

Part XIV

The Mystery of Pediments

Thousands of gravel-capped planation surfaces exist within valleys and alongside ridges or mountains not associated with valleys. These are called pediments and are another class of landforms whose origin is mysterious. They are not forming today but are being destroyed by present-day erosional processes. Uniformitarian scientists have several hypotheses for their formation, but as of yet, none of these is reasonable. Pediments can easily be explained by late Flood runoff. As the Floodwater was channelized and rapidly flowing toward the sinking ocean basins, planation surfaces would easily form within valleys and along the edges of mountains and ridges.

Chapter 64

Pediments—Another Remarkable Landforms

By now it is clear that uniformitarianism is a poor paradigm for the origin of landforms. Another landform unexplained by uniformitarianism is the common pediment

What is a Pediment?

A pediment was defined in Chapter 33 as, “A broad sloping rock-floored erosion surface or a low relief plain typically developed by subaerial agents (including running water), in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment...”¹ This is the formal definition, but a very broad one and subject to disagreement over terms.^{2,3} Essentially a pediment is a planation surface that lies at the foot of a mountain, mountain range, ridge, or plateau. They can be considered large strath terraces, also. It is assumed that the pediment is being eroded into the high terrain (Figure 64.1).



Figure 64.1. Pediment along the western slope of the Tobacco Root Mountains, northeast of Twin Bridges, southwest Montana. The pediment is about 11 miles (18 km) long parallel to the mountain front, 3 miles (5 km) wide perpendicular to the front, and about 1,000 feet (300 m) higher than the adjacent river.

Sometimes pediments can be confused with planation surfaces. The Sherman erosion surface in southeast Wyoming and western Nebraska (see Figures 38.4 and 38.5) has sometimes been

¹ Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson, 2005. *Glossary of Geology*, Fifth Edition. American Geological Institute, Alexandria, VA, p. 477.

² Thomas, M.F., 1994. *Geomorphology in the Tropics: A Study of Weathering and Denudation in Low Latitudes*, John Wiley & Sons, New York, NY, p. 244.

³ Dohrenwend, J.C., 1994. Pediments in arid environments. In, Abrahams, A.D. and A.J. Parsons (editors), *Geomorphology of Desert Environments*, Chapman & Hall, London, U.K., p. 322.

called a pediment, but this surface extends perpendicular to the mountains and not parallel as in pediments.

Pediments sometimes erode rock similar to that found in the adjacent mountains,⁴ while in southwest Montana, it appears they mostly cut valley-fill sediments and not the rocks at the edge of the mountains.

Some of the early geologists actually thought pediments were alluvial fans, since they look similar,⁵ but were greatly surprised to discover hard rock surfaces below a thin veneer of mostly rounded rocks.⁶ Sometimes there was no veneer at all. So, the pediment is in reality a surface left after the erosion of rock. The geologist Grove Karl Gilbert first recognized and described pediments back in 1877.



Figure 64.2 A pediment at the base of the East Kaibab monocline, Arizona.

Pediments—Easy to Recognize

Pediments usually go unnoticed when viewing the landscape, since mountains are much more picturesque. But, once you know what to look for, they are easy to spot. Sometimes pediments can be confused with other flat depositional surfaces (see Appendix 15) like alluvial

⁴ Ritter, D.F., 1978. Pediments. In, *Process Geomorphology*, Wm. C. Brown, Dubuque, IA, pp. 290-299.

⁵ Twidale, C.R. and J.A. Bourne, 1998. Origin and age of bornhardts, southwest Western Australia. *Australian Journal of Earth Sciences* 45:903-914.

⁶ Rich, J.L., 1935. Origin and evolution of rock fans and pediments. *GSA Bulletin* 46:999-1,024.

fans and bajadas, which are coalesced alluvial fans. Usually there is a dip between alluvial fans that indicates the nearly flat surface is a bajada.

Sometimes the pediment is disguised by an overlay of alluvial fans or bajadas debris from the mountain (see Figure A15.1 for a likely example). This hinders recognition of a pediment, as well as any determination of whether the capping debris originated during the formation of the pediment or was added later.⁷



Figure 64.3. Pediment on south side of John Day River Valley. Photo taken from pediment on north side of the Valley, north of Dayville, Oregon.

Pediments Not Confined to Dry Areas

Pediments are most evident in dry climates. This has led many geologists to ascribe their origin to a dry environment, as the definition above implies. This may only be a selection artifact since deserts preserve landforms through slower erosion rates and, the lack of vegetation makes it easier to observe and describe the pediments.⁸ But, pediments are *not* restricted to dry areas and may be found in *any* climate, cold or warm, wet or dry.^{9,10} For instance, pediments are common in the Yukon Territory of northwest Canada.¹¹ King stated:

They [pediments] are, however, not absent from the landscapes of humid regions, and

⁷ Blackwelder, E., 1931. Desert plains. *Journal of Geology* 39:133-140.

⁸ Summerfield, M.A. 1991. *Global Geomorphology*, Longman Scientific & Technical, New York, NY, p. 347.

⁹ Whitaker, C.R., 1973. *Pediments: A Bibliography*. Geo Abstracts Ltd, University of East Anglia, Norwich, England, p. 95.

¹⁰ Twidale, C.R. and Bourne, J.A., 2013. Pediments as etch forms: implications for landscape evolution. *The Journal of Geology* 121:607–622.

¹¹ Ritchie, J.C., 1984. *Past and Present Vegetation of the Far Northwest of Canada*, University of Toronto Press, Toronto, Canada, pp. 18-33.

current research indicates that pediments are, indeed, the most widespread and possibly the most important of all land-forms.¹²

Twidale and Lageat corroborate:

Similarly, both alluvial fans and covered pediments or *glacis* [rock-cut pediments], though widely regarded as desert and semi-desert forms, are in fact widely distributed ... Covered pediments are found in Colorado, Utah and Alaska, in Korea and Japan, as well as arid and semi-arid regions.¹³

Residual pediments also have been found in the Brazilian rain forest at the foot of the Serra do Mar.¹⁴



Figure 64.4. Close-up of the very coarse subrounded basalt gravel about 330 feet (100m) thick on top of the pediment in Figure 64.4 on the north side of the John Day River Valley.

Remarkably Flat and Often Capped with a Veneer of Rounded Gravel

Pediments are often *remarkably flat* across the broad scale (Figure 64.1).^{15,16} The very size, flatness, and abundance of these surfaces should cause us to wonder about their origin. On the finer scale channels and rills leading from the mountains often incise the surfaces of a pediment

¹² King, L., 1949. The pediment landform: some current problems. *Geological Magazine* 86:245.

¹³ Twidale, C.R. and Y. Lageat, 1994. Climatic geomorphology: a critique. *Progress in Physical Geography* 18(3):328.

¹⁴ Bigarella, J.J. and G.O De Andrade, 1975. Contributions to the study of the Brazilian Quaternary. In, Adams, G.F. (editor), *Planation Surfaces: Peneplains, Pediplains, and Etchplains*, Benchmark Papers in Geology 22, Dowden, Hutchinson & Ross, Inc, Stroudsburg, PA, p. 308.

¹⁵ Johnson, D., 1932. Rock fans of arid regions. *American Journal of Science* 23(137), fifth series:389-416.

¹⁶ Howard, A.D., 1942. Pediment passes and the pediment problem (Part I). *Journal of Geomorphology* 5(1):3-31.

(see Figure 33.1). In fact, most pediments are dissected,⁵ but the original planation surface can still be recognized by mentally filling in the channels and examining the tops of the uneroded portions. Dohrenwend stated:

Certainly one of the most remarkable physical attributes of any pediment is the generally planar and featureless character of most (or at least part of) its surface ... Although, many large pediments are generally smooth and regular with less than a few metres of local relief, a more complex morphology occurs where shallow drainageways locally incise the pediment surface into irregular patchworks of dissected and undissected topography.¹⁷

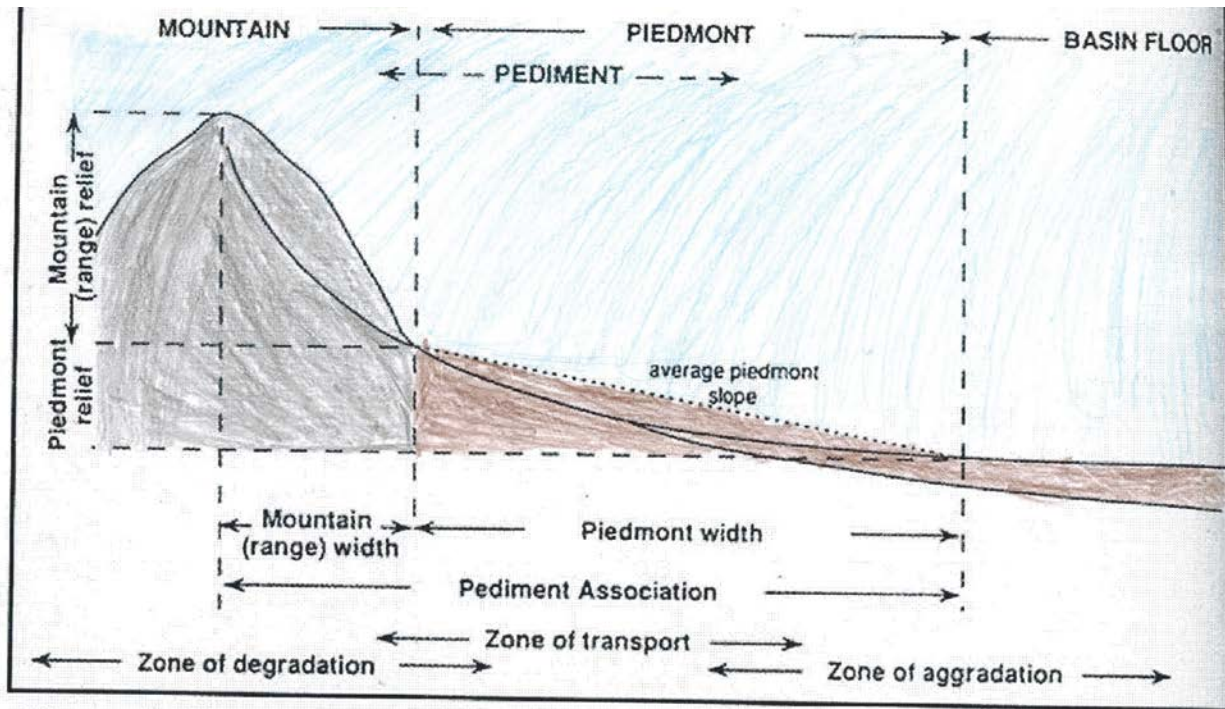


Figure 64.5. The relationship between the pediment, piedmont, and basin floor with inferred uniformitarian processes of gravel denudation and aggradation (after Dohrenwend, 1994, p. 324).

Generally, the remarkable smoothness is enhanced and protected by the deposition of a thin veneer of gravel, which may include cobbles and boulders.^{18,19} Boulders up to 3 feet (1 m) in diameter are occasionally seen on pediments along the Kaibab Monocline in northeast Arizona (Figure 64.2).²⁰ I have observed generally rounded basalt boulders larger than 3 feet (1 m) on pediments in the John Day Country, northeast Oregon (Figures 64.3 and 64.4). Although the pediment surface is smooth due to the veneer of gravel, the relief below the gravel is also generally smooth and can be described as a planation or erosion surface.²¹

¹⁷ Dohrenwend, Ref. 3, pp. 324, 329.

¹⁸ Twidale, C.R., 1981. Origins and environments of pediments. *Journal of the Geological Society of Australia* 28:423-434.

¹⁹ Thomas Ref. 2, p. 245.

²⁰ Miller, V. C., 1950. Pediments and pediment-forming processes near House Rock, Arizona. *Journal of Geology* 58:634-645.

²¹ Bourne, J.A., R. Hillis, M. Ruttly, and C.R. Twidale, 2002. Fan, fill or covered pediment? Seismic investigation of alluvial cover thickness, Hayward 'pediment', Flinders Ranges, South Australia. *Zeitschrift für Geomorphologie N. F.* 46(2):193-201.

Some smooth pediments lack a gravel veneer so the pediment morphology is *mostly a result of a smooth rock floor*, whether capped by coarse gravel or not. The gravel veneer smooths the pediment even more. The gravel normally thickens away from the mountains, sometimes blending into the thick gravel deposited near streams or rivers on a lower piedmont, which is a little different than a pediment. A piedmont is the province between the foot of the mountains and the river or stream running down the valley. Pediments are commonly found in the upper piedmont near the mountains (Figure 64.5).



Figure 64.6. Pediment in the Ruby River Valley along the western slope of the Gravely Range of southwest Montana. Note that the sedimentary beds of the valley fill sediments dip right (east), while the pediment surface dips left (west) and shears the sedimentary layers evenly.

The gravel that caps a pediment is generally rounded, indicating *water was involved in depositing the veneer and shaping the pediment*. Gravel, carried by the current, would act as sandpaper eroding and smoothing the rough surface, forming a pediment, in much the same way as a planation surface.^{22,23} Figure 64.6 shows a pediment at the edge of the Ruby River Valley in southwest Montana; Figure 64.7 shows a gravel veneer of generally rounded and subrounded rocks capping the pediment. The majority of the rocks on this pediment are quartzite originating about a hundred miles away in central Idaho (see Part IV).

Sometimes, the gravel veneer on pediments includes angular gravel, especially near the mountains. Just east of the Little Rocky Mountains in north-central Montana, angular limestone

²² Crickmay, C.H., 1975. The hypothesis of unequal activity. In, Melhorn, W.N. and R.C. Flemel (editors), *Theories of Landform Development*, George Allen and Unwin, London, U.K., p. 107.

²³ Twidale, Ref. 18, p. 425.

gravel overlies a pediment. The mountains are the likely source of this material since limestone is found atop their granite core, but this does not mean all of the gravel on a pediment came from the nearby mountains.



Figure 64.7. Coarse gravel veneer capping the pediment shown in Figure 64.7. Note that the rocks are rounded to subrounded, and most of them are exotic quartzite.

Pediments Can Be Sizeable

The size of pediments varies from less than 0.25 mi^2 (1 km^2) to large planation surfaces of a few hundred mi^2 (hundreds of km^2).²⁴ The pediment in Figure 64.1 is about 11 miles (18 km) long parallel to the mountain front, about 3 miles (5 km) wide at right angles to the mountain front, and around 1,000 feet (300 m) high between the mountain front and the river. It represents 33 mi^2 (90 km^2) of smoothly-planed rock with a coarse gravel veneer. The largest pediment in the Rocky Mountains is in southeast Arizona, and covers 240 mi^2 (615 km^2).²⁵ So, pediments are not tiny features that can be explained by local river erosion, but relatively large landforms that demand a different explanation.

Gentle Slopes

Although pediments are generally flat, they slope gently away from the mountain range, ridge, or plateau with a slightly concave upward profile, steepening slightly toward the adjacent mountains.^{26,27} The slope within about a half-mile (1 km) from the mountain front generally ranges from 1° to 6° ^{26,28} and flattens farther away from the mountains where it blends into the lower piedmont (Figure 64.6). A few pediment slopes are larger than 6° . Dowrenwend reported a

²⁴ Ritter, Ref. 4, p. 291.

²⁵ Tuan, Y.-F., 1959. Pediments of Southeastern Arizona, *University of California Publications in Geography* 13, University of California Press, Berkeley, CA.

²⁶ Mammerickx, J., 1964. Quantitative observations on pediments in the Mojave and Sonoran Deserts (Southwestern United States). *American Journal of Science* 262:417-435.

²⁷ Hadley, R.F., 1967. Pediments and pediment-forming processes. *Journal of Geological Education* 15:83-89.

²⁸ Twidale and Bourne, Ref. 5, p. 124.

slope up to 8.6° on a granite pediment in the Mojave Desert.²⁹ Where the pediment meets the mountain front, it has a noticeable angle, called the piedmont angle or junction.³⁰ The origin of the piedmont angle, which is usually quite sharp, has been the cause of much speculation.³¹ It does not seem to be related to either the pediment length, the drainage area in the mountains above the pediment, or the rock type.^{26,32}



Figure 64.8. Three pediments along the John Day River Valley downstream from the Sheep Rock Visitors' Center.

Multiple Valley Pediments

An interesting feature of some pediments is they are sometimes observed at multiple levels in the same valley (Figure 64.8). Twidale stated pediments in sedimentary terrains commonly occur in flights or steps.³³ More elevated pediments are occasionally detached or beheaded from the mountain front by a valley, leaving a pediment erosional remnant.

²⁹ Dohrenwend, J.C., 1994. Pediments in arid environments. In, Abrahams, A.D. and A.J. Parsons (editors), *Geomorphology of Desert Environments*, Chapman & Hall, London, U.K., pp. 321-353.

³⁰ Dohrenwend, Ref. 29, p. 326.

³¹ Hadley, Ref. 27, p. 88.

³² Cooke, R.U., 1970. Morphometric analysis of pediments and associated landforms in the Western Mojave Desert, California. *American Journal of Science* 269:26-38.

³³ Twidale, Ref. 18, p. 425.

Pediments Beveled in Granite and Dipping Sedimentary Rocks

Pediments are beveled into all types of rocks,^{26,34} but are most commonly cut in granitic rocks forming a flat surface.^{15,18,35,36} In sedimentary rocks, pediments often shear the sedimentary layers at an angle.²⁰ Figure 64.6 shows the pediment at the edge of the Ruby River Valley, Montana, along the western slope of the Gravelly Mountains of southwest Montana. Note the sedimentary layers tilt down to the right (east) at a low angle, while the surface of the pediment has been beveled to the left (west) at a low angle. They are cut evenly across rocks of varying resistance and angles of the sedimentary layers.^{37,38,39}

Pediments in mountain and valley terrain can both bevel the valley fill or cut into the edge of the hard mountain rock. For instance along the Ruby-East Humboldt mountain range of eastern Nevada, pediments on the west side of the range are beveled into generally soft rocks of the valley fill while on the east side, they have been cut entirely on the hard rocks at the edge of the range.⁴⁰

³⁴ Melton, M.A., 1965. The geomorphic and paleoclimatic significance of alluvial deposits in southern Arizona. *Journal of Geology* 73:1-38.

³⁵ Tuan, Ref. 25, pp. 113-114.

³⁶ Oberlander, T.M., 1972. Morphogenesis of granitic boulder slopes in the Mojave Desert, California. *Journal of Geology* 80(1):1-20.

³⁷ Paige, S., 1912. Rock-cut surfaces in the desert ranges. *Journal of Geology* 20:442-450.

³⁸ Johnson, D., 1931. Planes of lateral corrasion. *Science* 73:174-177.

³⁹ Small, R.J., 1978. *The Study of Landforms: A Textbook of Geomorphology*, second edition, Cambridge University Press, London, U.K., p. 319.

⁴⁰ Sharp, R.P., 1975. Geomorphology of the Ruby-East Humboldt Range, Nevada. In, Adams, G.F. (editor), *Planation Surfaces: Peneplains, Pediplains, and Etchplains*, Benchmark Papers in Geology 22, Dowden, Hutchinson & Ross, Inc, Stroudsburg, PA, p.257.