**MOUNTAINS LANDFORM ASSOCIATIONS**

**Mountain(s)** [Common Landform (singular), Landscape Term (plural)] (a) Any part of the Earth's crust higher than a hill, sufficiently elevated above the surrounding land surface of which it forms a part to be considered worthy of a distinctive name, characterized by a restricted summit area (as distinguished from a plateau), and generally having comparatively steep sides and considerable bare-rock surface; it can occur as a single, isolated eminence, or in a group forming a long chain or range, and it may form by earth movements, erosion, or volcanic action. Generally, a mountain is considered to project at least 300 m above the surrounding land. (b) Any conspicuous or prominent elevation in an area of low relief, esp. one rising abruptly from the surrounding land and having a rounded base. (c) A region characterized by mountains; term usually used in the plural. (Bates and Jackson, 1995)

No one process responsible for construction of mountains. They can be uplifted, tectonic, subduction of plates, folding, uplift, up and down warping of the mantle, inflation of molten lower crustal (batholiths), etc. Erosion of mountain systems occurs over time. The rate of erosion is dependent on the geomorphic process, the underlying rock structure, and the climate, including both freeze thaw and the amount and intensity of precipitation and runoff.

Mountains can be labeled low, medium, or high. Mountains classes of Landform Associations are initially differentiated by relief and roughness class into low, medium, high, based on the Meybeck[[1]](#footnote-1) global mountain scheme. **Mountain** is defined by mean elevation, exceeding 500 m, roughness exceeds 20 at low and medium altitudes (500-2000 m) and 40 at high and very high altitudes (2000-4000 m and 4000-6000 m). For convenience sake the word medium is not used in LfA names. For example there may be Glacial High Mountains, Glacial Mountains, and Glacial Low Mountains which all exhibit similar characteristics but have higher to lower relief classes respectively. Glacial Mountains would be the medium relief class.

Mountains are further defined and distinguished based on morphology visible on a 25m DEM hillshade, including the pattern and density of drainages, depth of drainages, overall morphology of the area between the drainages, evidence of a strong imprint of a surficial process such as glaciation, and presence of visible underlying rock structure. The names of mountains LfAs are the concatenation of a distinguishing geomorphic feature prefix(es) with the Meybeck class.

Mountains have simple to very complex forms that have arisen due to inherited rock structure, rock history, and are the net result of local to regional spatial scales of competing rates of upbuilding/uplift and downgrading/erosion. From a single conical stratovolcano mountain to a range of mountains, a mountain or mountains will have an inherited history from weathering and degradation of the underlying stack of earth materials that forms them. Vegetation, habitat, water interception, collection and transport will share a similar history in the same type of uplift and rock.

Serpentinitic is a term attached to the landform association if the base geology is peridotite or serpentine (from geologic maps. The resultant chemical (Mg/Ca) imbalance may or may not dominate the above ground vegetation assemblages. In some areas the chemical imbalance that results from this geology may be obscured by landslide geomorphology which neutralized the affect by mixing multiple parent materials.

**Fluvial Processes**

**Megaflood Scoured Uplands** are low mountain areas adjacent to the Columbia River where soil and unconsolidated geologic sediments were removed or swept away by Missoula Floods floodwaters. Much bedrock is exposed on this landform. Where they exist, soils are generally shallow, however, some deeper pockets remain downstream of prominent topographic features that protected them from the flood waters or caused eddy deposits.

**Glacial Processes**

***Glacial***

**Alpine Glacial Mountains** are the mountaintops that were above the maximal depth level but within the area covered by the Cordilleran Continental Icesheet. The terrain was carved by alpine glaciers is glacially scoured, with hanging valleys, large U-shaped valleys, with vertical to near-vertical slopes and bedrock common throughout.

Soils range from shallow soils to rock or exposed rock. In many locations ice has cleared out all sediment. Water routing across this Landform Association is chiefly sheetwash that is slope dependent, with common ponds and lakes in low-lying areas. Shallow glacial soils are droughty even in rainy areas. What keeps them from drying out is replenishment from precipitation. These landscapes are most vulnerable to climate change. With a reduction in precipitation the glacial soils behave like ones in arid climates.

**Angulate Glacial Mountains** are areas shaped by present and past glaciers with bedrock structure and fracture patterns regulating erosional processes. The terrain is glacially scoured with cirque basins and scoured valleys apparent in the upper landscape positions. In many locations ice has scoured mountainsides and left recessional moraines in lower valley positions. Angulate Glacial Mountains have a strong prominent stream system of drainages at other than right angles. Orientations of the valleys and tributaries have an angulate pattern identified by sharp angles that follow underlying bedrock structure (bedding, foliation, fractures and joints). These drainage patterns follow planes of weakness in the rock. In angulate areas, supply of rock to stream channels is greater than other areas. Depending on the competence of the rock, as it erodes, it cleaves along fracture planes as a result of physical weathering processes. Water routing along drainages follows dominantly straight reaches which may lead to flashy discharges during storms.

Soils range from shallow soils to rock or exposed rock to deeper gravelly soils on lower slope positions and in valley bottoms. Runoff from this Landform Association is rapid due to shallow soils and strong bedrock features. Water will be stored on lower slope glacial depositions and in valley bottom sediments.

**Cirque Basin Mountains** are mountainous landscapes that have obvious imprints of current or past glaciation. Glacial scour and downslope movement of the glaciers have created cirque basins. Cirque basins are semi-circular bowl-like excavation in a hanging valley or at the head of a valley. An aerial view of a cirque shows a horseshoe like shape with the open end of the shoe pointing away from the steep headwall and surrounding side slopes. This open end of the shoe is a raised threshold often supplemented by a recessional moraine. The closed depression of the cirque frequently hosts a meadow, lake or tarn.

In the Northern Hemisphere cirque basins usually have a north to northeastern aspect. At higher elevations or latitude cirque aspect can be to any point of the compass.

**Cirque Basin and Icefields** are mountain areas that hosted extensive icefields resulting in interconnected valley glaciers which scoured high elevation landforms. Alpine glaciers moved down valley from these icefields and resulted in cirque features which are semi-circular bowl like excavation in a hanging valley or the head of a valley. An aerial view of a cirque shows a horseshoe like shape with the open end of the shoe pointing away from the steep headwall and surrounding side slopes. This open end of the shoe is a raised threshold often supplemented by a recessional moraine. The closed depression of the cirque frequently hosts a meadow, lake or tarn. In the Northern Hemisphere cirque basins usually have a north to northeastern aspect.

The Icefield landform is the result of freeze thaw cycles and mass wasting of the long gone ice sheet. The terrain is usually worn down to bedrock. These areas host zero and first order drainages. The mass wasting and freeze thaw cycles of nivation features which include erosion of the ground beneath and at the sides of a snow banks, mainly as a result of alternate freezing and thawing which left small dimples and a bowl-like trend of the shoulder to footslope transitions. Rubble ridges from the receding glacier toe and till benches remain. Talus is present; there is little if any vegetation or soil. This landform has a flashy runoff regime and droughty soils which are reliant on continual moisture.

**Cirqued Glacial High Mountains** are mountainous areas that have obviously been sculpted by both current and past glaciation. High mountains have significant relief above a local base. These are the most prominent ridge systems in the landscape. Cirque features are semi-circular bowl like excavation in a hanging valley or the head of a valley. An aerial view of a cirque shows a horseshoe like shape with the open end of the shoe pointing away from the steep headwall and surrounding side slopes. In the Cirqued Glacial High Mountain Landform Associations, adjacent cirques have failed to coalesce into a basin and have formed spectacular arêtes and impressive relief in the sculpted mountainsides. These areas will lack the cirque lakes and meadows found in closed cirque basin landscapes.

**Cirqued Glacial Mountains** are mountainous areas with lower relief than Cirqued Glacial High Mountains. They have obviously been sculpted by both current and past glaciation. Cirque features are semi-circular bowl like excavation in a hanging valley or the head of a valley. An aerial view of a cirque shows a horseshoe like shape with the open end of the shoe pointing away from the steep headwall and surrounding side slopes. In the Cirqued Glacial Mountain Landform Associations, adjacent cirques have failed to coalesce into a basin and have formed spectacular arêtes and impressive relief in the sculpted mountainsides. These areas will lack the cirque lakes and meadows found in closed cirque basin landscapes.

**Glacial High Mountains** are areas entirely shaped by present and past glaciers. High mountains have significant relief above a local base. These are the most prominent ridge systems in the landscape. Active glaciers are still present within this map unit, as well as icefields, permanent snowfields, and widespread evidence of nivation features which include erosion of the ground beneath and at the sides of a snow banks, mainly as a result of alternate freezing and thawing. The terrain is glacially scoured, with hanging valleys, large U-shaped valleys, with vertical to near-vertical slopes in bedrock common throughout.

A variety of soil types are present in Glacial High Mountain Landform Associations. Soils range from shallow soils to rock or exposed rock. In many locations ice has cleared out all sediment. Only in the glacial valleys do you get deep glacial soils. Shallow glacial soils are droughty even in rainy areas. What keeps them from drying out is replenishment from precipitation. These landscapes are most vulnerable to climate change. With a reduction in precipitation the glacial soils behave like ones in an arid climate.

**Glacial Low Mountains** are areas shaped by past glaciers with scour features evident on Northerly aspects. Other portions of Glacial Low Mountains lack the obvious glacial scour features and instead have nivation features which include erosion of the ground beneath and at the sides of a snow banks, mainly as a result of alternate freezing and thawing which left small dimples and a bowl-like trend of the shoulder to footslope transitions. Ridge systems are broad, slope gradients are low and slope lengths are short in this landscape. Residual soils store moisture on the low slope angles and weather to moderately deep soils. Soil Taxa include Alfisols and Andisols.

**Glacial Mountains** are areas entirely shaped by present and past glaciers and have obvious signs of glacial scour. Ridges have been sculpted by alpine glacial movement, steep cirque basin or glacial valley headwalls compose the majority of this mapping unit.

A variety of soil types are present in Glacial Mountain Landform Associations. Soils range from shallow soils to rock or exposed rock. In many locations ice has cleared out all sediment. Shallow glacial soils are droughty even in rainy areas. What keeps them from drying out is replenishment from precipitation. These landscapes are most vulnerable to climate change. With a reduction in precipitation the glacial soils behave like ones in an arid climate.

**Glacial Stratal High Mountains** are areas entirely shaped by present and past glaciers. High mountains have significant relief above a local base. These are the most prominent ridge systems in the landscape. These areas have morphologies which reflect the underlying rock structure, which is exposed as a consequence of degradation or denudation of an upland area by glacial and, to a lesser extent, hillslope processes. Glacial sculpting of the mountains reveals obvious layering of the underlying rock structure principally expressed as dip and anti-dip slopes. Synonymous terms used for these features are cuesta and cuestaform. Anti-dip slopes are benchy, rocky and relatively steep slopes. Following the colluvium downhill on an anti-dip slope you find a repeating pattern of bedrock outcrops with intervening areas of accumulated sediment. Habitat and vegetation distribution corresponds to this pattern. Dip slopes, on the other hand, are broad plains with shallow soils and broad expanses of exposed rock. Water routing across this Landform Association is chiefly sheetwash that is slope dependent. Potential vegetation and habitat are sparse across the sloping plains on rock, whereas vegetation is dense in the cirques and small valleys.

**Glacial Stratal Mountains** are areas entirely shaped by present and past glaciers. These areas have

morphologies which reflect the underlying rock structure, which is exposed as a consequence of degradation or denudation of an upland area by glacial and, to a lesser extent, hillslope processes. Glacial sculpting of the mountains reveals obvious layering of the underlying rock structure principally expressed as dip and anti-dip slopes. Synonymous terms used for these features are cuesta and cuestaform. Anti-dip slopes are benchy, rocky and relatively steep slopes. Following the colluvium downhill on an anti-dip slope you find a repeating pattern of bedrock outcrops with intervening areas of accumulated sediment. Habitat and vegetation distribution corresponds to this pattern. Dip slopes, on the other hand, are broad plains with shallow soils and broad expanses of exposed rock. Water routing across this Landform Association is chiefly sheetwash that is slope dependent, with common ponds and lakes in low-lying areas. Potential vegetation and habitat are sparse across the sloping plains on rock, whereas vegetation is dense in the cirques and small valleys.

**Glacialscoured High Mountains** are those high mountains that were subject to significant glacial scour which smoothed and excavated the ridgetops and sideslopes. High mountains have significant relief above a local base. These Glacialscoured High Mountains have been scoured by ice to such an extent that the degree of smoothing includes knocking down ridges and in-filling of local or former fluvial valleys. The degree of scour is evident in the smooth topography of the area. They have moraine-like landforms that are rock cored. The underlying bedrock structure is very evident with resistant bedrock formations forming ridges and shelves and other distinct stratal landform features. Slopes are typically continuous and planear from toe to ridge and are distinctly smoother than adjacent mountain areas. Soil and regolith have been stripped off of these areas. Deeper soils occur in local areas where in-filling of till occurred otherwise there are thin soils on planear slopes.

**Glaciofluvial Mountainsides** formed as a result of sudden release of meltwaters of Pleistocene glaciers. Areas of glacially deposited sediments and scours sorting of sediments by subsequent fluvial processes are mixed in this mapping unit. Parent streams carried heavy sediment loads. As a consequence, thick, sandy to gravelly deposits can be found among areas of scour. Coarse rounded cobbly and bouldery deposits are found.

**Icesheet Mountains** are areas that have complex glacial origin. Alpine glaciers were run over by the Cordilleran Icesheet. With retreat of the ice sheet, they may or may not have gone back to alpine glaciers. This process may have occurred repeatedly. In areas of alpine glaciers, arêtes, cols and other intra glacier precipitous ridges occur. The effect of continental icesheet was to scour these off. Distinguishing features include pronounced alpine glacier topography with intervening ridges glacially scoured and smoothed so that they are not as prominent. These areas are less prone to producing rock debris than the areas with the alpine glacial alone without scouring. Rock debris does not accumulate at base of valley walls. Sheet flow dominates on the entire slope, all the way to ridge segments.

**Icesheet Uplands** are an extensive area of higher land that was scoured by the Cordilleran Icesheet. Icesheet Uplands do not have glacial valleys mapped in them. They tend to be in a lower landscape position than Icesheet Mountains. Icesheet Upland occur on the old piedmont plains that fronted the Icesheet Mountains, typically where the original glacial valleys under alpine glacial influence ended. They may have old moraine features. Icesheet Uplands are low relief, undulating terrain that have quite a bit of compacted till in places from the Cordilleran Icesheet. Water will stay on landscape due to low slope angles. The drainage networks may not be fully integrated; as a result, some areas will be moist. In pockets there may be lakes and ponds, soils may not be so drought prone. There may be drainages with no outlets that are filled with till deposition.

**Icecaplands** are a relatively new concept in mapping in the Cascades. This is terrain that has hosted or is hosting an ice cap. The terrain is a broadly scoured area and remnant glaciers may be present. The Olympic Mountains and North Cascades are examples of current icecaps. Upland areas show evidence of glaciation of an even greater magnitude than that which formed the adjoining glacial valley. Scouring and some deposition are evident at all elevations. In ranges where volcanism was present the tops of buttes that were extruded under the ice sheet have flat topped, fan or propeller shaped forms as a result of contact with the overlaying ice sheet. The ice sheet sheared the sub-glacial magma flows leaving these distinctly shaped forms. Eskers are left behind, as the ice cap melted. The eskers appear as cobble/sediment ridges and are the remains of deposits left in sub glacial channels. As water flowed under the ice cap there were areas of aggradation. As the ice cap melted these aggraded areas have a higher and linear relief above the scoured surrounding terrain. Eskers can be found ascending ridges as well as along valley floors. Moraines are also present with successive terminal moraines common and forming curvilinear ridges that fan across the landscape for miles. Medial moraines, that indicate the flow lines of glaciers long vanished, are often visible as ridges. Seemingly stranded in the landscape moraines or ice cap margins can indicate the borders of Pleistocene lakes and delineate icecap borderlands, landforms not entirely glacier formed that existed on the glacial margins. Ice cap uplands are mountains that the icecap flowed over and sculpted.

**Paraglacial Low Mountains** are influenced by and directly conditioned by glaciation and deglaciation, though the area is not in direct contact with glacial ice. Low mountains refer to the fact that the land surface is relatively lower in relief than neighboring area or other similar landform group. Paraglacial Low Mountain features are constructed by geomorphic processes active during the transition from glacial to post-glacial conditions such as deposition of debris washed off the newly exposed ice-free landscape up slope and deposited by high stream discharge associated with the retreating ice. The Landform Association includes periglacial landforms; pertaining to processes, conditions, areas, climates, and topographic features occurring at the immediate margins of glaciers and ice sheets, and influenced by cold temperature of the ice. Paraglacial Low Mountains have nivation features which include erosion of the ground beneath and at the sides of a snow banks, mainly as a result of alternate freezing and thawing which left small dimples and a bowl-like trend of the shoulder to footslope transitions. These features are present particularly on the north sides of ridges and headwalls of north facing slopes.

**Paraglacial Margins** occur around the edges of glacial mountains. These are locally complex landforms that result from more than one origin. Paraglacial Margins are those areas that include remnants of moraines and areas just beyond moraines where topography may have been directly or indirectly influenced by ice, ice borne debris and fans and other sediments that flowed off of melting glaciers. Catastrophic floods and collapse from abrupt glacial melt events and proto-glacial landforms are in evidence with meltwaters breaching moraines and flowing over the landscape. Paraglacial margins also include the patterned ground which developed from being adjacent to glaciers (frost heave). Patterned ground is the distinct, and often symmetrical geometric shapes formed by ground material in [periglacial](https://en.wikipedia.org/wiki/Periglacial) regions it is associated with [frost heaving](https://en.wikipedia.org/wiki/Frost_heaving), which refers to expansion that occurs when wet, [fine-grained](https://en.wikipedia.org/wiki/Fine-grained), and [porous](https://en.wikipedia.org/wiki/Porous) soils freeze. Paraglacial margins also include push-up deformational ridges resulting from ice movement.

**Paraglacial Mountains** are influenced by and directly conditioned by glaciation and deglaciation, though the area is not in direct contact with glacial ice. Features are constructed by geomorphic processes active during the transition from glacial to post-glacial conditions such as deposition of debris washed off the newly exposed ice-free landscape up slope and deposited by high stream discharge associated with the retreating ice. The Landform Association includes Periglacial landforms; pertaining to processes, conditions, areas, climates, and topographic features occurring at the immediate margins of glaciers and ice sheets, and are influenced by the cold temperature of the ice. Sediment scour and deposition patterns leave a mix of soil depths and textures in this map unit. Glacial cobbles and boulders are prominent in this landscape.

**Paraglacial Uplands** are low gradient mountainous areas that were influenced by and directly conditioned by glaciation and deglaciation, though the area was not in direct contact with glacial ice. Features are constructed by geomorphic processes active during the transition from glacial to post-glacial conditions such as deposition of debris washed off the newly exposed adjacent ice-free landscape and deposited by high stream discharge associated with the retreating ice. The map unit also includes topographic features occurring near margins of glaciers and ice sheets that were influenced by cold temperature of the ice such as freezing and thawing and fracture of underlying bedrock.

***Glaciated***

**Glaciated Escarpments** are escarpments that have been shaped by both past glaciers and more recent geomorphic processes. Along peaks and ridges there are indicators of past glacial action. The terrain is glacially scoured with vertical to near-vertical slopes in bedrock common throughout. The slopes are at or greater than the angle of repose and underlain with bedrock. They have significant relief, meet the toe slope at steep angle and generally face a lower angle landscape. They are the result of quaternary faults or a fault scarp line that has weathered back from the fault line presenting a steeply sloping mountain front. The escarpment can also be the product of a tectonic lift or the erosion of a river meander cutting into the mountainside. Competent bedrock overlain by a less competent formation if eroded will show the structural differences that are expressed as an escarpment.

The hydrology on these steep and cliffy landforms is flashy and debris flows and rock fall are common. The soils on the steep slopes are rocky with a few pockets of soil on benches. These pockets support vegetation and habitat for predator and prey species adapted to a vertical environment.

**Glaciated Low Mountains** are areas shaped by past glaciers and masked by more recent geomorphic processes and belong to the low mountain relief class. Glacial processes were active along peaks and ridges. Though marred by degradation, the terrain appears glacially scoured with signatures of cirque basins and scoured ridges. Since the cessation of glaciation in these areas, however, surface, mass wasting (shallow rapid or deep seated earthflow, rockfall, etc.) or fluvial erosion processes have dominated and masked much of the glacial signature of the mid to lower slopes. The landscape is muted and slope angles are low.

Soils in Glaciated Low Mountains are highly variable depending on the scour and deposition and subsequent fluvial and mass wasting erosion.

**Glaciated Mountains** are areas shaped by past glaciers and are somewhat masked more recent geomorphic processes. The terrain is glacially scoured, with hanging valleys, cirque basins, icefields, and large U-shaped valleys, with vertical to near-vertical slopes in bedrock common throughout.. Since the cessation of glaciation in these areas, however, surface, mass wasting (shallow rapid or deepseated earthflow, rockfall, etc.) or fluvial erosion processes have dominated and masked much of the glacial signature of the mid to lower slopes.

Soils in Glaciated Mountains are highly variable depending on the scour and deposition and subsequent fluvial and mass wasting erosion.

**Mass Wasting Processes**

**Collapsed Broad Crested Mountains** are indicative of large-area landslides or earthflow, drainage patterns may be interrupted. These large landslides have formed in a once Broad Crested Mountain. Broad Crested Mountains are rounded, broad ridged mountains. The underlying bedrock rock weathers at consistent rates, there are no resistant rock layers, and as a result, there is no prominent ridge system. Broad Crested Mountains have accumulations of soil on the low angle bedrock slopes that collects water which enhances soil development and water storage. These soils are thicker and consequently offer a good medium for grasses, forbs, shrubs, and trees. With the consistent bedrock underlay, water crosses the landscape mainly as sheet flow and there are few deep channels or ravines that develop. Runoff is retained in this landscape and does not lead to flashy stream flows.

**Collapsed Escarpments** are escarpments where many large landslides have collapsed large areas of the escarpments. The landslides may be from the pre-historic past or recent and current developments. The landslide areas have a hummocky appearance and water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. The upper area of intact bedrock are represented by a linear rock exposure. The slopes are at or greater than the angle of repose and underlain with bedrock. They have significant relief, meet the toe slope at steep angle and generally face a lower angle landscape. They are the result of quaternary faults or a fault scarp line that has weathered back from the fault line presenting a steeply sloping mountain front. The escarpment can also be the product of a tectonic lift or the erosion of a river meander cutting into the mountainside. Competent bedrock overlain by a less competent formation if eroded will show the structural differences that are expressed as an escarpment.

The hydrology on these steep and cliffy landforms is flashy and debris flows are common. The soils on the steep slopes are rocky with the few pockets of soil on benches. These pockets support vegetation and habitat for predator and prey species adapted to a vertical environment. The soils on the landslide area are variable with deep pockets developing from the enhanced water storage.

**Collapsed Glacial Mountains** are areas shaped by past glaciers yet have obvious signs of glacial scour that have been subject to large-scale landslide events. Ridges have been sculpted by alpine glacial movement, steep cirque basin or glacial valley headwalls are evident in this mapping unit.

Many large landslides that have collapsed large extents of mountainsides are present within this landform association. Landslide areas can cover many miles and may be from the pre-historic past or a recent and current development. Collapsed mountains consist of active and inactive zones. Many of these landslides are recognized and the more discreet, well-formed slide areas have been identified in geological maps. Water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of landslides. Sediment and water storage (such as a lake, meadow and or plain - current or historic) is locally significant upstream of landslide toes. Because of irregular slopes and varied surface water availability, this Landform Association has a most diverse upland habitat. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Glacial Stratal Mountains** are areas shaped by past glaciers yet have obvious signs of glacial scour that have been subject to large-scale landslide events. Ridges have been sculpted by alpine glacial movement, steep cirque basin or glacial valley headwalls are evident in this mapping unit. These areas have strong bedrock structural components that have been subject to large-scale landslide events. These areas have morphologies which reflect the underlying rock structure, which is exposed as a consequence of degradation or denudation of an upland area by glacial and, to a lesser extent, hillslope processes. Glacial sculpting of the mountains reveals obvious layering of the underlying rock structure principally expressed as dip and anti-dip slopes. Synonymous terms used for these features are cuesta and cuestaform. Anti-dip slopes are benchy, rocky and relatively steep slopes. Following the colluvium downhill on an anti-dip slope you find a repeating pattern of bedrock outcrops with intervening areas of accumulated sediment. Habitat and vegetation distribution corresponds to this pattern. Dip slopes, on the other hand, are broad plains with shallow soils and broad expanses of exposed rock. This is an almost featureless terrain with few features to orient by. Potential vegetation and habitat are largely invariable across these sloping plains.

Many large landslides that have collapsed large extents of mountainsides are present within this landform association. Landslide areas can cover many miles and may be from the pre-historic past or a recent and current development. Landslide features can consist of active and inactive zones. Many of these landslides are recognized and the more discreet, well-formed slide areas have been identified in geological maps.

Water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of landslides. Sediment and water storage is locally significant. Because of irregular slopes and varied surface water availability, this Landform Association has a diverse upland habitat. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Glaciated Mountains** are areas shaped by past glaciers and are masked by more recent geomorphic processes. Along peaks and ridges there are indicators of past glacial action. The terrain is glacially scoured, with cirque basins. Since the cessation of glaciation in these areas, however, other geomorphic processes have masked much of the glacial signature of the mid to lower slopes. Collapsed Glaciated Mountains are indicative of large-area landslides/mass wasting features that have entrained large extents of mountainsides. Landslide areas can cover many miles and may be from the pre-historic past or a recent and current development. Collapsed mountains consist of active and inactive zones. Many of these landslides are recognized and the more discreet, well-formed slide areas have been identified in geological maps.

Water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of landslides. Sediment and water storage is locally significant. Because of irregular slopes and varied surface water availability, this Landform Association has a diverse upland habitat. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Low Mountains** belong to the low mountain relief class and have many large landslides that have collapsed large extents of mountainsides. Landslide areas can cover many miles and may be from the pre-historic past or a recent and current development. The collapsed features consist of both active and inactive zones. Many of these landslides are recognized and the more discreet, well-formed slide areas have been identified in geological maps. Water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of landslides. Sediment and water storage (such as a lake, meadow and or plain - current or historic) is locally significant upstream of landslide toes. Because of irregular slopes and varied surface water availability, this Landform Association has a most diverse upland habitat. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Mountains**

The dominant features are the many large landslides that have collapsed large extents of mountainsides. Landslide areas can cover many miles and may be from the pre-historic past or a recent and current development. Collapsed mountains consist of active and inactive zones. Many of these landslides are recognized and the more discreet, well-formed slide areas have been identified in geological maps. Sides of whole mountains and entire ranges can be solely landslide derived. Water routing through this landscape may be irregular due to recent and on-going slope failure with its accompanying surface and subsurface drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of landslides. Sediment and water storage (such as a lake, meadow and or plain - current or historic) is locally significant upstream of landslide toes. Because of irregular slopes and varied surface water availability, this Landform Association has a most diverse upland habitat. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Stratal Low Mountains** belong to the low mountain relief class and have morphologies reflecting a mass-wasting obviously occurring along exhumed rock structure. Stratigraphy is present and visible in areas less or unaffected by landslides. Erosional exhumation reveals layering of the underlying rock structure, including dip and anti-dip slopes. Anti-dip slopes are benchy, rocky and relatively steep slopes. Transecting down an anti-dip slope one finds a repeating pattern of topographical benches with bedrock outcrops followed by intervening areas of accumulated slope sediment. Habitat and vegetation distribution corresponds to this pattern. In some map units, large rotational landslides are present along anti-dip slopes. Dip slopes, on the other hand, are typically shallower slopes underlain by extensive translational slides. Some of the well-formed slide areas have been identified in published geological maps, but the size and apparent morphological consistency of translational slides with surrounding stratigraphic morphology makes them cryptic. In this map unit, drainages are poorly integrated, leading to variable routing of surface and subsurface water through this type of landscape. Water routing through this landscape is irregular due to recent and on-going slope failure with its accompanying drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of these collapsed mountains. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Collapsed Stratal Mountains** are mountainous areas that have morphologies reflecting a mass-wasting obviously occurring along exhumed rock structure. Stratigraphy is present and visible in areas less or unaffected by landslides. Erosional exhumation reveals layering of the underlying rock structure, including dip and anti-dip slopes. Anti-dip slopes are benchy, rocky and relatively steep slopes. Transecting down an anti-dip slope one finds a repeating pattern of topographical benches with bedrock outcrops followed by intervening areas of accumulated slope sediment. Habitat and vegetation distribution corresponds to this pattern. In some map units, large rotational landslides are present along anti-dip slopes. Dip slopes, on the other hand, are typically shallower slopes underlain by extensive translational slides. Some of the well-formed slide areas have been identified in published geological maps, but the size and apparent morphological consistency of translational slides with surrounding stratigraphic morphology makes them cryptic. In this map unit, drainages are poorly integrated, leading to variable routing of surface and subsurface water through this type of landscape. Water routing through this landscape is irregular due to recent and on-going slope failure with its accompanying drainage diversions and impoundments. These areas are considered as sources of cool water to streams. Sediment recruitment by streams is significant along the margins of these collapsed mountains. The slide areas can hold deep soils, retain moisture and provide micro-climates that offer a variety of excellent resources for numerous floral and faunal communities.

**Dissected Broadcrested Mountains** are rounded broad ridged mountains that have been subject to significant fluvial erosion. The rock weathers at consistent rates, there are no resistant rock layers, and as a result, there is no prominent ridge system. Dissected Broadcrested Mountain landscapes have distinct stream system development with almost radial patterns developing off of a central highpoint. Inter fluvial ridges are rounded as well.

Broad Crested Mountains have accumulations of soil on the low angle bedrock that collect water which enhances soil development and water storage. These soils are thicker and consequently offer a good medium for grasses, forbs, shrubs, and trees.

**Dissected Glacial Low Mountains** are areas shaped by past glaciers with scour features evident on Northerly aspects. Other portions of Glacial Low Mountains lack the obvious glacial scour features and instead have nivation features which include erosion of the ground beneath and at the sides of a snow banks, mainly as a result of alternate freezing and thawing which left small dimples and a bowl-like trend of the shoulder to footslope transitions. Dissected Glacial Low Mountains are now characterized by the degree of fluvial erosion which has resulted in a high degree of dissection of the landscape. Ridge systems are broad, slope gradients are low and slope lengths are short in this landscape. Residual soils store moisture on the low slope angles and weather to moderately deep soils. Soil Taxa include Alfisols and Andisols.

**Dissected Glaciated Mountains** are areas shaped by past glaciers and are somewhat masked more recent geomorphic processes. Fluvial erosion has resulted in a high degree of dissection of the landscape The upper terrain is glacially scoured, with cirque basins and small U-shaped valleys. Since the cessation of glaciation in these areas, however, surface, mass wasting (shallow rapid or deepseated earthflow, rockfall, etc.) or fluvial erosion processes have dominated and masked much of the glacial signature of the mid to lower slopes. Dissected Glaciated Mountains have V-shaped valley walls, planar in form, that are contiguous from ridge-top to valley bottom. It is no longer evident what the landscape was like previously. Some slope angles are greater than repose and are bare rock or outcroppings. Thickest soils gather in valley bottoms and collect in tributary gullies.

**Dissected High Mountains** are mountainous areas below the equilibrium line altitude for ice accumulation to have formed glaciers and that have a high degree of dissection.These areas belong to the “high” relief class. Fluvial erosion and mass wasting over time has resulted in a highly dissected landscape with deep V-shaped valley walls, planar in form, that are contiguous from ridge-top to valley bottom. It is no longer evident what the landscape was like previously. Some slope angles are greater than repose and are bare rock or outcroppings. Thickest soils gather in valley bottoms and collect in tributary gullies.

**Dissected Low Mountains** are mountains with a high degree of dissection.These areas belong to the “low” relief class. Fluvial erosion and mass wasting over time has resulted in a highly dissected landscape with deep V-shaped valley walls, planar in form, that are contiguous from ridge-top to valley bottom. It is no longer evident what the landscape was like previously. The thickest soils gather in valley bottoms and collect in tributary gullies. Saddles along ridges in a dissected landscape can contain small well-defined protected pockets of soil as well.

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**Dissected Verrucated Mountains** are mountainous areas with few deep, V-shaped drainages eroded into uplands with a hummocky, warty morphology. Although the term hummocky is commonly used to describe the overall appearance of this map unit, mass failure cannot be definitely ascribed as the dominant surface process. Origins for this type of Landform Association include ancient landslides that have been eroded, such as exhumed deep-marine landslides incorporated in a bedrock formation, or exhumed ancient volcanic flows in bedrock strata. In this map unit, drainages are poorly integrated, leading to variable routing of surface water through this type of landscape. Because of irregular slopes and aspect, as well as varied surface water availability. Potential vegetation and habitat are quite variable across these map units.

**Incised Low Mountains** are mountains with a low relief class where weathering and erosion are just beginning to alter the topography of the area. The landform has retained most of their original outlines and the majority of their mass. Low stream densities and shallow stream channels occur.

**Low Mountains** are mountains with a low relief class where specific geomorphic development processes are not apparent. These are the “catch-all” landscapes that do not fit into another category. Ridge systems are broad, slope gradients are moderate and slope lengths are short in this landscape. Broad valleys may be present. Residual soils store moisture on the low slope angles and weather to deep and moderately deep soils.

**Smoothcrested Mountains** are areas with relatively low, smooth relief relative to basal area. Roughness is reduced with smooth convex slopes and no readily identifiable divide between catchments. The ridgeline has a low slope and may be a remnant of glacial ice caps or glacial passage. It may be stratified geology with bedrock weathering to bedding plains or stratigraphic breaks that are relatively smooth. The lack of a distinct drainage divide shows as low angle slopes where precipitation has sheet flow predominately instead of flow in channels or ravines. The mountains in this landform have extreme hypsometry, with long broad slopes minimal shoulders and a short transition to a toe-slope (think of it as a bracket ( { ) on its side). This is the opposite of a stereotypical mountain where the toe slope transitions to steepening shoulders and even steeper slopes above reaching to a peak or sharp ridge.

Smooth Crested Mountains have accumulations of soil on the low angle bedrock that collect water, enhancing soil development and water storage. These soils are thicker and consequently offer a good medium for grasses, forbs, shrubs, and trees. With the bedrock underlay there are few channels or ravines and water crosses the landscape mainly as sheet flow or as groundwater.

**Verrucated Glaciated Mountains** are areas shaped by past glaciers and are somewhat masked more recent geomorphic processes. Along peaks and ridges there are indicators of past glacial action. Since the cessation of glaciation in these areas, however, surface, mass wasting (shallow rapid or deep seated earthflow, rockfall, etc.) or fluvial erosion processes have dominated and masked much of the glacial signature of the mid to lower slopes. Verrucated Glaciated Mountains have a hummocky, warty morphology, including common hillocks and poorly organized to tortuous drainages, but cannot be definitely ascribed to mass failure as the dominant surface process. Origins for this type of Landform Association include ancient landslides that have been eroded, such as exhumed deep-marine landslides incorporated in a bedrock formation, or exhumed ancient volcanic flows in bedrock strata.

In this map unit, drainages are poorly integrated, leading to variable routing of surface water through this type of landscape. Because of irregular slopes and aspect, as well as varied surface water availability, potential vegetation and habitat are quite variable across these map units.

Soils in Verrucated Glaciated Mountains vary depending on scour and deposition but are generally deep and productive in the hummocky terrain.

**Verrucated Low Mountain** have a hummocky, warty morphology, including common hillocks and poorly organized to tortuous drainages, but cannot be definitely ascribed to mass failure as the dominant surface process. They belong to the low relief class. Origins for this type of Landform Association include ancient landslides that have been eroded, such as exhumed deep-marine landslides incorporated in a bedrock formation, or exhumed ancient volcanic flows in bedrock strata. In this map unit, drainages are poorly integrated, leading to variable routing of surface water through this type of landscape. Sediment recruitment is regular where this map unit intersects stream channels. Because of irregular slopes and aspect, as well as varied surface water availability, this Landform Association has a diverse upland habitat.

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**Tectonic Processes**

**Angulate High Mountains** are characterized by having a strong prominent system of drainages at other than at right angles due to rock structure, including joints and faults. High mountains have significant relief above a local base. There tends to be equal slope lengths on either side of a dominant ridge system. Subsidiary channel incision of these high mountains proceeds along these structural weaknesses. Drainage density is high. Water routing along drainages follows dominantly straight reaches which may lead to flashy discharges during storms. Unless overlain by loess or volcanic ash, these surfaces are mantled by thin, residual soils.

**Angulate Low Mountains** are characterized by having a strong prominent system of drainages at other than at right angles due to rock structure, including joints and faults. This mapping unit is in the “low” relief class. There tends to be equal slope lengths on either side of a dominant ridge system. Subsidiary channel incision of these high mountains proceeds along these structural weaknesses. Drainage density is high. Water routing along drainages follows dominantly straight reaches which may lead to flashy discharges during storms. Unless overlain by loess, these surfaces are mantled by thin, residual soils.

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**Escarpments** are linear with a unique narrow range of aspect. The slopes are at or greater than the angle of repose and underlain with bedrock. They have significant relief, meet the toe slope at steep angles and generally face a lower angle landscape. They are the result of quaternary faults or a fault scarp line that has weathered back from the fault line presenting a steeply sloping mountain front. The escarpment can also be the product of a tectonic lift or the erosion of a river meander cutting into the mountainside. Competent bedrock overlain by a less competent formation if eroded will show the structural differences that are expressed as an escarpment.

The hydrology on these steep and cliffy landforms is flashy and debris flows are common. The soils on the steep slopes are rocky with the few pockets of soil on benches. These pockets support vegetation and habitat for predator and prey species adapted to a vertical environment.

**Faulted Stratal Low Mountains** are mountains with morphologies which reflect both the underlying rock structure and faulting which exposes the bedrock stratigraphy. Low mountains refer to the fact that the land surface is relatively lower in relief than neighboring area or other similar landform group.

The Faulted Stratal Low Mountains are cut by parallel and sub-parallel faults. Typically these are normal faults with small amounts of lateral displacement. The faulting has created positive (uplands) and negative (drainages) patterns with repeating topographic elements. These Faulted Stratal Low Mountains are characterized by numerous parallel faults over a broad area up to several kilometers in extent. The stratigraphy is a consequence of degradation or denudation of an upland area by hillslope and fluvial processes. Stratigraphy is present and visible, as well as lineations such as unusually straight drainage reaches, indicative of faults in bedrock. Erosional exhumation reveals obvious layering of the underlying rock structure, including dip and anti-dip slopes. Synonymous terms used for these features are cuesta and cuestaform. Anti-dip slopes are benchy, rocky and relatively steep slopes. Following the colluvium downhill on an anti-dip slope you find a repeating pattern of bedrock outcrops with intervening areas of accumulated sediment. Habitat and vegetation distribution corresponds to this pattern. Dip slopes, on the other hand, are broad plains with shallow slopes underlain by relatively deep soils over rock. The dip slope is an almost featureless terrain with few features to orient by. Potential vegetation and habitat are largely invariable across these sloping plains. In this map unit, drainages patterns are more influenced by the faults or fault zones, leading to rectilinear or angulate drainage patterns and consequently diverse routing of surface water through this type of landscape.

The drainages in the Faulted Stratal Low Mountains are captured and redirected by displacement of the faults blocks. The rearrangement and redirection of precipitation runoff by the fault blocks gives a zig-zag appearance to catchment channels. The faults are zones of weakness and set up water flows along these zones. Sediment is impounded by fault scarps, in closed depressions, and at locations with lower slope angle. In these pockets of sediment accumulation there is increased soil development.

There are bedrock slopes that have appeared because of tectonic activity not erosion. These slopes have little if any soil mantle developed. The tectonic created slopes are steeper than the angle of repose of slopes created by erosion. The slopes in this landform are a mix of steep (tectonic) and not so steep (erosion processes) slope. There are valleys with flows that have been diverted or captured flow by other drainages. These captured or diverted drainages are essentially “hanging valleys”. These hanging valleys have sheet flow at a reduced rate and sediment transport is reduced.

**Stratal Low Mountains** are mountains with morphologies reflecting the underlying rock structure, which arises as a consequence of degradation or denudation of an upland area by hillslope and fluvial processes. Low mountains refer to the fact that the land surface is relatively lower in relief than neighboring area or other similar landform group. Stratigraphy is present and visible. Erosional exhumation reveals obvious layering of the underlying rock structure, including dip and anti-dip slopes. Synonymous terms used for these features are cuesta and cuestaform. Anti-dip slopes are benchy, rocky and relatively steep slopes. Following the colluvium downhill on an anti-dip slope you find a repeating pattern of bedrock outcrops with intervening areas of accumulated sediment. Habitat and vegetation distribution corresponds to this pattern. Dip slopes, on the other hand, are broad plains with shallow slopes underlain by relatively deep soils over rock. This is an almost featureless terrain with few features to orient by. Potential vegetation and habitat are largely invariable across these sloping plains.Ridge systems are broad, slope gradients are moderate and slope lengths are short in this landscape. Broad valleys may be present.

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1. Meybeck, M., P. Green and C Vörösmarty, 2001, A New Typology for Mountains and Other Relief Classes: An Application to Global Continental Water Resources and Population Distribution. *Mountain Research and Development*  21:34-45. [↑](#footnote-ref-1)