Chapter 44

South American Planation Surfaces

Planation surfaces in South America are found at various elevations in the Andes Mountains[1] and the lowlands east of the Andes.

The Andes Mountains

The Andes Mountains run the length of western South America. In the central portion, the high mountains are separated by the high, wide, north-south valley where we find Lake Titicaca. The Andes are believed to have uplifted in the late Cenozoic according to the uniformitarian timescale, and therefore, the Andes are very young.[2] Much of the Andes Mountains are composed of granite. But, there are many stratovolcanoes, which are cone-shaped mountains composed of cooled lava. The last major geophysical event in earth history was the Ice Age which lowered the snowline about 3,300 feet (1,000 m) from today in these mountains. The current glaciers are small remnants compared to the Ice Age glaciers.

One normally does not think of planation surfaces in the Andes, but there are many of them, even on the tops of some of the mountains.[3] Lower altitude planation surfaces are mainly found along the eastern foothills.[4] There are a few on the western flank of the Andes Mountains, as those in Peru,[5] but the vast majority of low altitude planation surfaces are along the eastern foothills of the Andes.[4,16]

Many who have examined the geomorphology of the Andes have become convinced the planation surfaces of various altitudes were once just one planation surface[2,6] that was subsequently uplifted, faulted, deformed, and eroded as the Andes formed.[7,8,9,10,11] The planation

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[1] Ollier, C. and C. Pain, 2000. *The Origin of Mountains*. Routledge, New York, NY, pp. 112–127.

[2] Coltorti, M. and C.D. Ollier, 1999. The significance of high planation surfaces in the Andes of Ecuador. In, Smith, B.J., W.B. Whalley, and P.A. Warke (editors), *Uplift, Erosion and Stability: Perspectives on Long-Term Landscape Development*, Geological Society of London Special Publication No. 162, The Geological Society, London, U. K., pp. 239–253.

[3] King, L.C., *The Morphology of the Earth—A Study and Synthesis of World Scenery*, Hafner Publishing Company, New York, NY, 1967, p. 310.

[4] Costa, C.H., A.D. Giaccardi, and E.F. González Díaz, 1999. Palaeolandsurfaces and neotectonic analysis in the southern Sierras Pampeanas, Argentina. In, Smith, B.J., W.B. Whalley, and P.A. Warke (editors), *Uplift, Erosion and Stability: Perspectives on Long-Term Landscape Development*, Geological Society of London Special Publication No. 162, The Geological Society, London, U.K., pp. 229–238.

[5] Myers, J.S., 1975. Vertical crustal movements of the Andes in Peru. *Nature* 254:672–674.

[6] Bowman, I., 1909. The physiography of the central Andes: I. the maritime Andes. *American Journal of Science* Fourth Series, 28(165):197–217.

[7] Mortimer, C., 1973. The Cenozoic history of the southern Atacama Desert, Chile. *Journal of the Geological Society, London* 129:505–526.

[8] Myers, J.S., 1976. Erosion surfaces and ignimbrite eruption, measures of Andean uplift in northern Peru. *Geological Journal* 11(1):29–44.

[9] Galli-Olivier, C., 1967. Pediplain in northern Chile and the Andean uplift. *Science* 158:653–655.

[10] Tosdal, R.M., A.H. Clark, and E. Farrar, 1984. Cenozoic polyphase landscape and tectonic evolution of the cordillera occidental, southernmost Peru. *GSA bulletin* 95:1,318–1,332.

[11] Kennan, L., 2000. Large-scale geomorphology of the Andes: interrelationships of tectonics, magmatism and climate. In, Summerfield, M.A. (editor), *Geomorphology and Global Tectonics*, John Wiley & Sons, New York, NY, pp. 167–199.

surfaces in the western Andes are tilted down toward the southwest caused by greater uplift toward the east. Deep canyons were incised into the planation surface *after* it formed, much the same as the Sierra Nevada Mountains of California (see Chapter 38). Erosion spread huge amounts of coarse gravel to the coast filling in the depressions. Some of the surfaces are capped by resistant gravel,[12] like quartzite.[13] Erosional remnants called monadnocks sometimes stick up above some planation surfaces. In some cases volcanism from the stratovolcanoes in the Andes erupted and partially covered them.[14]

The planation surfaces beveled (cut through) the strata,[15] providing additional evidence that they are truly planation surfaces. In Bolivia, the planation surfaces range in area from 2 to 780 mi^2 (5 to 2,000 km^2),[16] They bevel the sedimentary rock, and often are capped by cobbles and boulders up to about 65 feet (20 m) thick.[17] Some of the lower planation surfaces are considered pediments (see Part XIV on the subject of pediments).[18] These pediments bevel the uplands. Percussion marks are found on some pediment gravel indicating torrential water flow.[15] Interestingly, the eroded material from the Andes has been largely removed from the area.[16]

The plate tectonics model considers the Andes Mountains a convergent margin where the Nazca Plate is colliding with the South American Plate. The model provides a major problem for the formation of high altitude planation surfaces, or plateaus:

> The evolution of high plateaus at convergent margins, typified by the central Andean and Tibetan plateaus, is one of the fundamental problems of continental tectonics.[18]

In reference to planation surfaces in the Andes of South America, Hall also notes the difficulty: "…the details of how planation surfaces form are still very much unknown…"[19] It also seems that most geologists miss the significance of the planation surfaces for Andean geology:

> Most accounts of the structure of the Andes take no account of the planation surface, and totally miss the distinction between pre-planation surfaces and post-planation structures. … the full significance of the long recognized erosion surface is still to be appreciated in literature discussing the origin of the Andes.[20]

Figure 44.1 is a schematic of how Coltorti and Ollier view the origin of the Cordillera in the Andes Mountains of Ecuador, which would be similar to other areas of the Andes. The planation surfaces are believed to have formed in the mid to late Cenozoic.[21] In Ecuador the planation

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[12] Segerstrom, K., 1963. Matureland of northern Chile and its relationship to ore deposits. *GSA Bulletin* 74:513–518.
[13] McLaughlin, D.H., 1924. Geology and physiography of the Peruvian Cordillera, departments of Junin and Lima. *GSA Bulletin* 35:591–632.
[14] Kroonenberg, S.B., J.G.M. Bakker, and A. M. van der Wiel, 1990. Late Cenozoic uplift and paleography of the Columbian Andes: constraints on the development of high-andean[sic] biota. *Geologie en Mijnbouw* 69:279–290.
[15] Walker, E.H., 1949. Andean uplift and erosion surfaces near Uncia, Bolivia. *American Journal of Science* 247:646–663.
[16] Kennan, L., S.H. Lamb, and L. Hoke, 1997. High-altitude palaeosurfaces in the Bolivian Andes: evidence for late Cenozoic surface uplift. In, Widdowson, M. (editor), *Palaeosurfaces: Recognition, Reconstruction and Palaeoenvironmental Interpretation*, Geological Society of London Special Publication No. 120, The Geological Society of London, London, U.K., pp. 307–323.
[17] Lamb, S., 2000. Active deformation in the Bolivian Andes, South America. *Journal of Geophysical Research* 105(B11):25,627–25,653.
[18] Gubbels, T.L., B.L. Isacks, and E. Farrar, 1993. High-level surfaces, plateau uplift, and foreland development, Bolivian central Andes. *Geology* 21:695–698.
[19] Hall, S.R., D.L. Farber, L. Audin, R.C. Finkel, and A.-S. Mériaux, 2008. Geochronology of pediment surfaces in southern Peru: implications for Quaternary deformation of the Andean forearc. *Tectonophysics* 459:190.
[20] Coltorti and Ollier, Ref. 2, pp. 250–251.
[21] Barke, R. and S. Lamb, 2006. Late Ceenozoic uplift of the Eastern cordillera, Bolivian Andes. *Earth and Planetary Science Letters* 249:350–367.

surfaces bevel Tertiary basins that have sedimentary rock as deep as 33,000 feet (10,000 m), "…indicating that the planation surface is no older than earliest Pliocene."[22]

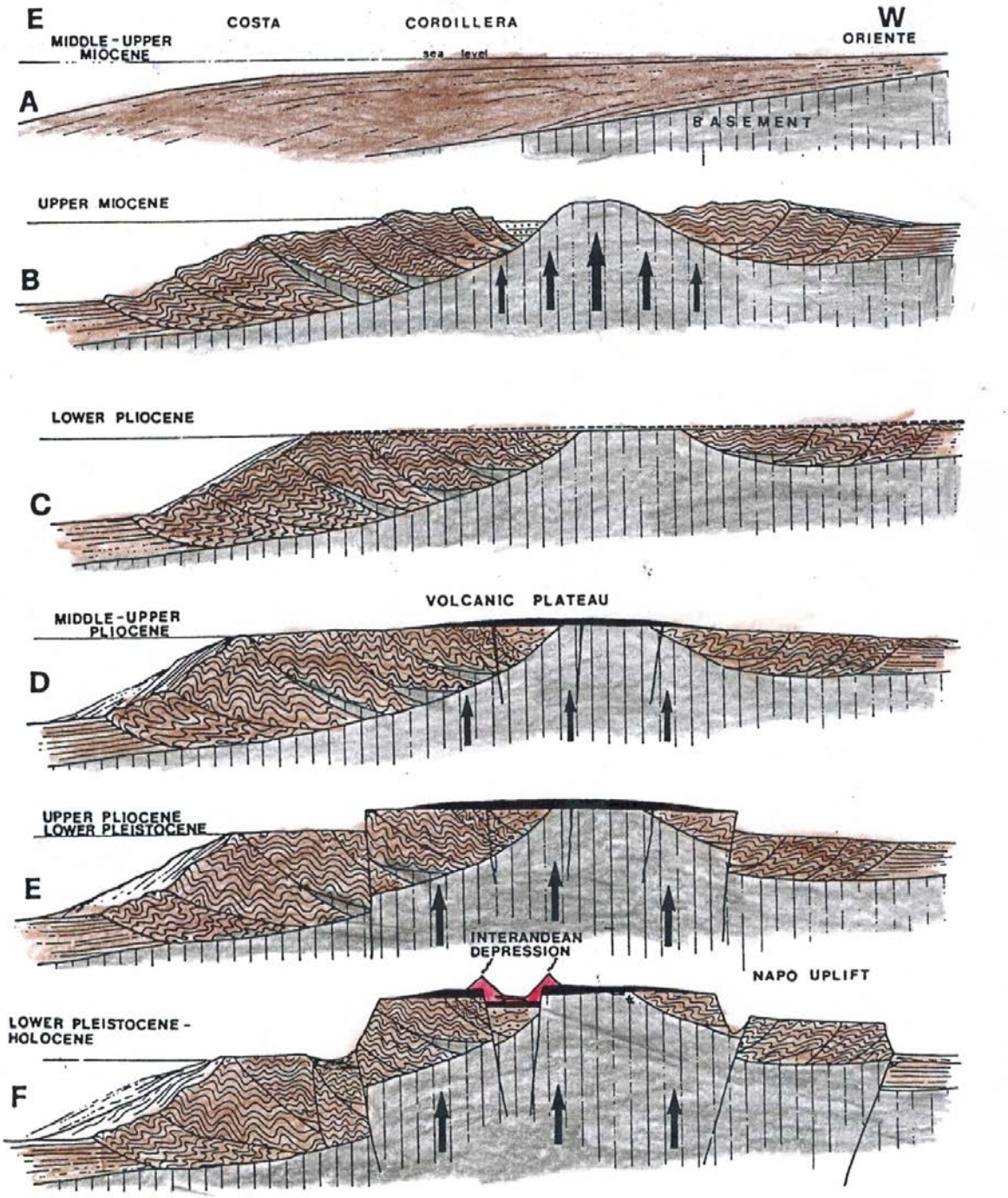

Figure 44.1. Schematic of the origin of the Andes Mountains in Ecuador with planation surfaces faulted to several levels (from Coltori and Ollier, 1999, p. 247.)

[22] Coltorti and Ollier, Ref. 2, p. 239.

The Guayana Shield North of the Amazon River

A large highland up to almost 10,000 feet (3,000 m) above msl exists north of the Amazon River in southeast Venezuela, northern Brazil and territory to the east. It has multiple planation surfaces, some with a veneer of gravel and cobbles capping them. They lie at different altitudes with pediments along the edge of the mountains.[23,24,25] The highest waterfall in the world, Angel Falls, drops 3212 feet (979 m)from one of the high planation surfaces (Figure 44.2). The area has the geomorphology of a very large stepped mesa, or large plateaus indicating a huge amount of erosion took place in northeast Brazil. Erosional remnants or inselbergs (also called bornhardts) rise up to 1,000 feet (300 m) above the planation surfaces.[26] Their height measures the minimum amount of erosion required to form the existing planation surface.

Figure 44.2. Angel Falls, Venezuela, is the highest uninterrupted falls in the world at 3,212 feet (979 m) high (Wikipedia).

[23] Briceño, H.O. and C. Schubert, 1990. Geomorphology of the Grand Sabana, Guayana Shield, southeastern Venezuela. *Geomorphology* 3:125–141.
[24] McConnell, R.B., 1968. Planation surfaces in Guyana. *The Geographical Journal* 134:506–520.
[25] Bishopp, D.W., 1940. Some problems of geomorphology and continental relationships in British Guiana. *Geological Magazine* 77(4):305–329.
[26] Eden, M.J., 1971. Some aspects of weathering and landforms in Guyana (formerly British Guiana). *Zeitschrift für Geomorphologie N.F.* 15:181–198.

Planation surfaces sometimes bevel the sedimentary rock that makes up the bedrock and is described as exceptionally smooth over an immense area.[27] The surfaces are also said to be a "…remarkable preservation of such an old surface…"[28] In fact some scientists believe the top surface may be as old as the Precambrian, older than 540 million years.[29] Numerous V-shaped valleys are cut into the surface.[30] There are a few duricrusts capping the planation surfaces (see Chapter 42 and 57 on duricrusts). Many think that these planation surfaces were formed by the weathering hypothesis,[31] but there are numerous problems with that hypothesis (see Chapter 51).

Planation Surface South of the Amazon River

There are planation surfaces in Brazil south of the Amazon River.[32] In fact, Lester King considers most of Brazil as one large planation surface.[33] Two planation surfaces are claimed associated with the Great Escarpment of eastern Brazil, one at the top and one at the bottom (see Appendix 5).[34] Remnant planation surfaces are preserved at the summits of many of eastern Brazil's hills and mountains.[35] The planation surfaces do not conform to Davis's "cycle of erosion" (see Chapter 50)[36] since some of the surfaces are very flat.[37] King remarks on the planation surfaces in Brazil:

> A traveller in Brazil, indeed, soon learns to recognize the horizon-wide planations of early-Cainozoic [Cenozoic] age… They represent, indeed, a "master surface" from which most of the existing landscape of Brazil has subsequently been carved."[38]

Ollier and Pain remark the planation surfaces in the Amazon Basin are on folded subsurface rocks, in other words the surface bevels tilted rocks.[39] And similar to most other planation surfaces of the earth, those in Brazil are sharply dissected by youthful valleys.[34,38]

The Character of the Planation Surfaces

It seems planation surfaces were cut over a wide area of South America during the mid to late Cenozoic. Those on the Guayana Shield are said to be caused by differential vertical tectonics:

> The whole situation points to warping: upheavel in the region south of the hinge zone, downwarping in the coastal area. … It is therefor [sic] legitimate to regard the structure

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[27] Schefer, C., Viçosa, and J. Dalrymple, 1995. Landscape evolution in Roraima, North Amazonia: planation, paleosols and paleoclimates. *Zeitschrift für Geomorphologie N.F.* 39:6.
[28] Schefer et al., Ref. 27, p. 9.
[29] Schubert, C. and O. Huber, 1991. *The Gran Sabana: Panorama of a Region.* Lagoven, Caracas, Venezuela, p. 36.
[30] Zonneveld, J.I.S., 1985. *Zeitschrift für Geomorphologie N.F. Suppl.-Bd* 54:71–83.
[31] Yanes, C.E. and H.O. Briceño, 1993. Chemical weathering and the formation of pseudo-karst topography in the Roraima Group, Grran Sabana, Venezuela. *Chemical Geology* 107:341–343.
[32] Klammer, G., 1981. Landforms, cyclic erosion and deposition, and Late Cenozoic changes in climate in southern Brazil. *Zeitschrift für Geomorphologie N.F.* 25(2):146–165.
[33] King, L.C., 1956. A geomorphological comparison between Eastern Brazil and Africa (Central and Southern).*The Quarterly Journal of the Geological Society of London* 112:445–474.
[34] James, P., 1959. The geomorphology of eastern Brazil as interpreted by Lester C. King. *The Geographical Review* 49:240–246.
[35] 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. 312.
[36] James, Ref. 34, p. 240.
[37] Young, A., IV. slope form in the Xavantina-Cachimbo area. *The Geographical Journal* 136:383–392,
[38] King, Ref. 3, p. 311.
[39] Ollier and Pain, Ref. 1, p. 8.

> of the hinge zone and the shelf area as a flexure, the marginal monocline of the South American Continent.[40]

The planation surfaces formed during differential vertical uplift of the continents and subsidence of the ocean basins. Then the surfaces were deeply dissected *since* planation. It is the same pattern worldwide, suggesting a common cause all over the earth (see Part XII).

[40] Zonneveld, Ref. 30, p. 82.