been removed from this updated document and the information incorporated into the either the text or appendices.

GEOLOGIC NATURE OF MISSOURI

The bedrock in Missouri ranges in age from 1,300 to1,500 million years old Mesoproterozoic volcanic and intrusive igneous rocks located in the St. Francois Mountains to Quaternary-age sediments deposited along the major rivers and in the Mississippi Embayment. Sandwiched in between these oldest rocks and youngest sediments is a thick sequence of Cambrian- through Pennsylvanian-age sedimentary rocks as well as Cretaceous through Neogene sediments. Appendix A provides a chronostratigraphic outline of Missouri's geology. Across Missouri there are several major structures. The Ozark Dome and its core consisting of the St. Francois Mountains is located in the southeastern part of the state and is a dominant feature on the landscape. Bordering the Ozark Dome to the northwest and east are the Forest City and the Illinois basins, respectively. Lying between the basins, in the northeast portion of Missouri, Ordovician-age bedrock has been warped upwards to produce a northwest-southeast trending anticline known as the Lincoln Fold.

The Paleozoic bedrock units exposed at the surface of the Ozark Dome are primarily Cambrian through Ordovician in age. These units deepen dramatically within the basins where they are overlain by Carboniferous age bedrock units. The southeastern corner of the state is underlain by the northern section of the Reelfoot Rift and the Mississippi embayment. This area has thick sediments of Paleogene, Neogene and Quaternary age overlying the deeply buried Paleozoic-age rocks.

Missouri's geology is surprisingly complex for being located in the middle of the North American tectonic plate. Several unconformities and paleo-erosional surfaces exist between the bedrock units of Missouri. These missing rock units represent gaps of time where either the bedrock units have been removed or were never deposited. Even when present, the geologic features of Missouri are often buried under thick Pleistocene glacial deposits as is the case in the northern portion of the state or several feet of windblown loess across the rest (Nigh and Schroder, 2002). Millions of years of stress have resulted in many large faults systems that extend across large parts of the state. The generalized geologic map shown in Figure 1 shows the distribution of mapped units across the state. Figures 2a through 2f highlight the outcrop patterns of bedrock from each of the different geologic periods.

MAJOR GEOLOGIC DIVISIONS OF MISSOURI

Geology and climate, which includes the resulting geomorphic processes, both build and destroy the natural character of Missouri's Landscape.

The continental United States is divided into 24 major geologic or physiographic regions. Missouri is a part of three (3) of those major divisions. Originally described for the country by Fenneman (1928) and further delineated in Fennemen and Johnson (1946) the geology and landscape of the nation is broken down into three broadest and most basic physiographic regions. Since then many scientist such as Thom and Wilson (1980) and Nigh and Schroeder (2000) have taken these broader physiographic regions and combined them with geomorphic, ecologic and climatic data to produce maps that outline the ecological or natural divisions of the state. These maps roughly coincide with the physiographic divisions of Missouri, however as can be expected the ecological and natural sub-regions are more diverse and on a smaller in scale. The physiographic regions and subdivisions for Missouri are outlined on the Physiographic Regions Map located in Figure 1.

At their broadest, the physiographic regions located within Missouri include the Central Lowlands subsection of the Interior Plains, Ozark Plateau subsection of the Interior Highlands and the Coastal Plain subsection of the Atlantic Plain. The geologic characteristics within each region are notably different and give each its unique properties. Based on these differences each of these regions are further subdivided into six (6) sub regions which include:

- Interior Plains
  - Central Lowlands
    - Dissected Till Plains
    - Osage Plains
- Interior Highlands
  - Ozark Plateau
    - Salem Plateau
    - Springfield Plateau
    - St. Francois Mountains
- Atlantic Plain
  - Coastal Plain
    - Mississippi Alluvial Plain

The section of this document detailing the major geologic divisions highlights a general geologic and topological description of the area and provides a regional framework for the GNFCS. To help further clarify and distinguish areas within the state which exhibit dissolution weathering, section one also includes a brief summary of the six distinct karst areas in Missouri.

INDIVIDUAL GEOLOGIC FEATURES

For some geologic features such as those in the St. Francois Mountains subsection of the Ozark Plateau, the initial igneous rock forming processes are the controlling factor. In other areas the factor of control is the current geomorphic process such as fluvial erosion or deposition. And yet in others the controlling factor is the tectonic or structural forces that control the types of geologic features.

The heart of Missouri's GNFCS is the classification of individual geologic features. Patterned after the Heritage Conservation and Recreation Service model (Heritage Conservation and Recreation Service, 1978), it is a generic system meaning that geologic features are classified according to the processes that formed them. Since all landforms, geologic relationships, and rock materials result from processes, all geologic features can be accommodated by the system. This does not mean it is general in nature; the original system included only features of a scale suited for designation as state natural areas and that actually exist in Missouri. Since many of the natural areas are large enough to include multiple geologic features additional geologic features have been added to the system. Examples of these additional terms include foot slope, toe slope and epikarst.

Examples are an important part of the definitions/descriptions of individual geologic features. Where possible, examples cited are Missouri natural areas. In a few cases, where no naturally exposed example is known, an artificially exposed site (road cut, quarry face, etc.) is noted. In many cases further description of many of the examples of geologic features can be seen in Geologic Wonders and Curiosities of Missouri (Beverage, 1978).

Of course no classification system of this magnitude is without problems. The major problem, repeatedly encountered, is in classifying features resulting from not one, but a combination of processes. In such cases the feature was assigned to that process critical or most important to its development. In others where multiple processes are equally as important to the formation of the feature a “composite” category was added within the section. An example of this would be an Oxbow Lake, which requires both fluvial erosion and fluvial deposition as part of its formation.

CHECKLISTS

The reference checklists that were a part of the original classification system included a description of the geologic time scale, general bedrock descriptions and localities, and fossil descriptions. Though never a formal part of the classification system, the reference checklists provided an aid in monitoring geologic diversity throughout the MONAC natural area determination process on many of the original sites.

These checklist, originally designed to aid in characterizing the geologic diversity of the natural areas system have been removed from this updated document and the information either discriminated into the other two sections or included as appendices at the end of this document.

CONCLUSION

The Geologic Natural Features Classification System outlined here was adopted for formal use by the Missouri Natural Areas Committee many years ago. It is understood that this classification is not now and probably never will be complete; additions necessitated by oversight will be required from time to time. But the system’s hierarchical framework and open-endedness make it flexible enough to allow for any future modification.

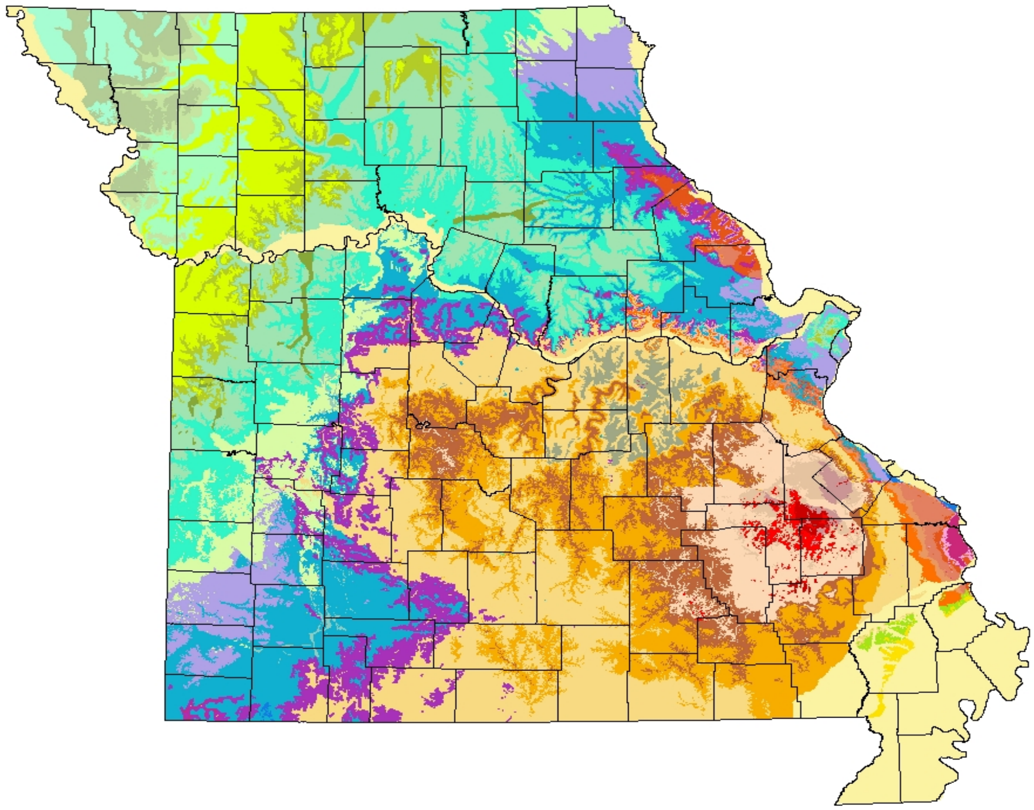

Figure 1. Generalize Geologic Map of Missouri. Source: Missouri Department of Natural Resources

Figure 2a. Outcrop Map of Precambrian Rock Units

Figure 2b. Outcrop Map of Cambrian Rock Units

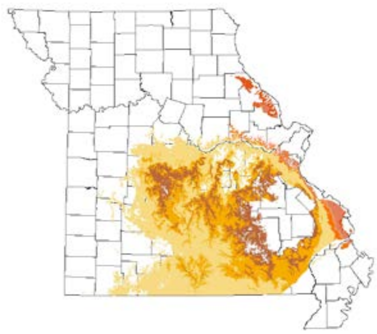

Figure 2c. Outcrop Map of Ordovician Rock Units

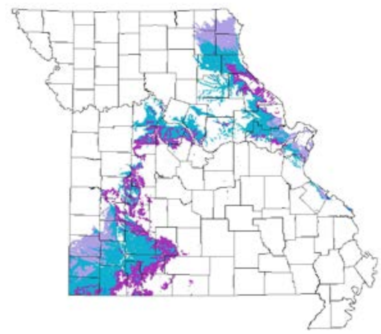

Figure 2d. Outcrop Map of Mississippian Rock Units

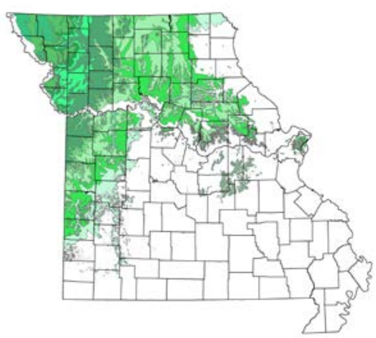

Figure 2e. Outcrop Map of Pennsylvanian Rock Units

Figure 2f. Map of Quaternary Alluvium Deposits

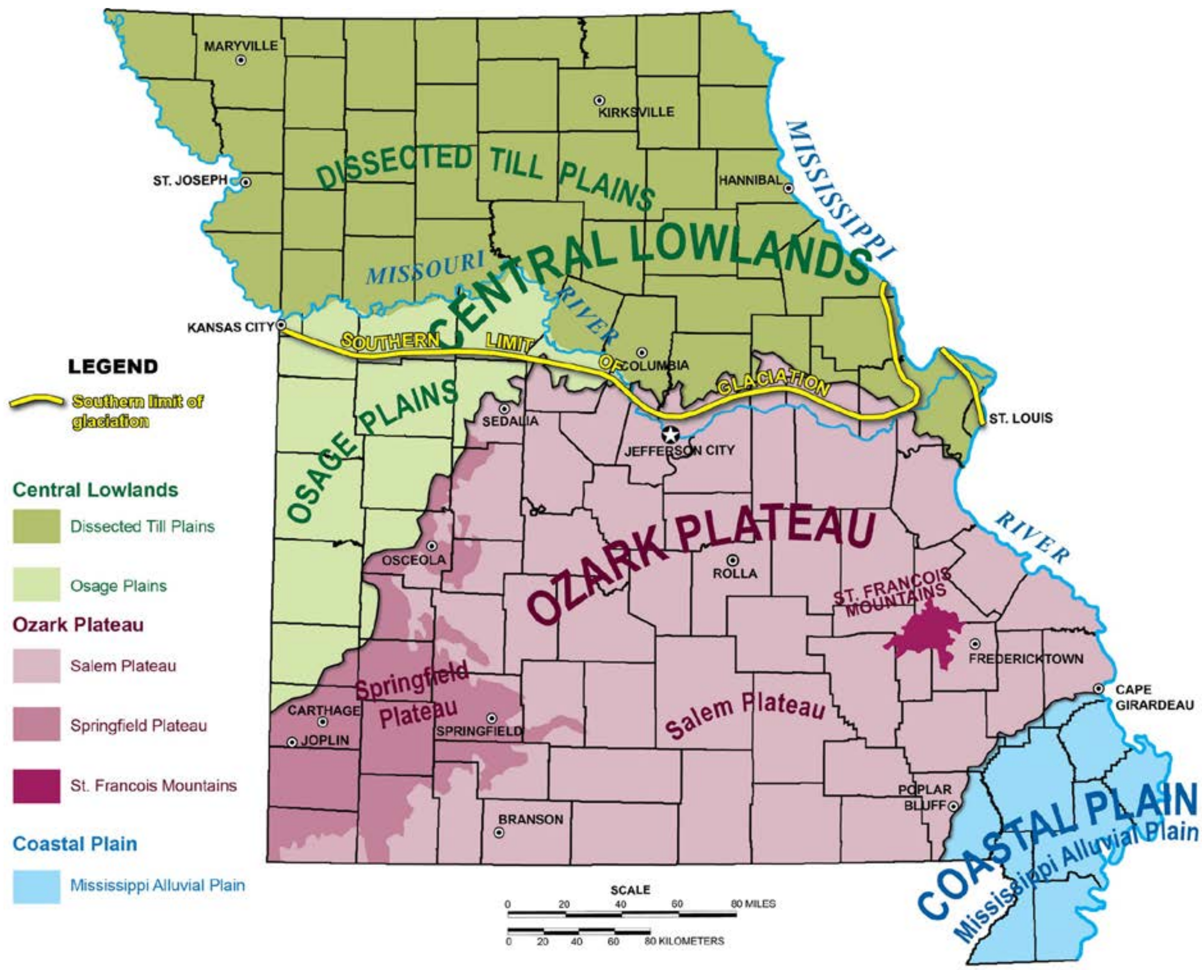

Figure 3. Physiographic Region Map of Missouri. Source: Missouri Department of Natural Resources after Fennemen and Johnson, 1946

MAJOR PHYSIOGRAPHIC REGIONS OF MISSOURI AND CHARACTERISTIC GEOLOGY

The framework of the Geologic Natural Features Classification System is subdivided into five major geologic regions based on the underlying geology. These subdivisions include the **Ozark Plateau**, **Osage Plain**, **Dissected Till Plain**, and **Mississippi Alluvial Plain** regions. The **St. Francois Mountains** subsection of the **Ozark Plateau** is recognized as a separate major geologic region for the purpose of this classification system due to the fact that it is one of the few igneous-rock terranes in the southern midcontinent.

Interior Plains – Central Lowlands

The Central Lowlands in Missouri consist of two sub-regions, the Osage Plain and Dissected Till Plains.

The Osage Plain covers west central Missouri, east central Kansas and central Oklahoma. In Missouri these unglaciated plains are underlain by Carboniferous-age Pennsylvanian cyclothems and Mississippian shallow marine limestones with broad gently rolling topography.

The Dissected Till Plains covers the north central portion of the country from Missouri to Minnesota. In Missouri, the physiographic region is located north of the Missouri River stretching from St. Louis to Kansas City. Along the Mississippi River and the Lincoln Fold, this region is underlain by Ordovician-age bedrock units, however the units quickly transition to carboniferous age as the bedrock dips towards the Forest City Basin in Northwestern Missouri.

A. Osage Plain

a. Gently rolling plain: broad valleys and low relief developed on Pennsylvanian-age shale, sandstone, and limestone. (Prairie State Park area, Barton County)

b. Moderately dissected plains: characterized by development of knobs/mounds; Pennsylvanian-age bedrock.

B. Dissected Till Plains

a. Moderately dissected glacial till plain: characterized by rolling hills and moderate relief. (Much of northern Missouri; Dark Hollow Natural Area, Sullivan County)

b. Undissected glacial till plain: areas of little relief developed on undissected plain interfluves between major drainage systems. (Chariton River Hills Natural Area, Macon County)

c. Moderately dissected glacial till plain with thick loess cover. (McCormack Loess Mounds Natural Area, Holt County)

d. Moderately to intricately dissected plains: uplifted Paleozoic strata along the Lincoln Fold with little or no till/loess cover: characterized by moderate to high relief, abundant bedrock exposures, and locally developed karst (Lincoln Hills Natural Area, Lincoln County)

Interior Highlands – Ozark Plateau

The Ozark Plateau is an asymmetrical dome with an uplifted core centered around the Mesoproterozoic porphyries and granites of the St. Francois Mountains. The eastern side of the dome drops steeply into the nearby Illinois Basin while the northern and western sides slowly drop until overlain by the Pennsylvanian-age bedrock units of the Osage Plain and Dissected Till Plains. The Ozark Plateau is underlain by Cambrian-, Ordovician-, and Mississippian-age sandstone and carbonate bedrock units with the oldest units nearest the igneous core and radiating younger bedrock units outwards.

A. Salem Plateau

a. Dissected Salem Plateau: deeply and intricately dissected plateau, mostly Cambrian- and Ordovician-age cherty dolomite bedrock; area characterized by rugged hills with steep slopes and high local relief; sinkholes and karst features locally common. (Most of the central Ozarks; Ozark National Scenic Riverways, Shannon and Carter counties)

b. Undissected Salem Plateau: gently rolling upland plains with undissected plateau interfluves between major drainage systems; Mostly Ordovician-age dolomite and sandstone bedrock; sinkholes and karst features locally common. (Quescus Flatwoods Natural Area, Texas County)

c. Moderately dissected segment of Salem Plateau: masked by loess or glacial deposits; typically along border areas; Karst features locally prominent. (Apple Creek Conservation Area, Cape Girardeau County)

B. Springfield Plateau

a. Dissected Springfield Plateau: moderately to intricately dissected plateau, mostly cherty Mississippian-age limestone bedrock; area characterized by deep rugged valleys separated by rolling upland areas; karst features locally common. (Roaring River State Park, Barry County)

b. Undissected Springfield Plateau: gently rolling upland plains with undissected plateau interfluves between major drainage systems. (Mount Vernon and Linden's Prairie Natural Area, Lawrence County)

C. St. Francois Mountains (including the Precambrian outcrop area of Shannon County)

The St. Francois Mountains are an ancient volcanic complex dating back to between 1.5 to 1.2 billion years old. They are the largest exposure of Mesoproterozoic (Precambrian) aged rocks located in the mid-continent region. The mountains are series of exposed knobs that create part of the core of the Ozark Plateau. The chronological history of the St. Francois Mountains is of multiple sequences of large volcanic eruptions, with gaps of as much as 100 million years between major episodes. Most of the volcanic rocks are rhyolite flows or tuffs. After extrusion of the molten materials onto the surface, the volcanoes collapsed back into the emptied magma chambers, thus creating one of the five calderas (Day et al,. 2016). Intrusive rocks, primarily granites with some minor mafic rocks, later intruded the complex. When we look at the St. Francois Mountains today, we are looking not at the large volcanic complex that was once there, but rather the exhumed highly eroded core of that complex.

The St. Francois Mountains Subsection covers several thousand square miles in an area roughly 30 by 50 miles. It is centered in northeast Iron County and crosses over into adjacent Washington, St. Francois, Madison and Reynolds counties (Figure 2). The actual extent of igneous exposures is approximately 560 square miles. Additional localized areas of igneous rocks occur in portions of Shannon and Carter counties along the Current River and in several locations of Wayne and southern Iron counties as well.

A. Rugged, highly dissected roots of ancient mountains: characterized by rounded igneous knobs, hills, and high local relief. (Royal Gorge Natural Area, Taum Sauk-Russell-Hogan Mountain area, Iron County)

B. Gently rolling inter-montane valleys developed on sedimentary rock. (Arcadia Valley, Iron County)

C. Rolling granite hills with relatively low relief. (Silvermines National Forest Recreational Area, Madison County)

Coastal Plain – Mississippi Alluvial Plain

The Mississippi Alluvial Plain, often called the Mississippi Embayment, is a broad arm of the Atlantic Coastal Plain that extends up the valley of the Mississippi River to approximately Commerce and includes the area locally referred to as the "Bootheel" of Missouri. The alluvial plain is broad, flat and slopes gently towards the south. Considered part of the failed Reelfoot Rift the Paleozoic bedrock units forms a downwarped synform structure with Cenozoic and Mesozoic sediments filling in the resulting trough and quaternary sediments of the Ohio and Mississippi rivers overtop. The north and west portion of the alluvial plain are demarcated by the rapid slope changes associated with the Ozark Escarpment. Two prominent features, Benton Hills and Crowley's Ridge, once separated the ancestral Mississippi and Ohio rivers prior to the stream piracies of Bell City Cutoff and Thebe's Gap and are considered erosional remnants of the Ozark Plateau.

A. **Alluvial Plains**: nearly flat broad plain developed on alluvial deposits; no consolidated sediments. (Drainage has been greatly modified through construction of canals and drainage ditches). (Big Oak Tree Natural Area, Mississippi County)

B. **Crowley's Ridge**: Moderately dissected erosional remnant ridges: Paleozoic, Cretaceous, and Tertiary bedrock; moderate relief and locally rugged; Portions are likely erosional remnant isolated from the Salem Plateau which may or may not be structurally controlled. (Benton Hills Area, Scott County; Holly Ridge Natural Area, Stoddard counties)

KARST REGIONS OF MISSOURI

Approximately two-thirds of Missouri is underlain by carbonate bedrock such as limestone and dolomite. When these types of bedrock units are located at or near the surface they are prone to dissolution into groundwater, creating features such as sinkholes, caves, springs, and losing streams, which slowly begin to dominate the landscape. This terrane, called "Karst" can best be characterized as a landscape with discreet recharge and minimal surface water flow. In Missouri, karst terrane development can be divided into 6 distinct primary regions (figure 4) based on the underlying bedrock formations and the way in which the karst features developed.

A. **Salem Plateau Region** – Deep groundwater circulation (phreatic), primarily developed in Lower Ordovician- (Roubidoux Formation and Gasconade Dolomite) and Upper Cambrian- (Eminence and Potosi dolomite) age bedrock units, large springs and associated recharge areas.
B. **Springfield Plateau Region** – Shallow groundwater circulation (meteoric), developed in Mississippian-age bedrock units (Burlington, Keokuk, and Reeds Spring formations), mid-sized to small springs.
C. **Central Missouri Region** – Area draped with glacial till which partially covers karst features, shallow groundwater circulation (meteoric), developed in Mississippian-age bedrock units (Burlington and Keokuk formation), mid-sized to small springs.
D. **Northeast Missouri Region** – Shallow groundwater circulation (meteoric), developed in Mississippian- (Burlington, Keokuk, and Warsaw formations) and Ordovician- (Kimmswick Formation and Plattin Group) age bedrock units, mid-sized small springs. Karst development in the confined Louisiana Limestone likely originated from deeper (phreatic) groundwater movement related to the nearby Lincoln Fold.
E. **St. Louis Region** - Shallow groundwater circulation (meteoric), developed in Mississippian-age bedrock units (St. Louis and Salem formation), small springs.
F. **Southeast Missouri Region** – Shallow groundwater circulation (meteoric), developed in Mississippian- (Ste. Genevieve and St. Louis formation) and Ordovician- (Joachim and Kimmswick formations, and Plattin Group) age bedrock units, mid-sized to small springs.

Three of these regions (Salem and Springfield Plateau and Southeast Missouri) developed on the unglaciated Ozark Plateau. The Northeast Missouri karst regions is a buried karst terrane which was located under ice as recently as 20,000 years ago. The St. Louis and Central Missouri regions are also historical (buried) karst terranes located near the periglacial boundary. These latter three karst areas have only been revealed and rejuvenated with the erosion and removal of the overlying glacial till and loess deposits.

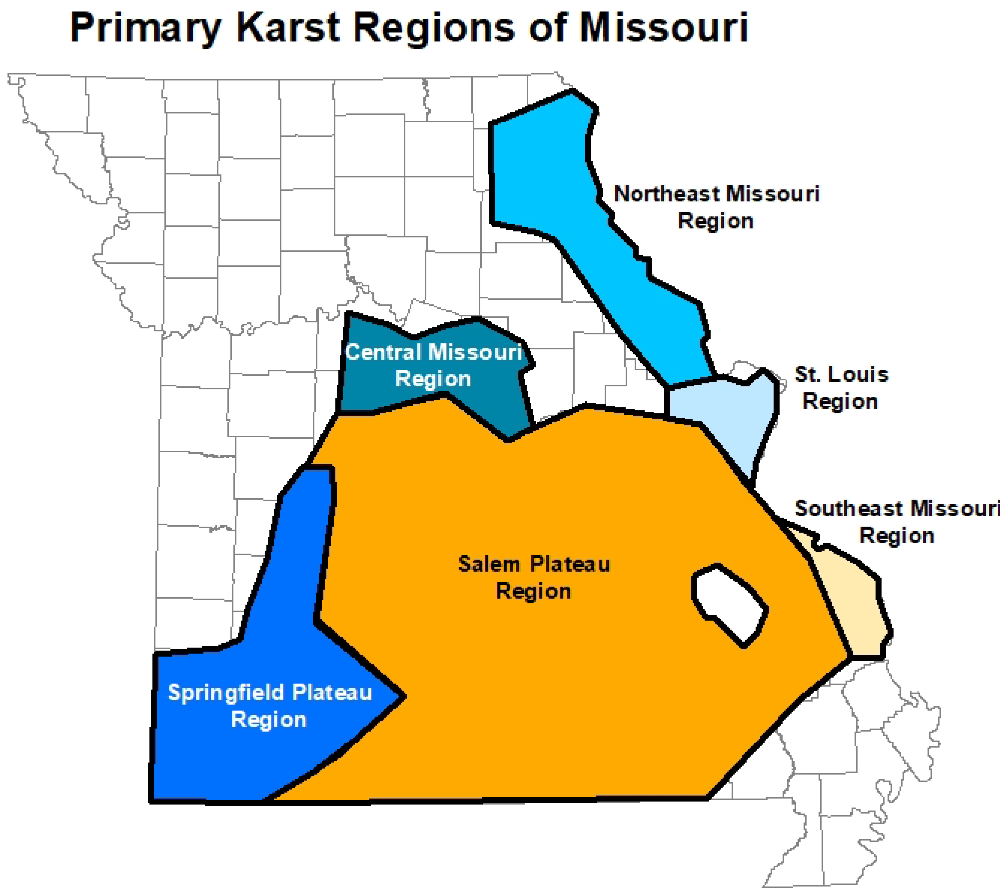

Figure 4. Map illustrating the primary karst regions of Missouri, Source: Missouri Department of Natural Resources.

INDIVIDUAL GEOLOGIC FEATURES OF MISSOURI

I. Fluvial (stream-related) Features

A. Erosional

1. **Canyon/Gorge**: A long, deep, relatively narrow, steep-sided, uppermost part of a valley confined between lofty and precipitous walls in a plateau or mountainous region, often with a stream at bottom and the result of head-ward erosion; similar to, but larger than a gorge. Stream down-cutting exceeds weathering
   a. Volcanic-rock canyon (Prairie Hollow Gorge, Shannon County)
   b. Granite canyon
   c. Dolomite canyon (Barn Hollow, Texas County)
   d. Limestone canyon (Turkey Creek, Boone County)
   e. Sandstone canyon (Pickle Springs Canyon, Ste. Genevieve County)
   f. Conglomerate canyon (Earthquake Hollow, Callaway County)
   g. Shale canyon
   h. Chert canyon
   i. Loess canyon

2. **Shut-In**: a narrow, steep-sided gorge along the course of an otherwise wide stream valley; characteristically located where the stream was forced to cut through a hard, resistant rock mass. In the case with the Thomasville Narrow, Oregon County, the resistant landmass can be the upthrown side of fault.
   a. Volcanic-rock shut-in (Johnson's Shut-ins, Reynolds County)
   b. Granite shut-in (Silver Mine Shut-in and Tiemann Shut-ins, Madison County)
   c. Sedimentary-rock shut-in (Wildcat Park, Newton County; Thebes Gap, Scott County). In the case of the Eleven-point River, (Thomasville Narrows, Oregon County) the resistant landmass likely emplaced by the up thrown side of faulting.

3. **Entrenched Meander**: an incised deepened stream meander, carved vertically downward into the surface on which it the meander was first originally formed; the down cutting initiated by rejuvenation due to either rapid uplift of the original meandering stream or lowering of base level. (Gasconade and Osage rivers, Central Missouri; White River, Southwest Missouri; many other Ozark rivers)

4. **Abandoned Meander Valley**: an entrenched meander that has been abandoned by its stream as a result of a neck cutoff (a breach of the Meander neck). (Rich Fountain abandoned meander loop, Osage County)

5. **Lost Hill**: an isolated hill formed by the cutoff of an entrenched meander; a prominent meander core. (Pine Hill, Bryant Creek, Ozark County; Lost Hill, Stoddard County; Lost Hill near Rich Fountain, Osage, County)

6. **Narrows**: a steep ridge or neck of land formed between two closely parallel streams or between the two limbs of an entrenched meander. (The Narrows, Big Piney River, Texas County; The Pinnacles, Boone County)

7. **Cut Bank**: Steep bare slope formed by the lateral extension of a stream. The result of water movement along the outer curve in a river bend. Characterized by a crescentic cut in a steam bank, bluff or valley wall, produced by a meandering stream.

8. **Stream Terrace:** (bedrock) (bench) an erosional stream terrace developed in bedrock; formed by differential erosion in rocks of varying resistance or by a change of base-level erosion. (along James River, Stone County)

9. **Island:** (Bedrock) a river island formed of bedrock. (Tower Rock, Mississippi River, Perry County) (Figure 5)

Figure 5. Bedrock Island (Tower Rock) at Tower Rock Natural Area, Perry County, Missouri. Photograph by Larry "Boot" Pierce

10. **Waterfall**: a perpendicular or very steep unsupported descent of the water of a stream.
    a. Resistant-ledge waterfall: stream drops over a hard, resistant ledge of rock. (Grand falls on Shoal Creek, Newton County; Spring Valley Falls, Laclede County; Falls Branch Falls, Perry County)
    b. Tectonic waterfall: stream drops into an enlarged fault- or joint-related crevice. (falls on Long Creek, Taney County)
    c. Wet-weather cataract: runoff water plummets over a precipice. (Mina Sauk Falls, Iron County)
    d. Solution-collapse waterfall: stream drops into a collapse sinkhole, collapse canyon, or cave. (falls at River Cave swallow hole, Ha Ha Tonka State Park, Camden County)

11. **Cliff of Bluff**: a high, very steep, vertical to overhanging face of rock.
    a. Volcanic-rock cliff (along Little St Francis River, Madison County)
    b. Granite cliff
    c. Rhyolite cliff (The Pinnacles, Little St. Francois River, Madison, County)
    d. Dolomite cliff (Jam Up Cave Bluff, Jacks Fork River, Shannon County; Red Bluff, Huzzah Creek, Crawford County)
    e. Limestone cliff (at Rocheport, Missouri River, Boone County; The Palisades, Meramec River, St. Louis County)
    f. Sandstone cliff (along River aux Vases, Ste. Genevieve County)
    g. Conglomerate cliff (Lover's Leap, Fulton area, Callaway County)
    h. Chert cliff (Eleven Point River, Oregon County)
    i. Shale cliff (Elk River overhanging bluffs, McDonald County)
    j. Loess cliff (St. Joseph area, Missouri River, Buchanan County)

12. **Hill, Knob, or Mound**: a natural elevation of the land surface, rising rather prominently above the surrounding land, usually of limited extent, and a well-defined outline, rounded rather than peaked or rugged.
    a. Volcanic-rock knob (southeast peak of Buford Mountain, Iron County)
    b. Granite knob (Breadtray Mountain, St. Francois County)
    c. Sedimentary rock knob/mound (Bird Hill, near Perkins, Scott County; White River Balds, Taney, County)
    d. Loess hills/mounds: rounded, mound like hills of loess (near Squaw Creek Wildlife Refuge, Holt County)

13. **Monadnock**: an isolated sedimentary-rock mound standing prominently above an erosional plain; a remnant of a former, higher land mass. (Caney Mountain, Ozark County; Blue Mount, Vernon County; Bird Hill, near Perkins, Scott County)

14. **Paleo-Topography**: the landforms of earlier geologic time periods buried beneath subsequently deposited rock strata and now exhumed by weathering and erosion or exposed in cuts.
    a. Paleo-hill: an ancient hill buried beneath younger rock strata. (buried Precambrian knob – 500+ million years old, power plant cut, Taum Sauk Power Project, Reynolds County)
    b. Paleo-valley/channel: an ancient valley or stream channel buried beneath younger rock strata. (boulder-filled Precambrian valley – 500+ million years old, road cut on State Highway 72, 7.2 km west of Fredericktown, Madison County; sandstone-filled Pennsylvanian-age channel–300 million years old, near Warrensburg, Johnson County)

B. Depositional

1. **Point Bar**: a crescent-shaped accumulation of sand and/or gravel deposited on the inside of a stream meander. Associated with cut bank which is the outside and erosional portion of the stream meander. (virtually every river in Missouri)

2. **Natural Levee**: a broad, low embankment of sand and coarse silt built up along both banks of a stream channel during times of flood; upper surface slopes gently away from the stream. (Locust Creek, Pershing State Park, Linn County)

3. **Alluvial Fan**: A broad fan shaped mass of alluvium deposited due the loss of stream flow velocity. The velocity loss results in deposition from stream competency reduction. Most often observed where a slope change (reduction) is present such as an escarpment or low order stream flows into higher order stream valley. (Several locations along Crowley's Ridge, Stoddard County; Common throughout the Ozarks, however often very subtle; Carter Creek confluence with Meramec River, Crawford County)

4. **Alluvial Fill**: A deposit of alluvium occupying a stream valley, conspicuously thicker than the depth of the stream. An indication of several depositional cycles. (Missouri or Mississippi rivers)

C. Composite

1. **Meander**: one of a series of sinuous curves, bends, loops, turns, or windings in the channel of a river, stream, or other watercourse developed on a flood plain. (upper Missouri River; lower Mississippi River)

2. **Abandoned/Cutoff Meander**: a meander that is no longer connected to its original stream or source of flow. (Salt River Floodplain, Ted Shanks Wildlife Management Area, Pike County; West channel of Upper Mississippi River State Wildlife Area, Pike County)

3. **Meander Scar**: an abandoned meander in which the abandoned channel no longer hold water. (Grand Pass Conservation Area, Saline County)

4. **Oxbow Lake**: an abandoned meander with water filled channel. (Big Lake State Park, Holt County; Sunshine Lake, Ray, County)

5. **Yazoo Stream**: A stream that runs essentially parallel to and within the floodplain of a larger stream. A natural Yazoo stream is forced to run along natural levees, However many of these streams are created when man-made levees are constructed. (Old Chariton River channel, Chariton, County; Wakanda Creek, Carroll, County)

6. **Stream Terrace**: (alluvial) a stream terrace composed of unconsolidated alluvium; the terrace is a remnant of an abandoned flood plain developed by the stream during a former stage of alluvial deposition. (Missouri River, St. Charles County)

7. **Island**: (Alluvial) a river island formed of alluvium. (Pelican Island, Missouri River, St. Louis County)

8. **Braided Stream Channel**: a stream channel characterized by an intricate network of smaller interlacing channels that repeatedly merge and separate.

9. **Narrow Flood Plain**: bounded marginally by bluffs or steep hillslopes cut into resistant rock strata: relatively straight or gently curving river segments. (Klondike-St. Albans area, St. Charles and Franklin counties)

10. **Wide Flood Plain**: bounded marginally by hills or bluffs: characterized by meandering streams (where not channelized), meander scars, oxbow lakes, etc. (Big Lake State Park area, Holt County)

11. **Broad Flood Plain**: no significant marginal boundaries-blends into, and is actually part of, adjacent alluvial plain: characterized by extremely broad large-scale meanders and meander scars, large oxbow lakes, etc. (New Madrid Floodway area, near Big Oak Tree State Park, Mississippi and New Madrid counties)

II. Residual Features

A. Erosional

1. **Residuum**: sequence of residual clay and rock debris (soils) formed and resting on consolidated rock from which it formed. Illustrating the character and process of in-place weathering. (anywhere in the Ozarks)

2. **Glade**: a rocky hillslope or ridgetop area with a very thin, residual (weathered-in-place) soil cover. (Figure 6)
    a. Volcanic-rock barren (Royal Gorge barren, Iron County; Hughes Mountain, Washington County)
    b. Granite barren (Breadtray Mountain, St. Francois County)
    c. Rhyolite Glade (Hughes Mountain, Washington County)
    d. Dolomite glade (Red Sink Glade, Ha Ha Tonka State Park, Camden County; Victoria Glade, Jefferson County)
    e. Limestone glade (Wolfpen Gap, Barry County)
    f. Sandstone glade (Channel Sand Glade, Lawrence County)
    g. Chert glade (Wildcat Park, Jasper County)
    h. Shale glade (Salt River area, Pike County)

3. **Pinnacle**: (related erosional landform) a relatively tall and slender, isolated, erosional pillar of rock standing prominently above its surroundings.
    a. Volcanic-rock pinnacle (The Pinnacles, Little St. Francis River, Madison County)
    b. Dolomite pinnacle (Chimney Rock, Rock Pile Mountain area, Madison County)
    c. Limestone Pinnacles (Chimney Rock, Boone County)
    d. Sandstone Pinnacle

e. Conglomerate Pinnacle (Earthquake Hollow, Callaway County)

4. **Granite Tor**: a group of spheroidal weathered, residual, granite boulders, underlain by massive granite bedrock; formed by prolonged groundwater weathering along block joints, followed by erosional stripping of the decayed rock material (grus) (Elephant Rocks State Park, Iron County) (Figure 7)

Figure 6. Sandstone Glade in St. Francois County. Photograph by Paul Nelson

5. **Hoodoo:** (Sandstone) castellated or beehive-shaped prominences resulting from differential weathering of (often cross bedded) sandstone. (Pickle Creek area, Ste. Genevieve County; Chimney Rocks, Ste. Genevieve County; Castle Rock, Madison County)

6. **Blossom Rock**: Sandstone formation that appears to "Blossom" out of the surrounding weathered carbonate formations. Originally proposed by Lee, (1913) as cave formations, the modern consensus is that these Blossom rocks represent sandstone infillings of sinkholes on a paleo karst surface. Ultimately, they are more resistant to weathering that the surrounding carbonate bedrock and thus remain as remnant outliers. Often associated with terrestrial clays and coal which were also deposited in the sinkholes. (Lane Springs Recreational Area, Mark Twain National Forest, Phelps County)

7. **Loess Badland**: an erosional landform characterized by sharp pinnacles, ridges, and spires developed in intricately gullied, unconsolidated loess. (Loess Badlands, Howard County)

8. **Shelter or Overhang**: (erosional) any of several shelter-like features, usually formed in sandstone, predominantly by differential weathering processes. In some cases stream erosion and, to a lesser extent, solution activity may be

involved. (Shelter Valley Overhanging Bluffs, Jefferson County; Devils Den Hollow, Warren County)

9. **Arch or bridge**: (Erosional) a natural arch or bridge, usually formed in stone, predominantly by differential weathering processes. In some cases stream erosion and, to a lesser extent, solution activity may be involved. (Pickle Creek area, Ste. Genevieve County; Cliffdale Hollow Natural Bridge, Jefferson County; Haynie Branch Natural Bridges, St. Clair County)

Figure 7. Granite Tors from Elephant Rock State Park, Iron County, Missouri. Photograph by Larry "Boot" Pierce

III. Solutional/Groundwater

A. Erosional

1. **Cave**: (Solution) A natural underground open space large enough for a person to enter and extending to darkness. Often open to surface. Most commonly associated with subterranean voids formed in carbonate rock strata by groundwater solution.
   a. Linear cave: a simple cave consisting predominantly of a single, usually joint-determined passageway.
      i. in dolomite (Corral Cave, Washington County)
      ii. in limestone (Flutestone Cave, McDonald County)
   b. Network cave: a cave characterized by a grid of intersecting, usually joint-determined passageways; may be simple to complex.

        i. in dolomite (Powder Mill Creek Cave, Shannon County; Carroll Cave, Camden County)
        ii. in limestone (Turnback Cave, Lawrence County)
    c. Maze cave: a very complex, intricately patterned network cave formed in intensely jointed (shattered) bedrock.
        i. in dolomite
        ii. in limestone (Cameron Cave, Marion County)
    d. Karst plain cave system: a complex cave system immediately underlying and directly interacting with a well-developed sinkhole plain.
        i. in dolomite (Crevice Cave, Perry County)
        ii. in limestone
    e. Pit cave: cave with great vertical extent; may have limited horizontal development.
        i. in dolomite (Coffman Cave, Laclede County)
        ii. in limestone (Bonacker Pit, Jefferson County; Crankshaft Pit, Jefferson County)
    f. Nonconformity cave: a cave developed along an igneous/sedimentary rock interface. (Cardareva Schoolhouse Cave, Shannon County)

2. **Sinkhole**: a surface depression formed by either collapse of an underlying cave or dissolution of surficial carbonate strata and vertical migration of the overlying surficial materials downward.
    a. Collapse sinkhole: steep-sided; usually with exposed bedrock. (Slaughter Sink, Pulaski County)
    b. Doline: broad shallow sink; often mantled with residual soil or loess. (west-central Oregon County)
    c. Sinkhole pond: water-filled doline. (Tupelo Gum Pond, Oregon County; Horseshoe Pond, Laclede County)
    d. Sinkhole plain: an upland plain characterized by a profusion of sinkholes. (North St. Louis Karst Plain, Sinks Road, St. Louis County)
    e. Karst valley: a large, elongate, closed depression formed by the coalescence of several sinkholes. (The Sunklands, Shannon County)
    f. Collapse canyon: a large, steep-walled gorge formed by collapse of a cave system. (Ha Ha Tonka Gorge, Camden County; Grand Gulf, Oregon County)
    g. Karst window: an unroofed cave, at the bottom of which can be seen a subterranean stream. (Saunders Valley Karst Window, Christian County; Jam Up Cave Karst Window, Shannon County; St. Joseph Karst Window, Perry County)
    h. Swallow hole: a sinkhole into which a surface stream flows. (upper entrance pit, River Cave, Ha Ha Tonka State Park, Camden County; Saunders Valley Swallow Hole, Christian County)

3. **Spring**: a place where groundwater flows or seeps naturally onto the land surface or into a body of water. Springs are present throughout the state of Missouri, but according to Vineyard & Feder, (1974) are most prominent on the Salem Plateau and Springfield Plateau subsections of the Ozark Plateau.

a. Phreatic (deep-seated) spring: large recharge area; developed by water circulating deep beneath the water table. (Figure 8) (Blue Spring, Current River, Shannon County; Ha Ha Tonka Spring, Camden County; Greer Spring, Oregon County)
b. Meteoric (shallow-seated) spring: small recharge area; developed by water circulating in the unsaturated zone or near the water table. (most small springs in Missouri; Blue Spring near Bourbon, Crawford County)
c. Bedding-plane seepage spring: vadose spring that seeps out, over a significant lateral distance, through a bedding plane.
d. Ebb and flow spring: discharge has a periodic flow variation due to siphoning or flushing of sediment plug. (Rymer Spring, Shannon County)
e. Resurgence: a spring rising from a cave, the water having entered the cave as a sinking stream. (Blue Spring, Christian County)
f. Mineralized spring: a spring containing enough dissolved mineral matter to give it a definite taste. (Blue Spring, Pettis County; Boone's Lick Spring, Howard County)

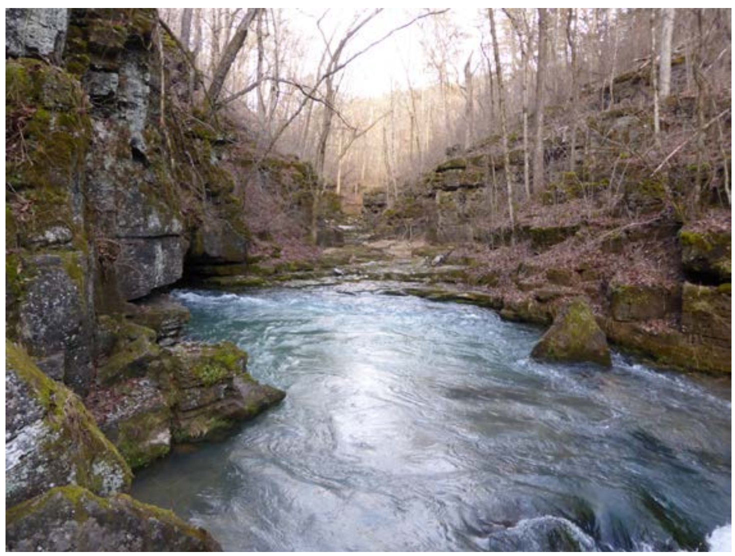

Figure 8. Greer Spring, Mark Twain National Forest, Oregon County. Photograph by Bill Duley and Cecil Boswell

4. **Fen**: A wetland that is sourced primarily by alkaline or neutral pH groundwater. They are located either at or near the water table (primary or perched) and may fluctuate depending on climatic conditions. Groundwater sources may vary from saturated aquifer, alluviated springs, localized springs or seeps located above confining layers, and perched waters located above fragipan or hardpan layers. (Grasshopper Hollow, Reynolds, County)

5. **Estavella**: A surface feature that either recharges or discharges groundwater depending on the level of the water table or potentiometric surface. See also Swallow Hole/Spring (Ball Mill Resurgence, Perry County)

6. **Natural tunnel/Bridge/Arch**: a tunnel or similar feature formed primarily as a result of solution activity; usually in limestone or dolomite.
    a. Lateral piracy origin: a stream uses a cutoff, usually a small cave or fissure, through a narrow ridge of rock to shorten its channel; the tunnel segment is then enlarged. (Clifty Hollow Natural Bridge, Maries County; The Sinks, Shannon County)
    b. Subterranean piracy origin: a surface stream cuts into the roof of a cave and is pirated underground; the tunnel is enlarged. (Jam Up Cave, Shannon County)
    c. Roof remnant of collapsed cave: segments of a cave roof collapse; an uncollapsed segment remains as a natural tunnel. (Ha Ha Tonka Natural Bridge, Camden County; bridge in Grand Gulf, Oregon County)
    d. Slice arch: a tunnel or arch is formed by solution enlargement of a joint that is usually adjacent and parallel to the face of a bluff or cliff. (Hootentown Arch, Stone County; Leatherwood Natural Arch, Shannon County)

7. **Epikarst**: The uppermost, near surface zone of solution weathering which may or may not be covered by surficial materials

8. **Karst Complex**: A collection of several karst features exhibited at one site or across one geographic area all with similar genesis and characteristics. (Ha Ha Tonka State Park, Camden County; Grand Gulf, Oregon County; Rockbridge State Park, Boone County)

9. **Pinnacle**: (solution) Formed by solution weathering of a carbonate-rock surface. (Springfield area, Greene County)

10. **Solution Enlarged Joint**: (aka. Cutter or Lapies) A joint in carbonated bedrock that is actively increasing in size due to the migration of fluids.

11. **Losing Stream**: Also referred to as Influent Stream, a steam in which surface waters contribute flow into subsurface zone of saturation through permeability within the stream bed. (Bear Creek, northeast corner of Laclede County)

12. **Abandoned Spring Conduit**: A spring conduit that has been abandoned either naturally by sediment infill or man-made through flow diversion.

13. **Chocked Spring Conduit**: An old spring conduit filled with gravel. (Bennett Spring area, Dallas County)

14. **Groundwater features: (paleontological)**
    a. Fossil-rich cave- or sink-fill: fossil bones accumulated in a cave or sinkhole-trap.) (Devils Hole, Barry County; Zoo Cave, Taney County)
    b. Fossil-rich spring/marsh: (Boney Spring, Hickory County-now flooded by Truman Reservoir; Mastodon State Park, Jefferson County)
    c. Fossil-rich fen (bog): fossil bones accumulated in the clay and gravel deposits associated with an old spring-bog or fen)

15. **Paleo-Karst**: Ancient karst feature infilled and buried beneath younger sedimentary rocks; often depicts an unconformable surface within the geologic sequence.

    a. Sandstone-filled sinkhole; exhumed examples often have topographic expression. See Blossom Rock. (Blossom Rock, Lane Spring Recreation Area, Phelps County)

    b. Clay-/shale-/coal-filled sinks. (Schaefferkotter Clay Pit, Gasconade County)

B. Depositional

1. **Surface Deposits**:
    a. Tufa deposits: Freshwater hard crystalline calcium carbonate deposits precipitated from meteogene or thermogene groundwater by a combination of biological and physio-chemical processes (Ford and Pedley, 1996). Deposits contain macrophytes and organic matter and often observed on bluffs below groundwater seep, adjacent to a spring orifice or below fens. (Tufa Creek, Shannon County; Shut-in Fen Preserve, Shannon County)
    b. Travertine deposit: freshwater hard crystalline calcium carbonate deposits precipitated from meteogene or thermogene groundwater by physio-chemical processes and typically void of macrophyte or organic materials. Typically found adjacent to a spring orifices.

2. **Subsurface Deposits**: As these deposits are internal features of caves, they would necessarily have to be designated in conjunction with a solution cave.
    a. Speleothems: display of secondary mineral deposits illustrating the various mechanisms of precipitation and the diversity of speleothem forms. (Powder Mill Creek Cave, Shannon County; Onondaga Cave, Crawford County)
    b. Detrital fill: sequence of clay and/or gravel fills illustrating the materials, processes, and significance of cave sediments.

IV. Gravity (mass-wasting) Features

A. Erosional

1. **Escarpment**: A long steep slope produced by mass wasting, faulting or erosion of a resistant bedrock layer that typically faces a general direction and breaks the continuity of two gentler sloping sections of land. (Ozark Escarpment, Southeast Missouri; Eureka Springs Escarpment, Southwest Missouri)

2. **Scarp**: Shortened version of "Escarpment" however, the term is most commonly used in relation to faulting or mass wasting.

B. Depositional

1. **Foot Slope**: Area of reduced gradient located at the base of a hillslope created as unconsolidated colluvium materials are deposited. Material can vary from gravels to fines and movement is predominantly via gravity as downslope creep in combination with assistance from non-channelized water flow (sheet flow).

2. **Toe Slope**: Area located beyond the foot slope, typically with gentle gradient and consisting of finer materials than the adjacent foot slope. Due to the reduced gradient the finer materials of the toe slope likely receive greater assistance in movement from non-channelized water flow (sheet flow).

C. Composite

1. **Talus Slope or Apron**: a steep slope at the base of a cliff formed, usually over a period of time, from an accumulation of loose rock fragments.
   a. Igneous-rock talus slope (East Fork of Black River, south of Johnson's Shut-ins, Reynolds County)
   b. Granite talus slope
   c. Dolomite talus slope (Vilander Bluff, Crawford County)
   d. Limestone talus slope
   e. Sandstone talus slope
2. **Rock Fall**: a sizeable mass of fallen bedrock heaped at the base of a precipitous cliff-face; it is inferred that it represents a single detached mass and was relatively free-falling. (Waynesville rock fall, Gasconade River, Pulaski County)
3. **Rockslide/Debris Slide**: a large, broken, and jumbled mass of bedrock or soil and rock debris that slid rapidly downward along a plane of weakness, usually a bedding-, joint-, or fault-plane. (Riverside Slide, North Kansas City, Clay County)
4. **Slump**: a detached mass of bedrock or other surficial material that slowly moved downward and out as a single mass; the mass characteristically shows a backward rotation-the upper surface tilts back away from the direction of movement.
5. **Creep**: The slow more of less continuous downslope movement of rocks and soil particles due to gravitational stress.

V. Glacial Features

A. Erosional

1. **Glacial Striations**: grooves cut into bedrock by moving glacial ice. (in St. Joseph area-see Todd 1896)

B. Depositional

1. **Glacial Erratic**: a large boulder moved south by glacial ice. (Figure 9) (Bairdstown Church Erratic, Sullivan County)

2. **Drift**: sequence of till and/or outwash deposits illustrating the materials and mechanisms of continental glaciation as it pertains to Missouri.

Figure 9. Glacial Erratic in Sullivan County, Missouri. Photograph by Larry “Boot” Pierce

VI. Eolian (wind-related) Features

A. Depositional

1. **Sand Dune**: A collection of loose sand heaped upwards by wind. Sand dunes in Missouri are typically associated with large river valleys and developed during the dryer periods of glacial advance during the Pleistocene. (Ash Hills, Butler County)

2. **Loess Series**: sequence of loess beds and intervening paleosols (fossil soils) illustrating the materials, mechanisms, and environments of eolian deposition during the Pleistocene. (Figure 10)

Figure 10. Windblown loess deposited over glacial till. Lincoln County, Missouri. Photograph by Larry "Boot" Pierce

VII. Ocean Features

A. Depositional

1. **Sedimentary Strata**: sequence of sedimentary beds illustrating geologic events, the variety of sedimentary rock types, or the diversity of depositional environments responsible for accumulation of Missouri's stratified bedrock. (shelf/tidal-flat sequence; cyclothem sequence; etc.)

2. **Fossiliferous Sedimentary Strata**: sequence illustrating the diversity of animal and plant life existing in Missouri during the depositional eras. (many possibilities)

3. **Depositional Dip**: dip that bedded deposits acquire through compaction after sedimentation. Sediments laid down on a steeply sloping surface may develop significant dip not due to tectonic forces. (dipping beds on slope of buried Precambrian knob, power plan cut, Taum Sauk Power Project, Reynolds County)

VIII. Igneous Features

A. Volcanic (Extrusive) features

1. **Volcanic Pile**: a complex sequence of volcanic extrusions illustrating the variety of volcanic rock types and textures and indicating the several types of volcanic activity responsible for emplacement of Missouri's oldest rocks (section at Johnson's Shut-ins, Reynolds County; section exposed on Russell and Vail Mountains, Iron County)

2. **Columnar Rhyolite**: polygonal jointing in volcanic rocks; the result of contraction during cooling of the eruptive rock. (Figure 11) (Hughes Mountain, Washington County)

3. **Caldera**: Large basin-shaped volcanic structure or depression, more or less circular and formed by inward and downward collapse during or following a volcanic eruption.

Figure 11. Outcrop of Columnar Rhyolite, Hughes Mountain Natural Area, Washington County, Missouri. Photograph by Larry "Boot" Pierce

4. **Diatreme**: volcanic pipe characteristically composed of peridotite, usually with large amounts of brecciated county rock. Diatreme origin is a gas charged, explosive volcanic intrusion, often resembling a pipe form. When magma rises to the surface through a crack and makes contact with a shallow body of ground water, rapid expansion of heated water vapor and volcanic gases can exhibit an explosive behavior. (Bucholz Diatreme, Ste. Genevieve County; Avon Diatremes, Ste. Genevieve, County)

B. Intrusive features

1. **Pluton**: a large nontabular intrusive body.

a. Granite Pluton: a large body of granite that intruded volcanics or older granites. (intrusive contact exposed in quarry on Graniteville Pluton, Graniteville, Iron County)

2. **Dike**: small, usually near vertical, tabular intrusive body.
   a. Felsic dike: small tabular body of granite or other felsic rocks intruded into older igneous rocks; may have topographic expression. (resistant felsic dike exposed along Pickle Creek, Hawn State Park, Ste. Genevieve County)
   b. Mafic dike: small, near vertical black or greenish-black dike (usually basalt or diabase), intruded into older igneous rocks; may have topographic expression. (Figure 12) (weathered diabase/basalt dike cutting granite just below dam on St. Francis River, Silver Mine area, Madison County)
3. **Sill**: Small tabular, horizontal, intrusive igneous rock body.
   a. Mafic Sill: small, horizontal black or greenish-black dike (usually basalt or diabase), intruded into older igneous rocks; (Possibly Mudlick Dellenite, Sam A. Baker State Park)

IX. Tectonic (crustal movement) Features

A. Joint-related features

1. **Exposed Joint Pattern**: pattern of vertical fractures is seen on bedding-plane surface with little or no soil cover, or pattern maybe enhanced by weathering and erosion. (along Glade Top Trail, Ozark County; in stream bed at Johnson's Shut-ins, Reynolds County)

2. **Joint-Determined Valley**: valley segment developed along a prominent joint.

3. **Tectonic Cave**: an underground chamber formed by collapse, shifting, or weathering along joint planes; usually in rocks of limited solubility. (tectonic cave in Prairie Hollow Gorge, Shannon County)

4. **Tectonic Arch**: an arch or similar feature formed by collapse, shifting, or weathering along joint planes; usually in rocks of limited solubility. (tectonic arch in Prairie Hollow Gorge, Shannon County)

B. Fault-related features

1. **Fault Trench**: a visible surface crack or cleft along a fault trace. (Approximately 50 meters downstream of Bainbridge Road bridge on William's Creek, Cape Girardeau County)

2. **Fault-Determined Valley**: valley segment developed along a fault trace. (Beaver Creek Fault, Phelps County)

3. **Fault Scarp or Fault-Line Scarp**: a bluff or prominent hillslope developed on the upthrown side of a fault trace. (Chesapeake Fault, Lawrence County, Buzzard Rocks, St. Francois County)

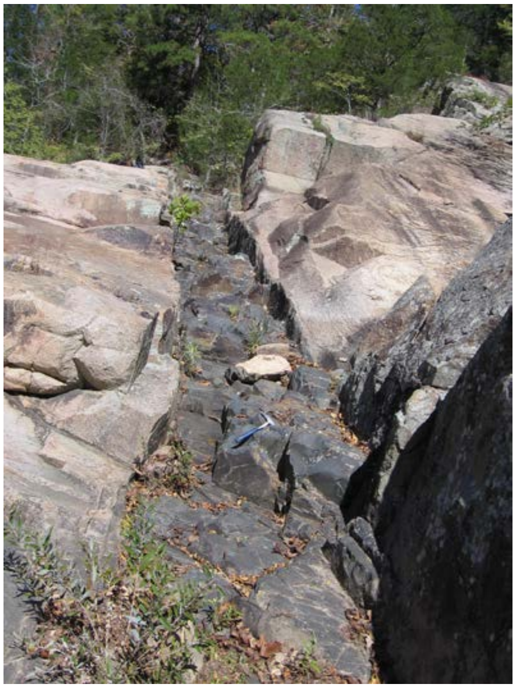

Figure 12. Basalt (mafic) dike cutting through the felsic Silver Mines Granite, USFS Silver Mines Recreational Area, Madison County, Missouri. Photograph by Larry "Boot" Pierce

4. **Horst**: an elongate uplifted block of rock, bounded by faults on its long Sides; may have topographic expression. (Valley Water Mills Fault Block, Greene County; Buford Mountain, Iron County)

5. **Graben**: an elongate, down-dropped block of rock bounded by faults on its long sides; may have topographic expression. (Belleview Basin, Iron County)

6. **Displaced Beds**: illustrates the relative movement of bedrock blocks on opposite sides of a fault plane. (road cut on U.S. Highway 65, 8 km south of Selmore, Christian County)

7. **Fault Gouge**: brecciated or broken rock along a fault plane; depending on displacement, may or may not have topographic expression. (Displaced fault gouge – in road cut on U.S. Highway 65, 8 km south of Selmore, Christian County; Non-displaced fault gouge – House Springs Fault in road cut on Highway 30 just north of House Springs, Jefferson County)

Figure 13. Inclined bedrock and fault scarp of the House Springs Fault, Jefferson County, Missouri. Photograph by Larry "Boot" Pierce

C. Fold-related features

1. **Anticlinal Structure**: rock strata folded convex-upward. (Lincoln Fold, Northeast, Missouri; Eureka-House Springs Anticline, Jefferson County (Figure 13); Browns Station Anticline, Boone County)

2. **Synclinal Structure**: rock strata folded concave-upward.

3. **Escarpment**: a long, steep slope that forms as a result of faulting or erosion and separated two distinct landforms or areas of relatively different elevation. (Ozark Escarpment, Southeast, Missouri)

4. **Escarpment:** (cuesta) a long, more or less continuous bluff or steep hill-slope, facing in one general direction, and separating two flat or gently sloping plateau surfaces; a "step-up" from one plateau to an adjacent, stratigraphically higher plateau. (Crystal Escarpment, Jefferson County; Eureka Springs Escarpment, southwest Missouri)

D. Miscellaneous Tectonic Features

1. **Dip Slope**: a flat, tilted land surface approximately paralleling the bedding plans of a tilted rock sequence.

2. **Paleo-seismic Features**: Surface features generated by earthquake activity. These features include liquefaction features such as Sand blows and Sand Fissures, ground support failure and earthquake induced landslides on areas of sufficient slope. Much of the evidence of the most recent (1811-1812 New Madrid) earthquake no longer remains or has been altered due to modern development and/or farming practices.

   a. Sand blows: A circular feature consisting of a mixture of sand and water that has been vented to the surface through fractures. Evidence of deep liquefaction. (numerous altered examples exist to the west of the city of New Madrid, New Madrid County; unaltered examples located at Duck Creek State Wildlife Refuge, Stoddard County)
   b. Sand fissures: A linear feature consisting of a mixture of sand and water that has been vented to the surface through fractures. Evidence of deep liquefaction. (Sand Blow Ridge, Mingo National Wildlife Refuge, Stoddard County)
   c. Earthquake inducted landslides: (Morris State Park, Dunklin, County)
   d. Earthquake induced lateral spread: (Ash Slough failure, Advance, Stoddard County

XI. Features of Extra-terrestrial Origin

1. **Meteorite Impact Structure**: Complex meteorite impact structures are characterized by a central uplift surrounded by a ring graben. They contain shatter cones, shocked quartz, breccia dikes, faults, fractured and disoriented rock. (Decaturville Structure, Camden and Laclede counties; Crooked Creek Structure, Crawford County (Figure 13); Weaubleau-Osceola structure, St. Clair County)

Figure 14. Inclined sandstone beds of the Roubidoux Formation located on the periphery of the Crooked Creek Impact Structure. Crawford County. Photograph by Larry "Boot" Pierce

LITERATURE CITED

Beveridge, T.R., 1978 (Vineyard, J.D.., revised edition, 1990). Geologic wonders and curiosities of Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, Educational Series No. 4, 400 p.

Cohen, K.M., Finney, S.M., Gibbard, P.L., Fan, J-X., 2013 (updated). The ICS International Chronostratigraphic Chart. Episodes 36, p. 199-204. www.episodes.org Accessed July, 2019

Day, W.C., Slack, J.F., Ayuso, R.A., Seeger, C.M., 2016. Regional geologic and petrologic framework for iron oxide ± apatite ± rare earth element and iron oxide copper-gold deposits of the Mesoproterozoic St. Francois Mountains Terrane, southeast Missouri, USA. Economic Geology, Volume 111, no. 8, p. 1825-1858

Fenneman, N.M., 1928. Physiographic divisions of the United States. Annals of the Association of American Geographers, vol. 18, no. 4, p. 261–353., doi:10.1080/00045602809357034.

Fenneman, N.M., and Johnson, D.W., 1946, Physiographic Divisions of the United States, U.S. Geological Survey (USGS), Washington, D.C., http://water.usgs.gov/GIS/dsdl/physio.gz.

Ford, T.D., Pedley, H.M., 1996. A review of tufa and travertine deposits of the world. Earth-Science Reviews, v. 41 p. 117-175.

Hebrank, Arthur W., 1983, Geologic Natural Features Classification System for Missouri, Missouri Department of Natural Resources, Division of Geology and Land Survey, Unpublished Manuscript, MSC-70605, 16p.

Hebrank, Arthur W., 1989, Geologic Natural Features Classification System for Missouri, Natural Areas Journal 9(2) 106-116 p.

Heritage Conservation and Recreation Service, 1978. Draft geological classification system. U.S. Department of the Interior, Washington, D.C. 24 p.

Lee, W. 1913. Geology of the Rolla Quadrangle. Missouri Geological Survey and Water Resources, v 12, 2nd Series, 111 p.

Missouri Department of Natural Resources, Division of Geology and Land Survey, 1993 (Updated 2019). Stratigraphic nomenclature - adopted for use by the Missouri Department of Natural Resources Geological Survey. Missouri Department of Natural Recourses, Information Circular Number 31, 37 p.

Nelson, P.W. 2010. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City, Mo. 550 p.

Nigh, T.A., Schroeder, W.A., 2002. Atlas of Missouri ecoregions. Missouri Department of Conservation, Jefferson City, Missouri. 212 p.

Neuendorf, K.E., Mehl, M.P., Jackson, J.A., 2011. Glossary of geology. American Geological Institute, 783 p.

Pflieger, W.L. 1989. Aquatic community classification system for Missouri. Aquatic Series No. 19. Missouri Department of Conservation, Jefferson City, Missouri, p

Thom, R.H., Wilson, J.H., 1980. The natural divisions of Missouri. Transactions of the Missouri Academy of Science 14:9-23.

Thompson, T.L., 1995. The stratigraphic succession of Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, Volume 40 (2nd series) Revised, 190 p.

Todd, J.E. 1896. Formation of the quaternary deposits, Pp. 121-122 *in* Surface features of Missouri. Missouri Geological Survey, Volume 10 (1st series), Jefferson City, Mo.

Vineyard, J.D., and Feder, G.L., 1974, Springs of Missouri: Missouri Department of Natural Resources, Division of Geology and Land Survey, Water Resources Report, no. 29, 212 p.

APPENDICIES

Appendix A - Geologic Time Scale

Geologic Time Scale

The dates and ages of the geologic time scale have been standardized and published by the International Commission on Stratigraphy as the International Chronostratigraphic Chart. The original version was published by Cohen et al. (2013), but has been updated since. A copy of version 2018/08 can be found at www.stratigraphy.org. All ages are in "Million Years Ago" (mya).

A. Precambrian
1. Hadean 4,600 mya to 4,000 mya
2. Archean 4,000 mya to 2,500 mya
3. Proterozoic 2,500 mya to 541 mya

B. Paleozoic
1. Cambrian 541 mya to 485 mya
2. Ordovician 485 mya to 443 mya
3. Silurian 443 mya to 419 mya
4. Devonian 419 mya to 358 mya
5. Mississippian 358 mya to 323 mya
6. Pennsylvanian 323 mya to 299 mya
7. Permian 299 mya to 252 mya

C. Mesozoic
1. Triassic 252 mya to 201 mya
2. Jurassic 201 mya to 145 mya
3. Cretaceous 145 mya to 66 mya

D. Cenozoic
1. Tertiary 66 mya to 2.6 mya
2. Quaternary 2.6 mya to present

Many of the chronological and stratigraphic (bedrock formation) names referenced since the inception of the Missouri Natural Area Committee have changed over time. Information Circular No. 31 published by the Missouri Department of Natural Resources in 1993 and revised in 2019 provides a chronostratigraphic outline of the stratigraphic nomenclature adopted for use by the Missouri Department of Natural Resources' Missouri Geological Survey.

A detailed description of the bedrock units located within the state of Missouri was been published in The Stratigraphic Succession of Missouri by Thompson in 1995. While some of the stratigraphic nomenclature may have been revised since its original publication the descriptions of the physical characteristics and stratigraphic relationships provided in the volume are still quite definitive.

Appendix B – Glossary of Selected Geologic Terms

Glossary of Selected Geologic Terms

Alluvial – Pertaining to or composed of alluvium or deposited by a stream or running water.

Alluvium – Unconsolidated detrital materials such as clay, silt, sand or gravel deposited by a stream or flowing water.

Base level – The lowest level of which a stream can erode its bed and is generally accepted to be the point where running water flows into stagnant water. Ultimate base level is considered sea level, however many stream have temporary elevated base levels in the forms of lakes or dams.

Breccia – Rock produced when coarse angular grains (boulders to gravel sized) are cemented together by mineralized materials such as calcite, silica, or iron oxides. A breccia differs from a conglomerate in that the grains have angular or unworn edges. The angular nature of the grains typically indicates that minimal travel and weathering has occurred and that the grains were near their original source when cementation occurred.

Chert – A hard, dense, sedimentary rock consisting of microcrystalline quartz crystals. Chert is harder than glass and typically breaks in conchoidal fractures.

Clay – A detrital rock particle or mineral fragment less than 1/256 mm size.

Conglomerate – Rock produced when coarse rounded grains (boulders to gravel sized) (greater than 2mm) are cemented together by mineralized materials such as calcite, silica, or iron oxides. A conglomerate differs from a breccia in that the grains have rounded or worn edges.

Dolomite – A carbonate sedimentary rock of which greater than 50 percent is made up of the magnesium carbonate mineral dolomite [$CaMg(CO_3)_2$] or a variety of limestone rich in magnesium carbonate.

Fault – A fracture in bedrock in which displacement has occurred

Felsic – Composed of silica-rich minerals such as quartz, plagioclase feldspars and mica.

Felsic Rock – An igneous rock (such as granite or rhyolite) composed of silica-rich minerals such as quartz, plagioclase feldspars and mica with minor amounts of pyroxenes and amphiboles present.

Fracture – General term for breaks in bedrock. Two types of fractures occur, joints and faults, and are classified based on the presence or absence of displacement.

Glacial Drift – A general term given to all sedimentary deposits related to glacial activity.

Glacial Till – A heterogeneous unconsolidated, unstratified, and unsorted glacial drift located adjacent to or beneath a glacier without reworking from meltwater. Highly variable mixture of clay, silt, sand and gravel.

Granite – A coarse crystalline, intrusive, felsic igneous rock composed of silica-rich minerals such as quartz, plagioclase feldspars and mica with minor amounts of pyroxenes and amphiboles. Mineral crystals are visible to the naked eye.

Gravel – A detrital rock particle or mineral fragment greater than 2 mm in size.

Igneous Rock – A rock produced by the cooling and crystallization of molten magma or lava.

Joint – A fracture in bedrock in which no displacement has occurred. Often geometrical in nature

Karst – A type of topography characterized by sinkholes, caves, losing streams, and springs, resulting from the dissolution of soluble bedrock (limestone, dolomite or gypsum) by groundwater.

Liquefaction – The transformation of a saturated or cohesionless soil into a liquid due to an increase in pore pressure. Typically the result of sudden loading due to earthquake shock.

Limestone – A carbonate sedimentary rock of which greater than 50 percent is made up of the calcium carbonate mineral calcite ($CaCO_3$). May contain some amount of magnesium carbonate (dolomite).

Loess – A widespread, homogenous, non-stratified, windblown sediment believed to be the result of Pleistocene glacial recessions. The composition of loess is primarily silt-sized silica, with minor amounts of fine sand and clays present.

Mafic – Composed primarily of ferromagnesium minerals (olivine, pyroxenes or amphibole).

Mafic Rock – An igneous rock (such as basalt, gabbro, or peridotite) composed primarily of ferromagnesium minerals.

Meteogene – Groundwater or groundwater discharge at ambient temperature.

Rhyolite – A finely crystalline, felsic igneous rock composed of silica-rich minerals such as quartz, plagioclase feldspars and mica with minor amounts of pyroxenes and amphiboles. Rhyolite is extrusive and often shows evidence of flow or fused ash.

Sand – A detrital rock particle or mineral fragment greater than 1/16 mm but less than 2mm in size.

Sandstone – A rock produced when sand-sized grains (greater than 1/16 mm but less than 2mm) are naturally cemented together. The predominant mineral in sandstones is quartz, however other minerals may be present and in cases of highly eroded igneous rocks feldspars may constitute the dominant grain type.

Sedimentary Rock – A rock resulting from the consolidation of loose materials (clastic sedimentary rocks such as sandstone or shale), precipitation of minerals directly from solution (chemical sedimentary rock such as micritic limestone, halite or gypsum), or the extraction/precipitation of minerals due to biological organisms (biochemical sedimentary rocks such as fossiliferous limestone or coquina).

Silt – A detrital rock particle or mineral fragment less than 1/16 mm but greater than 1/256 mm in size.

Siltstone – A rock produced when silt-sized particles (less than 1/16 mm to greater than 1/256 mm) are cemented together.

Shale – A laminated, fissile rock produced when clay-sized particles (less than 1/256 mm) are cemented together. If lamination or fissile characteristics are not present the term mudstone is often used.

Stream capacity – The total volume of sediment load a flowing stream can carry in both bed and suspended load.

Stream Competency – The largest particle size that a stream can move. Competency is a function of stream gradient and flow velocity.

Thermogene – Groundwater or groundwater discharge that has been geothermally heated.

Tuff – Consolidated or cemented volcanic ash.

Volcanic Rock – A finely crystalline to glassy igneous rock (basalt, rhyolite, tuff or obsidian) located at or near the earth's surface as a result of volcanic activity. Typically it is either extruded in the case of lava or ejected in the case of ash.

Appendix C – Alphabetical Listing of Individual Geologic Features

Alphabetical listing of individual geologic features including the process of formation

Abandoned/cutoff Meander – Fluvial, Erosional
Abandoned Meander Valley – Fluvial, Erosional
Abandoned Spring Conduit – Groundwater, Erosional
Alluvial Fan – Fluvial, Depositional
Alluvial Fill – Fluvial, Depositional
Anticline Structure – Tectonic/Crustal, Fold related
Arch/Bridge (Erosional) – Weathering, Erosional
Arch/Bridge (groundwater) – See Natural Tunnel – Groundwater, Erosion

Blossom Rock – Residual, Erosional
Braided Stream Channel – Fluvial, Composite

Caldera – Igneous, Composite
Cave – Groundwater, Erosional
Canyon/Gorge – Fluvial, Erosional
Choked Spring Conduit – Groundwater, Erosional
Cliff – Fluvial, Erosional
Columnar Rhyolite – Volcanic, Extrusive
Creep – Landslide feature – Gravity, Composite
Crypto-explosion – Meteor impact structure
Cut Bank – Fluvial, Erosional
Cutter – See Solution Enlarged Joint

Depositional Dip – Ocean, Depositional
Detrital Fill – Groundwater, Depositional
Diatreme – Volcanic, Extrusive
Dike – Igneous, intrusive
Dip Slope – Tectonic/Crustal, Miscellaneous
Displaced Beds – Tectonic/Crustal, Fault related
Drift – Glacial, Deposition
Dunes – Eolian, Depositional

Earthquake Feature – Tectonic/Crustal, Miscellaneous
- Landslide – Tectonic/Crustal, Miscellaneous
- Lateral Spread – Tectonic/Crustal, Miscellaneous
- Sand Blow – Tectonic/Crustal, Miscellaneous
- Sand Fissure – Tectonic/Crustal, Miscellaneous

Entrenched Meander – Fluvial, Erosional
Epikarst – Groundwater, Erosional
Escarpment – Tectonic/Crustal, Fold related
Escarpment (Cuesta) – Tectonic/Crustal, Fold related
Estevelle – Groundwater, Erosional
Exposed Joint Pattern – Tectonic/Crustal, Joint related

Fault Determined Valley – Tectonic/Crustal, Fault related
Fault Gouge – Tectonic/Crustal, Fault related
Fault Scarp – Tectonic/Crustal, Fault related

Fault Trench – Tectonic/Crustal, Fault related
Felsic Dike – Igneous, Intrusive
Floodplain
    Narrow Floodplain – Fluvial Composite
    Wide floodplain – Fluvial Composite
    Broad Floodplain – Fluvial Composite
Floodplain Meander – Fluvial, Composite
Foot Slope – Gravity, Depositional
Fossil Rich Fen (Bog) – Groundwater, Erosional
Fossil Rich Cave- or Sink-Fill – Groundwater, Erosional
Fossil Rich Spring/Marsh – Groundwater, Erosional
Fossiliferous Sedimentary Rock – Ocean, Depositional

Glacial Striation – Glacial, Erosion
Glacial Erratic – Glacial, Deposition
Glade – Weathering, Erosional
Gorge – See Headwater Canyon
Graben – Tectonic/Crustal, Fault related
Granite Pluton – Igneous, Intrusive
Granite Tor – Weathering, Erosional

Headwater Canyon – Fluvial, Erosional
Hill – Fluvial, Erosional
Hoodoo (Sandstone) – Weathering, Erosional
Horst – Tectonic/Crustal, Fault related

Island (Alluvial) – Fluvial, Composite
Island (Bedrock) – Fluvial, Erosional

Joint – Tectonic/Crustal, Joint related
Joint Determined Valley – Tectonic/Crustal, Joint related

Karst Complex – Groundwater, Erosional
Knob – See Hill – Fluvial, Erosional

Lapies – See solution enlarged joint, Groundwater, Erosional
Loess Badlands – Weathering, Erosional
Loess Series – Eolian, Depositional
Losing Stream – Groundwater, Erosional
Lost Hill – Fluvial, Erosional

Mafic Dike – Igneous, Intrusive
Monadnock – Fluvial, Erosional
Meander Scar – Fluvial, Erosional
Mound – See Hill – Fluvial, Erosional

Narrows – Fluvial, Erosional
Natural Levee – Fluvial, Depositional
Natural Tunnel – Groundwater, Erosional

Lateral Piracy Origin – Groundwater, Erosional
Roof Remnant of collapse Cave – Groundwater, Erosional
Slice Arch – Groundwater, Erosional
Subterranean Piracy Origin – Groundwater, Erosional

Outwash Deposit – See Drift – Glacial, Deposition
Oxbow Lake – Fluvial, Composite

Paleo-hill – Fluvial, Erosional
Paleo-karst – Groundwater, Erosional
Sandstone Filled Sinkhole – Groundwater, Composite
Clay/shale/coal Filled Sinkhole – Groundwater, Composite
Paleo-topography – Fluvial, Erosional
Paleo-valley – Fluvial, Erosional
Pinnacle – Weathering, Erosional
Pluton – Igneous, Intrusive
Point Bar – Fluvial, Depositional

Residuum – Weathering, Depositional
Rock Fall – Landslide feature – Gravity, Composite
Rock Slide – Landslide feature – Gravity, Composite

Sand Dune – Eolian, Depositional
Scarp – Gravity, Erosional
Sedimentary Strata – Ocean Features, Depositional
Shelter (erosional) – Weathering, Erosional
Shut-in – Fluvial, Erosional
Sinkhole – Groundwater, Erosional
Collapse Sinkhole – Groundwater, Erosional
Doline – Groundwater, Erosional
Sinkhole Pond – Groundwater, Erosional
Sinkhole Plain – Groundwater, Erosional
Karst Valley – Groundwater, Erosional
Collapse Canyon – Groundwater, Erosional
Karst Window – Groundwater, Erosional
Swallow Hole – Groundwater, Erosional
Slump – Landslide feature – Gravity, Composite
Solution Cave – Groundwater, Erosional
Linear Cave – Groundwater, Erosional
Network Cave – Groundwater, Erosional
Maze Cave – Groundwater, Erosional
Karst Plain Cave (System) – Groundwater, Erosional
Pit Cave – Groundwater, Erosional
Non-conformity Cave – Groundwater, Erosional
Solution Enlarged Joint – Groundwater, Erosional
Speleothem – Groundwater, Depositional
Spring – Groundwater, Erosional
Deep-seated – Groundwater, Erosional
Shallow (vadose) – Groundwater, Erosional

Bedding Plane Seepage Spring – Groundwater, Erosional
Ebb and Flow Spring – Groundwater, Erosional
Resurgence – Groundwater, Erosional
Mineralized Spring – Groundwater, Erosional

Stream-Terrace (alluvial) – Fluvial, Composite
Stream Terrace (bedrock) – Fluvial, Erosional
Synclinal Structure – Tectonic/Crustal, Fold related

Talus – Gravity, Composite
Tectonic Arch – Tectonic/Crustal, Joint related
Tectonic Cave – Tectonic/Crustal, Joint related
Till – See Drift – Glacial, Depositional
Toe Slope – Gravity Depositional
Travertine – Groundwater, Depositional
Tufa – Groundwater, Depositional

Volcanic Pile – Volcanic, Extrusive

Waterfall – Fluvial, Erosional

Yazoo Stream – Fluvial Composite

Appendix D – Outline of individual geologic features with associated process

I) Fluvial (Stream Related) Feature

- A) Erosional
  1) Canyon/Gorge
  2) Shut-in
  3) Entrenched Meander
  4) Abandoned Meander Valley
  5) Lost Hill
  6) Narrows
  7) Cut Bank
  8) Stream Terrace (Bedrock)
  9) Island (Bedrock)
  10) Waterfall
  11) Cliff
  12) Hill, Knob, or Mound
  13) Monadnock
  14) Paleo-topography
- B) Depositional
  1) Point Bar
  2) Natural Levee
  3) Alluvial Fan
  4) Alluvial Fill
- C) Composite
  1) Meander
  2) Abandoned/cutoff Meander
  3) Meander Scar
  4) Oxbow Lake
  5) Yazoo Stream
  6) Stream Terrace (Alluvial)
  7) Island (Alluvial)
  8) Braided Stream Channel
  9) Narrow Flood Plain
  10) Wide Flood Plain
  11) Broad Flood Plain

II) Residual Features

- A) Erosional
  1) Residuum
  2) Glade
  3) Pinnacle
  4) Granite Tor
  5) Hoodoo
  6) Blossom Rock
  7) Loess Badlands
  8) Shelter or Overhang
  9) Arch/Bridge (Erosional)

III) Solution/Groundwater Feature

- A) Erosional
  - 1) Cave
  - 2) Sinkhole
  - 3) Spring
  - 4) Fen
  - 5) Estevelle
  - 6) Natural Bridge or Tunnel
  - 7) Epikarst
  - 8) Karst Complex
  - 9) Pinnacle (Solution)
  - 10) Solution Enlarged Joint
  - 11) Losing Stream
  - 12) Abandoned Spring Conduit
  - 13) Choked Spring Conduit
  - 14) Groundwater Feature (paleontological)
  - 15) Paleo-Karst
- B) Depositional
  - 1) Tufa Deposits
  - 2) Travertine Deposits

IV) Gravity (Mass-Wasting) Features

- A) Erosional
  - 1) Escarpment
  - 2) Scarp
- B) Depositional
  - 1) Foot Slope
  - 2) Toe Slope
- C) Composite
  - 1) Talus Slope
  - 2) Rock Fall
  - 3) Rock Slide
  - 4) Slump
  - 5) Creep

V) Glacial Features

- A) Erosional
  - 1) Glacial Striations
- B) Depositional
  - 1) Glacial Erratic
  - 2) Drift

VI) Eolian (Wind Related) Features

- A) Depositional
  - 1) Sand Dune
  - 2) Loess Series

VII) Ocean Features

A) Erosional
   1) Rip up clast
B) Depositional
   1) Sedimentary Strata
   2) Fossiliferous Sedimentary Strata
   3) Depositional Dip

VIII) Igneous Features

A) Volcanic (Extrusive) Features
   1) Volcanic Pile
   2) Columnar Rhyolite
   3) Caldera
   4) Diatreme
B) Intrusive Features
   1) Pluton
   2) Dike
   3) Sill

IX) Tectonic (Crustal Movement) Features

A) Joint Related Features
   1) Exposed Joint Pattern
   2) Joint-Determined Valley
   3) Tectonic Cave
   4) Tectonic Arch
B) Fault Related Features
   1) Fault Trench
   2) Fault-Determined Valley
   3) Fault Scarp or Fault-Line Scarp
   4) Horst
   5) Graben
   6) Displaced Beds
   7) Fault Gouge
C) Fold Related Features
   1) Anticlinal Structure
   2) Synclinal Structure
   3) Escarpment
   4) Escarpment (Cuesta)
D) Miscellaneous Tectonic Features
   1) Dip Slope
   2) Earthquake Features
      (a) Sand Blows
      (b) Sand Fissures
      (c) Earthquake Induced Landslides
      (d) Earthquake Induced Lateral Spread

X) Features of Extra Terrestrial Origin

1) Meteorite Impact Structure