Landforms, Geology, and Soils of the MOFEP Study Area

Dennis Meinert[1], Tim Nigh[2], and John Kabrick[3]

Abstract.—We summarize important landform, geological, and soil characteristics that affect the distribution of plants and animals at the MOFEP sites and that can potentially affect the observed response to MOFEP experimental treatments. The Missouri Ozark Forest Ecosystem Project (MOFEP) is located within the Current River Hills Subsection of the Ozark Highlands Section. The Ozark Highlands is an assemblage of nearly level to deeply dissected plateaus comprised primarily of Ordovician dolomites or sandstones. Soils are formed primarily in loess, hillslope sediments, and/or residuum. Natural vegetation consists of oak-hickory and oak-pine forests and woodlands, oak savanna, bluestem prairie, and glades. The Current River Hills Subsection encompasses moderately rolling to steeply dissected hills; oak-hickory and oak-pine forests are common. MOFEP occurs in the Current-Black River Breaks (Breaks) and Current-Eleven Point Hills (Hills) Landtype Associations (LTA's). The Breaks LTA has greater relief, more geological strata, greater variety of soils, and more mesic vegetation and glade-savanna complexes than the Hills LTA. Detailed landform, geology, and soil information for each LTA provides a means for (1) interpreting vegetation differences, (2) identifying potential treatment response differences among MOFEP sites, and (3) refining ecological landtype definitions applied during MOFEP initiation.

Landforms, geological parent materials, and soils largely control the distribution of water, nutrients, and sunlight in the landscape. This ultimately influences plant and animal distributions and their responses to land management. A thorough understanding of landforms, geology, and soils is critical for interpreting and integrating results of many studies of the Missouri Ozark Forest Ecosystem Project (MOFEP).

In this paper, we summarize important landform, geological, and soil characteristics potentially affecting plant and animal distributions and responses to cultural treatments implemented in the MOFEP study area. We do this using the USDA Forest Service - Ecological Classification System (ECS) framework (USDA Forest Service 1993). Under this framework, attributes of climate, landform, geology, vegetation, and soil are used at various scales to divide the Earth's surface into progressively finer ecological units. The influence of each of these attributes varies, depending upon the scale of application.

The hierarchical nature of the ECS framework is illustrated in table 1. Broad-scale ecoregions and subregions provide a general ecological context for MOFEP based on regional patterns in climate, geomorphology, soil, and vegetation. Landforms, geology, and associated soils play especially important roles in defining the lower, "working levels" in the classification: landtype associations, ecological landtypes, and ecological landtype phases. These finer scale classification levels are key to understanding patterns in environmental characteristics within and between MOFEP study sites.

[1] Soil Scientist, Missouri Department of Natural Resources, Sullivan, MO 63080.
[2] Ecologist, Missouri Department of Conservation, P.O. Box 180, Jefferson City, MO 65102.
[3] Postdoctorate fellow, School of Natural Resources, University of Missouri, Columbia, MO 65211.

Table 1.—*National hierarchical framework for ecological classification (USDA-FS 1993) and application to MOEFEP.*

Scale	Ecological units	Map scales	Major differentiating criteria	MOFEP types
ECOREGION	Domain	1:30 Million to 1:100 Million	Continental and regional climate zones Broad soil and vegetation lifeform patterns	Humid temperature domain (2)
	Division			Hot continental division (22)
	Province			Moderately humid broadleaf forest province (222)
SUBREGION	Section	1:1 Million to 1:125,000	Regional and subregional ppt. and temp. Geomorphology Major soil great groups Potential vegetation formations	Ozark Highlands Section (222A)
	Subsection			Current River Hills Subsection (222 Af)
LANDSCAPE	Landtype Association (LTA)	1:100,000	Local climate Landform/topography Geologic parent materials Soil associations Potential vegetation alliances	Current-Black River Breaks LTA Current-Eleven Point Hills LTA
LAND UNIT	Landtype (ELT)	1:24,000	Landform/topographic position Geologic parent material Soil series Potential vegetation association	To be developed
	Landtype Phase (ELT-P)			

We begin by providing a broad ecological context for the MOFEP study sites using Forest Service ecological sections and subsections (Bailey 1980, Keys *et al.* 1995, McNab and Avers 1994). Next, we describe the landscapes (landtype associations) that encompass MOFEP (Nigh 1997). We then summarize important landform, geology, and soil characteristics that distinguish MOFEP sites and land units within sites based upon an intensive soil investigation conducted on MOFEP sites (Meinert 1997). Finally, we provide insights of how this and future work may lead to further development of finer scale ecological units (ELT's).

SECTION, SUBSECTION, AND LANDTYPE ASSOCIATIONS OF THE MOFEP STUDY AREA

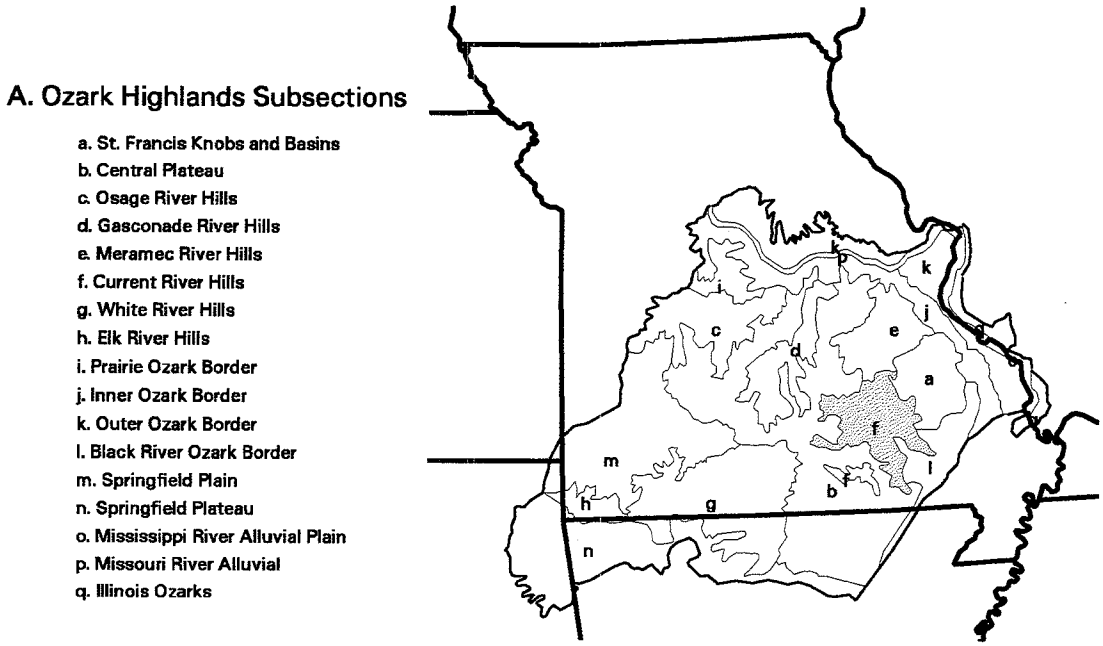
Ozark Highlands Section

The MOFEP study area is located in the Ozark Highlands Section (fig. 1) (McNab *et al.* 1995). The Ozark Highlands is an assemblage of maturely dissected, high plateaus, where millennia of erosion have created a region of variable topography and relief. High, flat to gently rolling plateau remnants are dissected by dendritic and radial drainages. Crystal clear, spring-fed streams have cut deeply into the plateaus, forming a region of steep to moderately rolling hills with local relief mainly 200 to 500 ft (60 to 150 m), but occasionally up to 1,000 ft (300 m). Karst features, including caves, springs, and sinkholes, are common.

Bedrock stratigraphy is dominated by Ordovician dolomites and sandstones. Silurian, Devonian, Mississippian, and Pennsylvanian bedrock (limestone, chert, sandstone, shale) are less frequent and concentrated around the section's margins. Precambrian rhyolite, andesite, granite, and gabbro occur in the eastern part of the section, forming the highest hills.

Quaternary loess deposits are common on the uplands with thin layers on stable landforms overlying hillslope sediments and/or residuum. On steep or unstable landforms, loess has been eroded or incorporated locally into hillslope sediments. Valley bottoms contain Quaternary gravel, sand, silt, and clay alluvium.

Soils are formed primarily in loess, hillslope sediments, residuum, or gravelly alluvial parent materials. Most soils in the section are highly weathered Ultisols and Alfisols with mesic temperature and humid moisture regimes (USDA 1975). Soils range from shallow unconsolidated materials over bedrock to very deep,



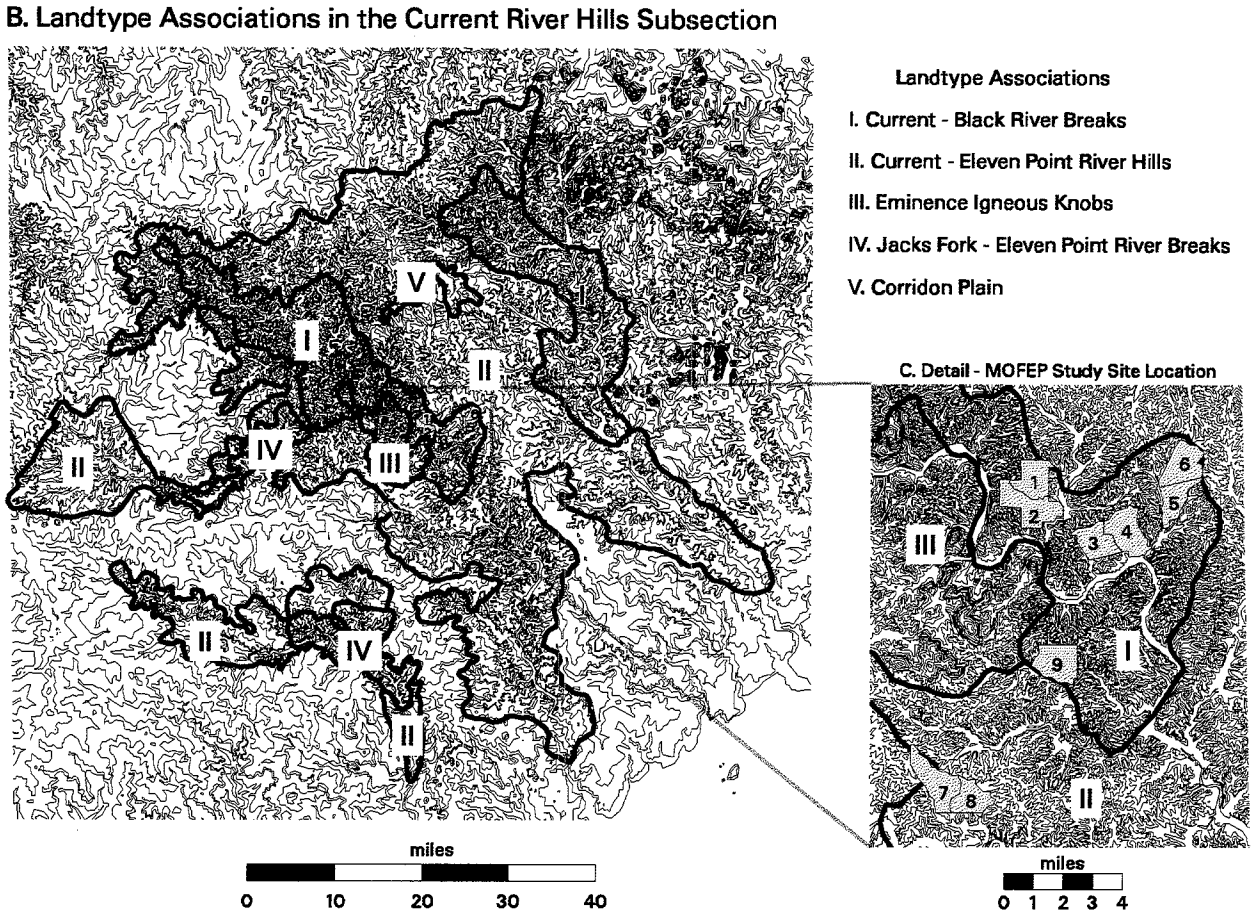


Figure 1.—*MOFEP study sites and ecological units.*

highly weathered soils in hillslope sediments and residuum. Bedrock outcrops and fragipans are common in many soils of the section.

The natural vegetation of the Ozark Highlands consists mainly of oak-hickory and oak-shortleaf pine forests and woodlands, oak savanna, bluestem prairie, and glades. Bottomland and mixed upland hardwood forests occur in large valleys and adjacent sideslopes. Forest and woodlands were originally common where topography was steeper, while savannas and prairies were common on higher, more gently sloping lands.

Current River Hills Subsection

The Ozarks Highlands Section has been divided into 17 ecological subsections (Keys *et al.* 1995), based mainly on variations in relief, geologic parent materials, soils, and vegetation pattern (fig. 1). The MOFEP study area is located in the center of the Current River Hills Subsection. This subsection encompasses the moderately rolling to steeply dissected hills associated with the Current, Eleven Point, and Black Rivers in the eastern Missouri Ozarks. Here, broad to narrow ridges give way to moderate and steeply sloping sideslopes and narrow, sinuous valley bottoms. Local relief ranges from 150 to over 400 ft (50 to 130 m). High, sheer, rock cliffs are common along the rivers.

Bedrock stratigraphy is dominated by Ordovician cherty sandstone and dolomites from the Roubidoux and Gasconade formations. Areas of Cambrian dolomite from the Eminence and Potosi formations occur nearer the Current and Black Rivers. A relatively small area of Precambrian igneous knobs occurs in the center of the Current River Valley.

Thin layers of Quaternary loess deposits are common on flatter, more stable landforms in this subsection. Most of the landscape is mantled in deeply weathered residual materials and hillslope sediments. Valley bottoms have Quaternary alluvium.

Soils in the region have not been extensively inventoried or studied. They appear to be typical of the hilly subsections of the Ozarks, with deeply weathered Ultisols and Alfisols, interspersed with soils that are shallow to bedrock, contain fragipans, or have formed in alluvium.

The Current River Hills Subsection is located in the center of the largest, contiguous block of forest in the Ozark Highlands, and one of the largest in the Midwestern United States. Oak-hickory and oak-shortleaf pine forests dominate the landscape. Local areas of oak and oak-pine woodlands and savannas occur on shallower soils and exposed slopes. Occasional glades occur on sideslopes, especially near the rivers. Bottomland and upland mixed hardwood forests occur along the streams and adjacent slopes. Cleared pastureland is only a minor component of the subsection and is associated with richer bottomland soils.

Landtype Associations in the Current River Hills Subsection

The Current River Hills Subsection has been divided into five landtype associations (LTA's) based on variations in landform, relief, geologic parent materials, soils, and vegetation patterns (fig. 1) (Nigh 1996).

Two of the LTA's are relatively small, but distinctive. The Corridon Plain is a high, flat to gently rolling divide between the Current and Black River Valleys. This flat plain, covered in a thin layer of loess, underlain by Roubidoux sandstone, historically supported shortleaf pine forest and woodland. Today, it is covered in pasture and second-growth pine-oak forest. The Eminence Igneous Knobs LTA contains an isolated series of Precambrian igneous knobs characterized by unique igneous glades, woodlands, and forests.

The remainder of the subsection is divided into three LTA's: Current-Black River Breaks, Jacks Fork-Eleven Point River Breaks, and Current-Eleven Point River Hills. The two Breaks LTA's are characterized by narrow ridges and steep sideslopes with 300 to 450 ft (90 to 140 m) local relief, narrow sinuous valleys, and common cliffs, caves, and springs; all are associated with the steepest, most dissected lands near the rivers. The two Breaks LTA's are distinguished based on geologic parent materials and corresponding soil and vegetation patterns. The Current-Black River Breaks LTA cuts into Eminence and Potosi dolomites, which add distinctive landforms, soil, and vegetation patterns not found on the Jacks Fork-Eleven Point Breaks. The Current-Eleven Point River Hills LTA makes up the rest of the matrix of this subsection. It consists of broad to narrow ridges and moderately steep sideslopes with

local relief less than 300 ft (90 m). Valleys are generally broader and less sinuous than in the Breaks. The Roubidoux and Gasconade formations make up most of the geologic parent materials. The Hills LTA is covered mainly by forests of shortleaf pine and oak, with occasional glade and woodland openings. Approximately 15 percent of the Current-Eleven Point River Hills is open pasture, associated with richer bottomland soils.

The MOFEP study sites occur in two of these LTA's - the Current-Black River Breaks and the Current-Eleven Point River Hills. Detailed mapping of the landforms, geology and soil patterns of the MOFEP sites provides the basis for more detailed characterization of the physical features at the MOFEP sites and a better understanding of the potential impacts of physical characteristics on MOFEP treatment response.

CHARACTERIZING LANDFORMS, GEOLOGY, AND SOILS OF THE MOFEP STUDY AREA

Integrated Soil Mapping— Geo-landform Approach

A detailed soil investigation and mapping project was initiated at the MOFEP sites in July 1994. Soil investigation and mapping techniques used differed from those of the National Cooperative Soil Survey. First, the hierarchical framework of the ECS was used to explicitly and systematically stratify the landscape by geology and landform before the detailed soil mapping was conducted. Second, mapping was done at a larger scale (1:12,000) than the National Cooperative Soil Survey scales (1:>15,840). Third, *Soil Taxonomy* (USDA 1975), the national soil classification system, was not used to set soil property boundaries for map units. A detailed report with soil maps, map unit descriptions, and MOFEP study site descriptions resulted from this effort (Meinert, In prep.). This section is a synthesis of the soil and geo-landform relationships identified in the more detailed report.

The soil mapping process consisted of two phases. The first "phase" identified key geological strata, landforms, and slope classes within landforms (collectively referred to as "geo-landform") potentially affecting soil distributions. The second phase identified the range and distribution of important soil properties within each geo-landform to delineate map units with meaningful implications for use and management.

Soil descriptions were made at each of the 648 MOFEP vegetation plots (Brookshire *et al.* 1997). Additional soil borings were made where necessary for identifying map units. Important soil properties that distinguished map units were: depth to bedrock, water holding capacity, drainage class, texture and mineralogical character of horizons, and depth to residual clays. Map unit delineations were made on 1:12,000 scale aerial photographs in the field. This photographic base allowed finer resolution than standard 1:15,840 scale aerial photographs used for the National Cooperative Soil Survey; map units as small as 0.1 acre were delineated.

Laboratory soil information was determined for most soil map units. One to four backhoe excavations were made in each major soil map unit. Soils were described, sampled by horizon, and samples were sent to the University of Missouri Soil Characterization Laboratory. Laboratory analyses included: particle size distribution, extractable acidity, extractable aluminum, extractable bases, cation exchange capacity, base saturation, organic carbon content, and pH.

Landforms, Geology, and Soils of the MOFEP Study Area

The 12 landforms used in the MOFEP soils investigation are defined in table 2. Definitions generally follow Ruhe (1960, 1975), but they have been refined for the MOFEP study area.

Landforms are important because they locally affect water flow, soil parent material movement, and consequently, soil development. Landform positions relatively high in elevation (e.g., summits, shoulders, shoulder ridges, upper backslopes) are sources of subsurface water, nutrients, and eroded sediment that collects in lower landform positions (e.g., lower backslopes, footslopes). In addition, the shape of a landform (linear, convex, or concave) influences the degree and type of water and sediment movement. Convex landforms normally lose surface water and sediment, concave landforms gain surface water/sediment, and linear landforms are neutral. For example, sinkholes occurring on summit landform positions are concave and accumulate eroded silty sediments from slightly higher elevations around them. Shoulders and shoulder ridges are convex areas high in the landscape that tend to lose both surface water and sediments

Table 2.— *Landforms in the MOFEP study region.*

Alluvial Fan — A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream at the junction of a narrow drain with a higher order drain.

Backslope — The landscape position that forms the steepest inclined surface and principal element of many hillslopes. Slope (>20 percent) contains sideslope, noseslope, and headslope components.

Flood Plain — The nearly level plain that borders a stream and is subject to inundation under floodstage conditions. Slopes 0-4 percent.

Footslope — The landscape position that forms the inner, inclined surface at the base of a hillslope. It is a transition zone, commonly concave in profile. Slopes 0-20 percent.

Shoulder — The landscape position that forms the uppermost inclined surface near the top of a hillslope. It is commonly convex in shape and comprises the transition from summit to backslope. Slopes 8-20 percent.

Shoulder Ridge — A long, narrow elevation of the land surface, usually sharp crested and convex with steep sides, and forming an extended upland between valleys. Slopes 8-20 percent.

Sinkhole — A closed depression formed either by solution of the surficial bedrock or by collapse of underlying caves.

Strath Terrace — Erosional surfaces cut into bedrock and thinly mantled with stream deposits.

Structural Bench — A platform-like, nearly level to gently inclined erosional surface developed on resistant strata in areas surrounded by otherwise sloping land surfaces.

Summit — The topographically highest hillslope position of a hillslope profile and exhibiting a nearly level surface. Slopes 0-8 percent.

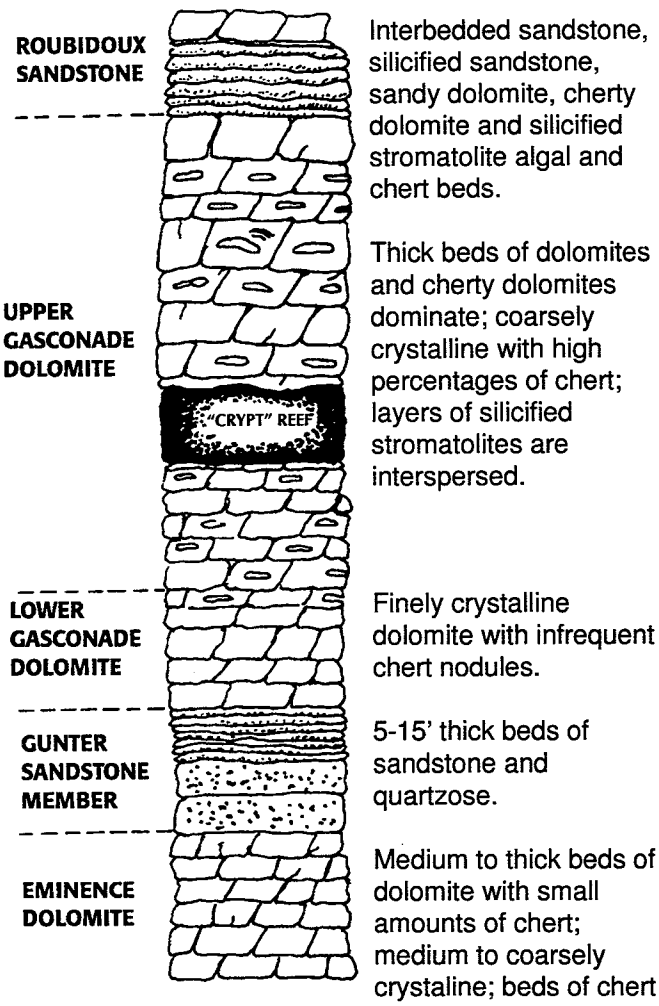
Terrace — One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of erosion or deposition.

Upland Drainages — Narrow, sloping (>8 percent) concave-shaped waterways, which carry intermittent flows of water during rain events.

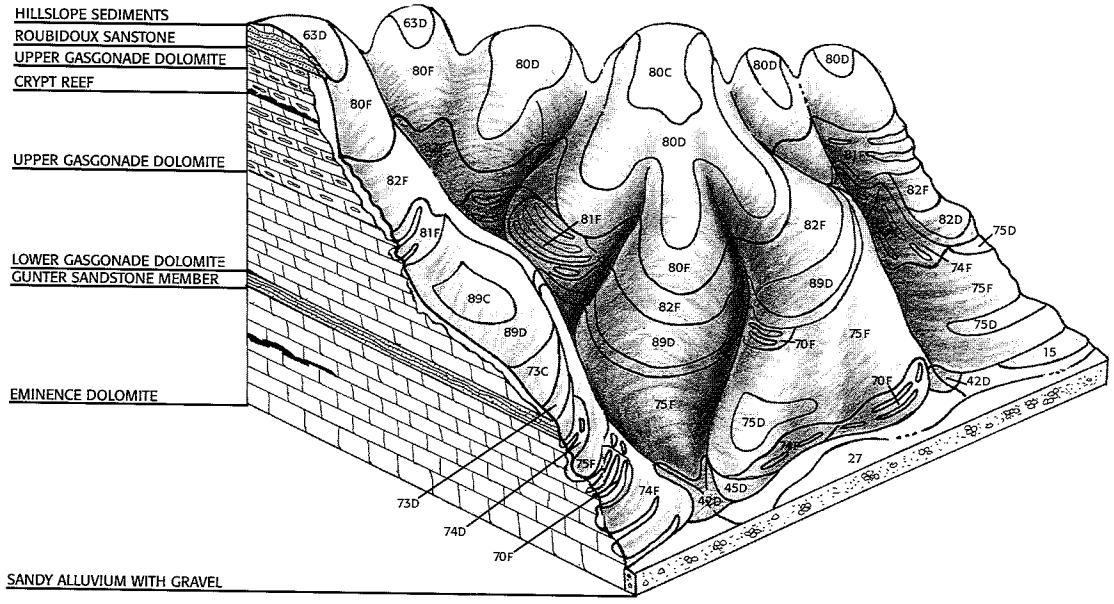
to backslopes below. Upland drainages, terraces, and floodplains are relatively low in the landscape and are domains of sediment accumulation and transport, primarily by water.

Roubidoux, Upper and Lower Gasconade, and Eminence are the dominant geologic formations within the MOFEP study area (fig. 2). The compositon of these strata influences the character of the soil parent materials across the site. Strata within these formations strongly affect hillslope sediment textures. Sandier hillslope sediment textures are associated with sandstone in the Roubidoux formation and with the Gunter member of the Lower Gasconade formation. While most strata yield very cherty residual materials, the degree of stoniness varies somewhat between strata. The Lower Gasconade and Eminence formations, for example, are relatively chert-free compared to

Figure 2.—*Bedrock stratigraphy in MOFEP region.*



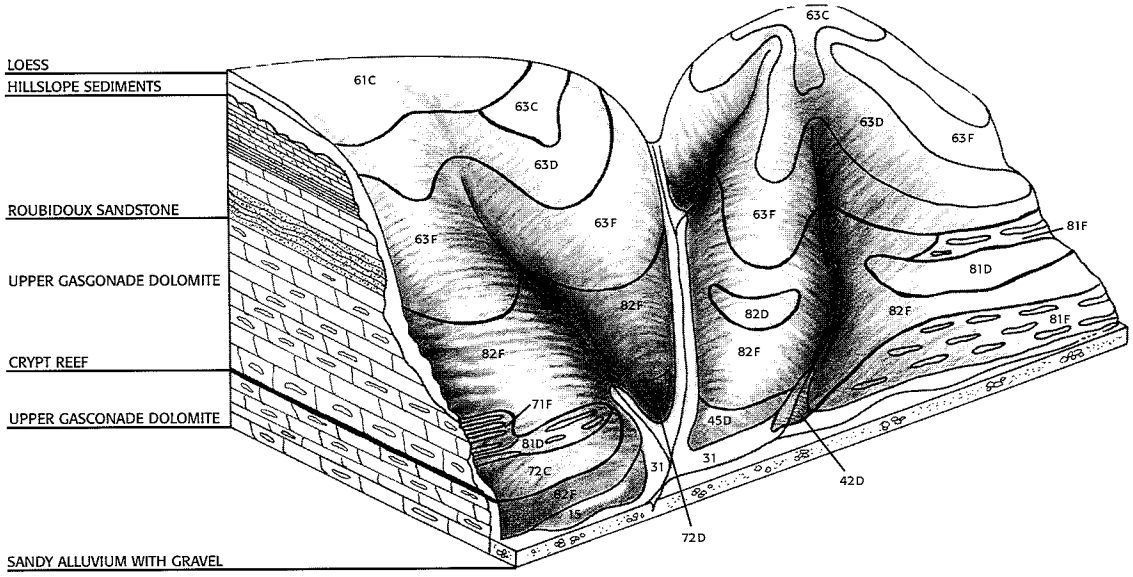
Current-Black River Oak-Hickory Forest Breaks LTA



GEOLOGY	LANDFORM	SOIL CHARACTERISTICS	MAP UNIT
Roubidoux	Summits	Very deep soil with fragipan at 20 to 26"; moderately well to well drained; fine-loamy; low base saturation.	61C
	Summits	Moderately to very deep soil with intermittent fragipan; moderately well to well drained; loamy-skeletal/clayey and loamy-skeletal; low base saturation.	63C
	Shoulder/Shoulder Ridges	Moderately to very deep soil with intermittent fragipan; moderately well to well drained; loamy-skeletal/clayey and loamy-skeletal; low base saturation.	63D
	Backslopes	Moderately to very deep soil with intermittent fragipan; moderately well to well drained; loamy-skeletal/clayey and loamy-skeletal; low base saturation.	63F
Upper Gasconade	Summits	Very deep soil with fragipan at 20 to 26"; moderately well drained; fine-loamy; low base saturation.	61C
	Summits	Very deep soil with intermittent fragipans; moderately well to well drained; loamy-skeletal/clayey and loamy-skeletal; low base saturation.	80C
	Shoulder/Shoulder Ridges	Very deep soil with intermittent fragipans; moderately well to well drained; loamy-skeletal/clayey and loamy-skeletal; low base saturation.	80D
	Backslopes	Very deep soil with few intermittent fragipans on lower side slopes; well drained; loamy-skeletal and loamy-skeletal/clayey; low base saturation.	80F
	Benches (Cryp Reef)	Very deep soil with intermittent fragipans at 20 to 40"; moderately well drained; fine-loamy; low to medium base saturation.	72C, 72D
Lower Gasconade (Van Buren)	Shoulder Ridges	Shallow soils, well drained; loamy-skeletal; high base saturation; >50% rock outcrop.	71D
	Shoulder Ridges	Shallow to moderately deep soils; moderately well to well drained; very fine; high base saturation; 10 to 50% rock outcrop.	81D
	Shoulder Ridges	Deep to very deep soils; well drained; loamy-skeletal/clayey and loamy skeletal; low to high base saturation.	82D
	Backslopes	Shallow soils, well drained; loamy-skeletal; high base saturation; >50% rock outcrop.	71F
	Backslopes	Shallow to moderately deep soils; moderately well to well drained; very fine; high base saturation; 10 to 50% rock outcrop.	81F
	Backslopes	Deep to very deep soils; well drained; loamy-skeletal/clayey and loamy skeletal; low to high base saturation.	82F

Figure 3.—*Integrated Soil Map Units on the MOFEP Sites (Meinert 1997).*

Figure 3.—Continued **Current-Eleven Point River Hills LTA**



GEOLOGY	LANDFORM	SOIL CHARACTERISTICS	MAP UNIT
Lower Gasconade (Continued)	Benches	Deep to very deep; moderately well drained; loamy-skeletal/clayey and very-fine; low to high base saturation.	89C
	Benches	Deep to very deep; moderately well drained; loamy-skeletal/clayey and very-fine; low to high base saturation.	89D
	Benches	Very deep soils with intermittent fragipans at 20 to 40"; moderately well drained, fine-loamy; low to medium base saturation.	73C
	Benches	Very deep soils with intermittent fragipans at 20 to 40"; moderately well drained; loamy skeletal and loamy-skeletal/clayey; low to medium base saturation.	73D
Eminence/ Gunter	Shoulder Ridges	Shallow soils; well drained; very fine; high bases; >50% rock outcrop.	70D
	Shoulder Ridges	Shallow to deep soils; well drained; very fine; high base saturation; 10 to 50% rock outcrops.	74D
	Shoulder Ridges	Deep to very deep soils; well drained; loamy skeletal/clayey and loamy skeletal; medium to high base saturation.	75D
	Backslopes	Shallow soils; well drained; loamy skeletal; high bases; >50% rock outcrop.	70F
	Backslopes	Shallow soils; well drained; very fine; high base saturation; 10 to 50% rock outcrop.	74F
	Backslopes	Deep to very deep soils; well drained; loamy skeletal/clayey and loamy skeletal; medium to high base saturation.	75F
Hillslope Sediments	Footslopes	Very deep soils; moderately well drained and well drained; fine-loamy; low base saturation.	45D
Alluvium	Upland Drainage	Very deep soils; well drained; loamy-skeletal; medium base saturation.	27
	Strath Terraces	Very deep soils; moderately well drained; fine-loamy; low to medium base saturation.	41D
	Terraces	Very deep soil; well drained; fine-loamy to loamy-skeletal; low to medium base saturation.	15
	Terraces	Very deep soils; somewhat excessively drained; loamy-skeletal; coarse-loamy; low to medium base saturation.	18
	Alluvial Fans	Very deep soils; well drained; loamy-skeletal; low to medium base saturation.	42D
	Floodplains	Very deep soils; excessively well drained; loamy-skeletal and coarse-loamy; low to medium base saturation.	31

the other strata. Residuum from dolomites in these formations is chert-free compared to the other strata. Residuum from dolomites in these formations is clayey, but the depth to clay and clay mineralogy vary with parent material and landform.

Strata within these formations also affect landform shape or occurrence in the MOFEP study region. Midslope structural benches in the Current-Black River Breaks LTA occur primarily on the Gunter sandstone member of the Lower Gasconade formation. Gunter sandstones are more resistant to weathering than the surrounding strata. The Cryptozoan reef chert bed of the Upper Gasconade formation controls the occurrence of structural benches when located in mid slope and low slope positions, and it controls the elevation of summits and ridges when located in high slope positions. Sinkholes are most common in the Roubidoux formation and form as underlying Upper Gasconade dolomites partially dissolve and collapse.

The landforms and geologic strata used to hierarchically and systematically stratify the landscape, as well as important soil characteristics and map units, are summarized in figure 3. Forty-three map units were developed for the MOFEP study area, but only common units are illustrated in figure 3. There was considerable variation in soil depths, fragipan occurrence, drainage class, soil family level classification, base saturation, and degree of rock outcropping within each geo-landform. Several soil map units within each geo-landform were created to accommodate some of this variation (fig. 3). However, considerable soil variation occurs *within* soil map units and is described in the soil mapping report (Meinert 1997).

Despite the degree of variation in soil properties, some meaningful generalizations can be drawn. Soils of Roubidoux and Upper Gasconade summits, shoulders, and backslopes are typically very deep cherty silt loams with few rock outcrops, intermittent fragipans, and low base saturation; many of these soils are classified as Ultisols. In contrast, while soils of Lower Gasconade and Eminence shoulder ridges, backslopes, and benches are mainly deep, they have higher base saturation, more variable in depths, and many rock outcrops. Most soils in these geo-landforms are classified as Alfisols. Flat summit and bench landforms often have deep soils with a silty surface horizon and frequent fragipans. Alluvial soils on upland drainages, terraces, and floodplains are deep, coarse-textured, and have medium base saturation (fig. 3).

Patterns in Landform, Geology, and Soil of Landtype Associations and MOFEP Sites

As pointed out earlier, MOFEP sites occur within two distinct Landtype Associations (LTA's): the Current-Black River Breaks LTA (sites 1-6, and 9) and the Current-Eleven Point River Hills LTA (sites 7 and 8). Soil mapping efforts revealed distinctive patterns in landform, geology, and soils between these LTA's and consequently, between MOFEP sites. These patterns are illustrated in figure 3 and are summarized below.

MOFEP sites 1-6, and 9 are in the Current-Black River Breaks LTA. This LTA is characterized by down cutting into bedrock, largely due to proximity to the Current River. Local relief is 300 to 450 ft (90 to 140 m). The Roubidoux formation is restricted to the highest summits, ridges, and backslopes; the Upper and Lower Gasconade formations make up most of the backslopes; and the Eminence formation materials commonly make up the lower backslope. Quaternary loess deposits are confined mainly to isolated summits or broad benches. Narrow, undulating ridges, steep backslopes, and narrow sinuous valleys are typical of landforms in the Current-Black River Breaks LTA. In addition, structural benches supported by the Gunter sandstone are common in midslope positions. Relatively narrow, alluvial floodplains have Quaternary alluvial deposits, consisting of gravel, sand, and to a lesser degree silts. While water-losing stretches of stream are common in the Roubidoux and Upper Gasconade stream reaches, water-gaining streams are common in the Lower Gasconade and Eminence materials.

Deep, loamy-skeletal soils with low base saturation (fig. 3; map units 63,80) formed in Roubidoux and Upper Gasconade residual materials dominate the ridges and upper backslopes in the Current-Black River Breaks LTA. Higher base saturation soils (Alfisols), with clays nearer the surface (fig. 3; map units 82,89,75) are associated with the Lower Gasconade and Eminence landforms. Variable depth, relatively shallow soils with bedrock outcrops (fig. 3; map units 70,71,74,81) occur frequently within the Current-Black River

Breaks LTA, especially in association with the Lower Gasconade and Eminence formations. The Gunter bench has mainly deep, high base saturation soils just below the backslope (fig. 3; map unit 89) and deep, highly weathered, low base saturation soils formed in loess and residuum on its broader, flatter positions (fig. 3; map unit 73). Footslopes, terraces, and bottoms commonly have very deep, colluvial and alluvial soils with texture, drainage, and base saturation varying with parent material (fig. 3; map units 42,45,15,27,18,31,41).

Sites 7 and 8 occur within the Current-Eleven Point River Hills LTA, which is characterized by more gentle relief (150 to 250 ft [45 to 75 m]) and less geologic complexity than the Breaks. The Roubidoux and Upper Gasconade formations make up all of the Hills landscape. Broad, flat ridges are commonly mantled in Quaternary loess deposits. Narrower ridges and upper backslopes are mainly in very deep, highly weathered Roubidoux materials, while middle and lower backslopes are in Upper Gasconade materials. Slopes are more gentle and valley bottoms are wider and less sinuous than in the Breaks. The Cryptozoan Reef forms less prominent structural benches on the lower slopes or occurs across valley bottoms in this LTA. Most stream reaches are water-losing.

There are fewer soil map units in the Hills than in the Breaks. Deep, skeletal, cherty silt loams confined to the highest parts of the Breaks (map unit 63), make up a majority of the soils in the Hills. Sandier textures, associated with the Roubidoux formation, occur. Broad summits, only rarely found in the Breaks, commonly have a silt cap with deep, loamy, ultic soils and fragipans (fig. 3; map unit 61). Deep, higher base soils (fig. 3; map units 82,89) do occur in the Gasconade portion of the landscape. Soils on the Cryptozoan reef benches are very deep, loamy skeletal with occasional fragipans (fig. 3; map unit 72). Variable depth soils with frequent bedrock outcrops (fig. 3; map units 71,81) are less common in the Hills LTA, but are associated with the Upper Gasconade formation.

Vegetation Patterns for Landtype Associations and MOFEP Sites

Both the Hills and Breaks LTA's are largely forested in oak and oak-pine timber types. The composition and structure vary with landscape position and soil-geo-landform environment. Some of these relationships are described in other papers in this volume (Kabrick *et al.* 1997, Grabner *et al.* 1997). Others are being further investigated by the Ecological Classification System Project (Nigh and Amelon 1995). Current observations indicate that mixed oak-pine forests are most prevalent on the deep, ultic soils in both LTA's. Shortleaf pine occurs in mixtures primarily with scarlet oak (*Quercus coccinea*) and black oak (*Q. velutina*) on these sites. Huckleberry (*Vaccinium stamineum*) is a common associate of these forests. While the current presence of pine is variable, old pine stumps indicate that the species was once associated with these conditions. Because the deep, ultic soils are strongly associated with landforms in the Roubidoux and Upper Gasconade materials, this type of mixed oak-pine forest is widespread across sites in the Current-Eleven Point Hills LTA. These site and forest conditions appear less widespread on sites in the Current-Black River Breaks, where they occur most often on ridges and exposed upper backslopes, and on the Gunter bench. Geo-landforms with deep alfic soils appear to have a lower pine component and more abundant white oak (*Q. alba*). These conditions are more frequent in the Current-Black River Breaks LTA. Soils with variable depth to bedrock support glade and savanna complexes on exposed slopes and mixed oak-hardwood forest on protected slopes. Chinkapin oak (*Q. muehlenbergii*), red oak (*Q. rubra*), sugar maple (*Acer saccharum*), and bitternut hickory (*Carya cordiformis*) are more common here and on the more mesic bottomland sites. Again, these variable depth conditions are more prevalent in the Current-Black River Breaks.

Differences within and between these two LTA's help explain some of the variation in the baseline MOFEP data. Further analysis of relationships between geology, landform, soil, and vegetation will lead to the development of a refined of ecological classification system for the MOFEP sites and surrounding regions.

DEVELOPMENT OF ECOLOGICAL LANDTYPES (ELT'S) AND ELT-PHASES FOR MOFEP

Ecological landtypes (ELT's) and their phases are the "finest scale" categories in the ECS heirarchy (table 1). Initial stratification of the MOFEP sites into ELT's relied on definitions developed for Mark Twain National Forest lands (Miller 1981). Table 3 lists the ELT's delineated

Table 3.—*Initial ELT Definitions on MOFEP.*

ELT	Definition
3	**Landform**: High Flood Plain, Low Terrace; **Aspect:** Neutral; **Percent Slope:** 0-4; **Soil Series:** Ashton, Secesh, Huntington, Gladden, Razort, Elk; **Vegetation Community:** Mesic bottomland forest
5	**Landform:** Upland Waterway; **Aspect:** Neutral; **Percent Slope:** 0-4; **Soil Series:** Midco, Elsah, Cedargap; **Vegetation Community:** Dry bottomland forest
6	**Landform:** Upland Waterway; **Aspect:** Neutral; **Percent Slope:** 0-4; **Soil Series:** Midco, Elsah, Cedargap; **Vegetation Community:** Dry-mesic bottomland forest
7	**Landform:** Toe Slope; **Aspect:** All; **Percent Slope:** 0-14; **Soil Series:** Clairborne, Peridge, Mindale, Viraton, Crider; **Vegetation Community:** Mesic forest
11	**Landform:** Ridge; **Aspect:** Neutral; **Percent Slope:** 0-8; **Soil Series:** Clarksville, Coulstone, Poynor, Doniphan; **Vegetation Community:** Dry chert forest
15	**Landform:** Flat; **Aspect:** Neutral; **Percent Slope:** 0-8; **Soil Series:** Captina, Macedonia, Doniphan, Viraton; **Vegetation Community:** Dry chert forest
17	**Landform:** Side Slope; **Aspect:** South and West; **Percent Slope:** 8-99; **Soil Series:** Clarksville, Coulstone, Poynor, Doniphan, Ocie; **Vegetation Community:** Dry chert forest
18	**Landform:** Side Slope; **Aspect:** North and East; **Percent Slope:** 8-99; **Soil Series:** Clarksville, Coulstone, Poynor, Doniphan, Ocie; **Vegetation Community:** Dry-mesic chert forest, Dry-mesic sand forest
19	**Landform:** Side Slope; **Aspect:** South and West; **Percent Slope:** 8-99; **Soil Series:** Bardley, Opequon, Gatewood; **Vegetation Community:** Glade savanna
20	**Landform:** Side Slope; **Aspect:** North and East; **Percent Slope:** 8-99; **Soil Series:** Bardley, Opequon, Gatewood; **Vegetation Community:** Dry mesic limestone forest
21	**Landform:** Side Slope; **Aspect:** All; **Percent Slope:** 5-99; **Soil Series:** Gasconade, Rockland; **Vegetation Community:** Dolomite glade, Limestone glade
22	**Landform:** Side Slope; **Aspect:** All; **Percent Slope:** 5-99; **Soil Series:** Gasconade, Rockland; **Vegetation Community:** Xeric limestone forest
23	**Landform:** Side Slope; **Aspect:** All; **Percent Slope:** 5-99; **Soil Series:** Gasconade, Rockland; **Vegetation Community:** Dry limestone forest

on the MOFEP sites and their definitions. Note that ELT definitions rely on landforms, aspect, soil, and vegetation factors. Using these definitions, we initially stratified the MOFEP sites into 12 ELT's. Because little information on soils or vegetation of MOFEP sites was available at the time of the initial stratification, ELT delineation was based mainly on landform and aspect. Figure 4 illustrates the resulting stratification. While landform and aspect do describe some of the obvious ecological environments within the MOFEP sites, it is apparent that many important relationships between landform, geology, soil, and vegetation are not described by this initial stratification.

The Missouri Ecological Classification System Project (Nigh and Amelon 1995) is currently cooperating with MOFEP scientists to further refine ELT and phase level relationships and definitions in the Current River Hills Subsection. The project is building upon concepts developed through the MOFEP soil-geo-landform mapping effort. Study areas are being stratified by geo-landform and aspect, and are being used for sampling soils and vegetation and for identifying and testing relationships. The objective of the project is to provide a rigorously tested set of ELT and ELT-Phase definitions for the subsection by October 1998.

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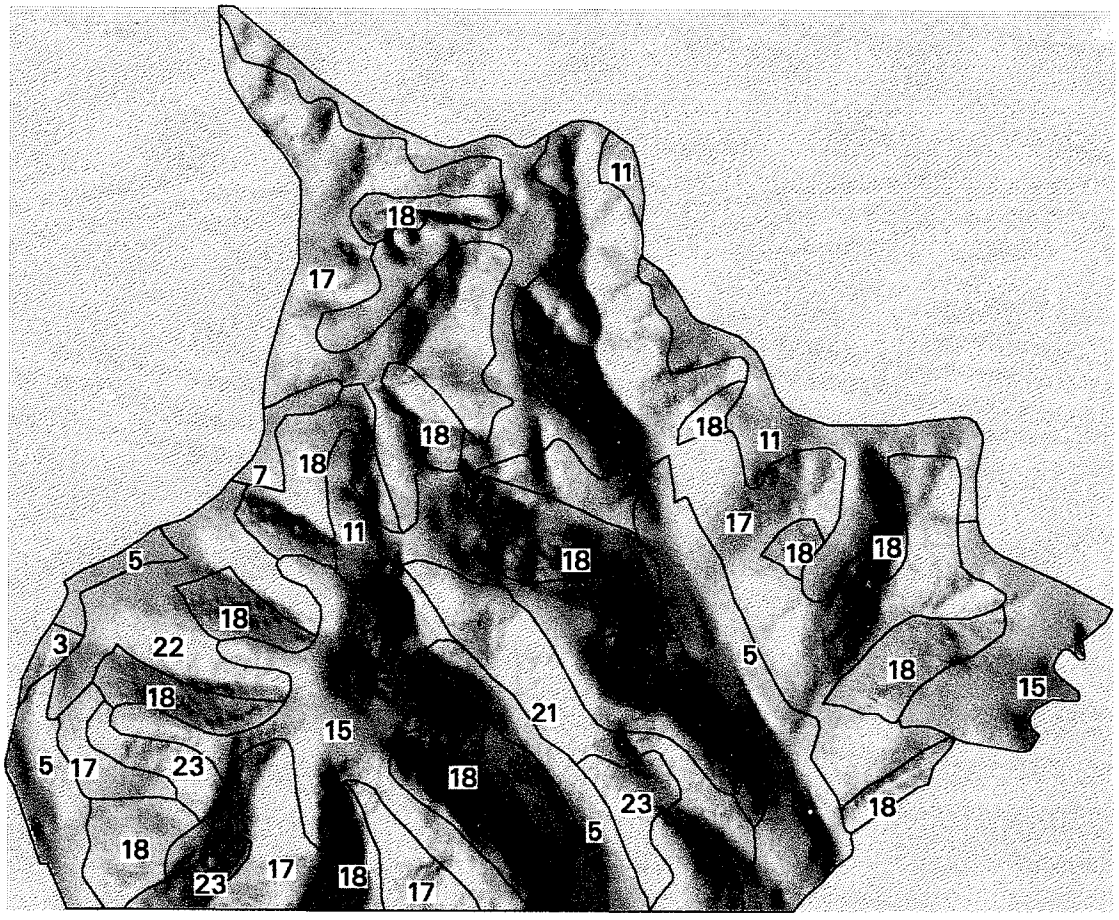

Figure 4.—*Initial ELT Stratification on MOFEP Site 8.*

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