

Terraces of Hell Canyon and its tributaries, Memorial Draw and Ojo de la Cabra

DAVID W. LOVE

New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro,
NM 87801-4796

INTRODUCTION

According to Jackson (1997, p. 657) a terrace is only a geomorphic form, a “valley-contained, aggradational form composed of unconsolidated material” at elevations separated from the present drainage system—above channel, floodplain, and graded valley borders. Terraces consist of both steep risers and flat treads. Leopold et al. (1964) argue that deposits beneath the form should not be called terraces, but alluvial fill or alluvium or alluvial deposits. In contrast, Bull (1991) coined terms relating the material beneath the form as well as the form: “fill terrace”, “fill-cut terrace”, and “strath terrace”, depending on whether the terrace is underlain by thick fill, beveled fill, or thin fill on bedrock. Paired terraces are interpreted to imply widespread or long-duration geomorphic episodes related to tectonics and/or climatic regimes whereas unpaired terraces imply local, short-duration, perhaps not climatically, tectonically, or alluvially significant events.

Geomorphologists have conventional expectations of terraces. Generally terraces are preserved along margins of stream valleys. They commonly parallel modern stream gradients or they diverge downstream or converge downstream. Commonly terraces exhibit equal amounts of preservation/degradation along reaches. They relate to one kind of climatic regime (or sequence of regimes) during episodic downcutting and aggradation. Holocene terraces along arroyos may reflect discontinuous downcutting and backfilling (Schumm and Hadley, 1957) but such ephemeral events are not postulated for larger Pleistocene terraces. Schumm and Parker (1973) also interpret terraces as products of complex response wherein multiple terraces result from autogenic changes in water and sediment discharges within a drainage without external changes in climate, slope/base level, or sediment availability. The terraces along Hell Canyon and two of its tributaries do not exhibit these conventional phenomena. In fact, they fly in the face of all common expectations. The terraces of Hell Canyon drainages are described below after introducing the geomorphic fundamentals of the system.

GEOMORPHIC FUNDAMENTALS OF THE HELL CANYON DRAINAGE

Hell Canyon and its subsidiary drainage basins currently encompass about 300 km² and are elongate east-west. Hell Canyon drainage arises in the Manzano and Manzanita Mountains at elevations up to 2,880 m and debouches to the Rio Grande floodplain just below 1,500 m. More than half of the drainage is above 1,880 m (6000 ft, roughly lower tree line). The terraces of Hell Canyon are almost exclusively below 1,880 m. The two tributaries preserving multiple terraces, Ojo de la Cabra and Memorial Draw (a northern tributary of Hell Canyon, named here for a small memorial erected to honor Navy personnel killed in a plane crash in the draw in 1946), arise on the piedmont below 1,880 m. Memorial Draw covers about 19 km² and Ojo de la Cabra is less than 2.3 km², but its drainage has fluctuated in size and connectedness to mountain headwaters through time due to stream capture and piedmont progradation near the mouth of Sanchez Canyon drainage. Annual precipitation ranges from about 200 mm at the lowest elevations to more than 500 mm in the headwaters. Precipitation intensity ranges up to 150 mm per 24 hours (United States Department of Commerce, 1973). At present, much of the small drainage basins appear not to experience even decadal overland flow events. Channel gradients range from 6 to 26 m/km (0.006 to 0.026). Hell Canyon Arroyo ranges up to 40 m wide and 5 m deep and is continuous from the mountains to the Rio Grande valley. Boulder bars along the valley floor outside the arroyo attest to at least one large flood in the first half of the 20th century. Boulders along tributaries suggest prehistoric high-discharge events that reworked adjacent Pleistocene deposits into Holocene channels. All three drainages cross multiple strands of faults. Ojo de la Cabra and Memorial Draw cross strands of the Hubbell Spring fault zone and lower Memorial Draw follows part of the main strand of the McCormick Ranch fault. Hell Canyon crosses the Manzano fault zone, multiple strands of the Hubbell Spring fault zone, McCormick Ranch fault zone, and strands of the Palace-Pipeline fault zone. Downstream from the Western Hubbell Spring and McCormick Ranch faults, Hell Canyon and Memorial Draw are bordered with loose pebbly sand of the ancestral Rio Grande. Upstream, their borders are various ages of piedmont alluvium. Along the periphery of the drainage basins, eolian sand sheets and dunes have disrupted tributary drainages so that very little runoff is contributed to the drainages themselves.

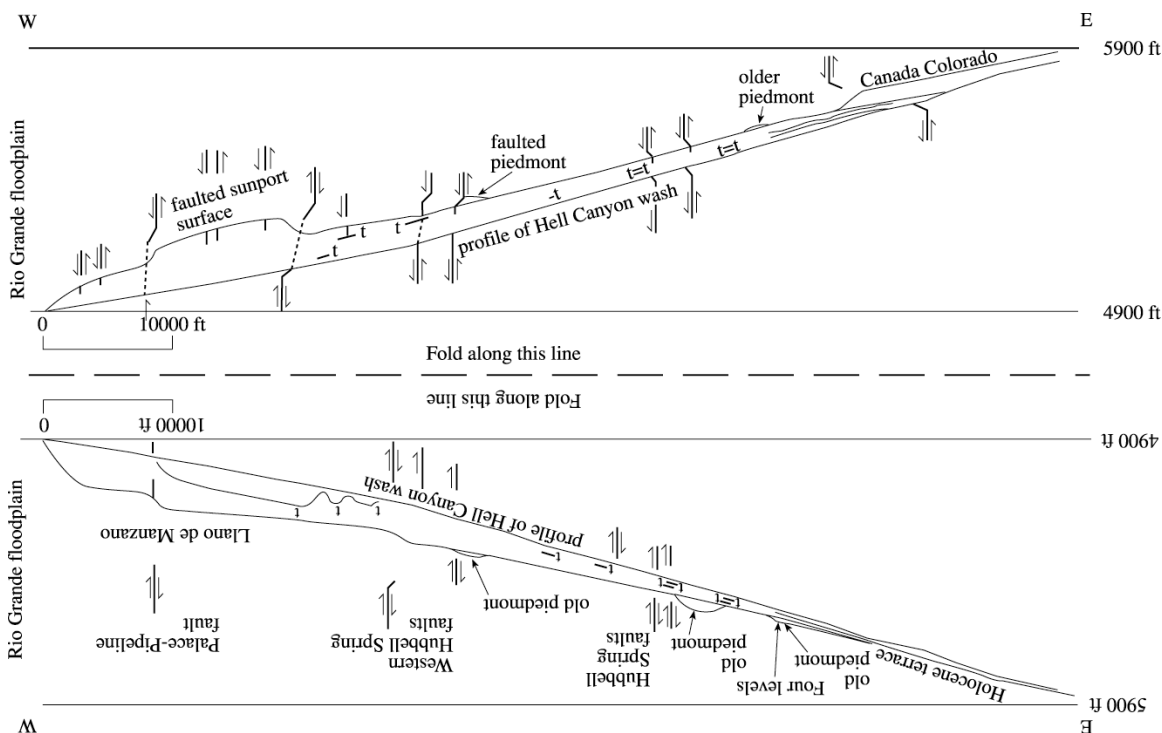


Figure 1. Figure 1. Longitudinal profile of Hell Canyon Wash from the Rio Grande floodplain to the upper piedmont (5900 ft) with terrace reaches and faults shown. Above the fold line is the stream profile, terrace levels, and faults viewed to the north. Below the fold line is the profile, terrace levels, and faults viewed to the south. Kinks in fault symbols portray oblique fault traces. To see differences between the north and south sides of Hell Canyon, fold the paper in half along the fold line and hold it up to strong light or copy the image onto a transparency and fold the two profiles together. Superimposing the two images will show not only the differences between the canyon sides, they will show that one image of both sides would be too complicated for illustrative purposes.

TERRACES

Along these three drainages, geomorphologists may see many subtle stretches of tread surfaces (Fig. 1), but the deposits and soils underneath the surfaces are not well exposed. Similar sub-terrace alluvial deposits occur at different terrace levels; conversely terraces with different sub-terrace deposits and/or soils show up at the same height above the thalweg in different reaches. So-called “fill terraces” crop out near the centers of drainages but these become strath terraces along the valley margins so the terms “fill” and “strath” are a matter of preservation, not fundamental behavior. Terraces may be offset or tilted by faulting, but without better correlation techniques, it is difficult to tell which surface is which across faults. Ephemeral eolian and alluvial cover apparently affects soil development on parts of terraces so that correlations based on soil development are suspect. Finally, on both footwalls and hanging walls of faults shallow, carbonate-precipitating groundwater cemented the deposits and made mounds near the faults and spread laterally and longitudinally to form thin sheets and plates of calcium carbonate (micrite and sparite) both perpendicular and parallel to the ground surface. Degraded spring mounds are not uncommon along

some small tributaries and along fault scarps. Yet, springs are rare along the fault traces now (Hubbell Spring and Ojo de la Cabra) and the water table is hundreds of feet below the surface along some stream reaches.

High “terraces” along the lower reach of Hell Canyon are only partially related to the drainage (Fig. 1). The highest surface on the north side of the drainage consists of uplifted and tilted gravelly sands deposited by the Rio Grande, only overtopped locally by piedmont gravels on the downthrown sides of the Palace-Pipeline fault zone. The south rim of the lower reaches of Hell Canyon is capped with piedmont gravel from the Manzanita Mountains and therefore could be considered a “terrace” relative to the inset drainage. Similarly, higher “terraces” along Ojo de la Cabra and Memorial Draw are not related to the streams that currently are cut into them. Rather, some terraces are related to broader aggradational events related to Hell Canyon drainage before it became incised and to local tectonic movements. Such “terraces” are broad surfaces on one side of a tributary (and therefore can not be termed “terraces”), but are inset against uplifted older surfaces on other side. Terraces at similar levels (i.e. the highest levels) on different sides of faults in adjacent reaches may or may not be related.

Along Hell Canyon and Memorial Draw, some inset terraces become wider downstream and overtop the landscape, spreading out to become broad piedmont-like surfaces on both sides of the drainages (Fig. 1). Strands of the Hubbell Spring fault zone cut some of these, particularly along Memorial Draw; others are unfaulted, but are high on the landscape relative to Hell Canyon drainage and much higher than terraces inset in Hell Canyon.

As one follows terraces upstream along Memorial Draw and Ojo de la Cabra, most of the terraces are very poorly preserved at their downstream ends, are discontinuous and highly eroded, and high on the valley sides in inset positions. As the terraces are followed upstream, they become better preserved and less eroded, more continuous, but still entrenched. Farther upstream they have Holocene alluvium and eolian sands on top of more gravelly alluvium. Even farther upstream, the terraces are unentrenched, occupied by a late Holocene-historic channel and floodplain. New, discontinuous, eroded terraces appear on the landscape above the Holocene drainageway. These new terraces in turn become more continuous and then buried upstream. The higher discontinuous terrace of the lower Ojo de la Cabra canyon may be traced to the upper part of the drainage where it becomes buried by Holocene distal piedmont prograding from the east (in part from lower Sanchez Canyon drainage) and eolian sand prograding across the drainage from the southwest.

The upper part of Memorial Draw is incised into the Canada Colorado surface (Tsp on color map elsewhere in guidebook) as are similar ephemeral drainages to the north. These drainages have intermediate terraces inset below the level of the Canada Colorado and slightly lower piedmont surfaces. They also commonly have only a thin veneer of canyon-bottom Holocene alluvium resting on well cemented Pleistocene conglomerate (not older Tps or Qps; see color map) and groundwater-related platy carbonates. The pervasive platy calcium carbonate cements both within the drainages and along the valley borders suggest (perhaps wrongly) that the drainages are relict from a time when the water table was high and that not much sediment transport or deposition has taken place in the past few thousand years at least. The platy carbonate is commonly broken up and transported short distances downslope, making the shallow exposures difficult to distinguish from degraded Stage IV pedogenic laminar carbonate. These platy carbonate clasts are particularly confusing in young fans along the hanging walls of faults, causing geomorphologists to question the age of the deposits on both sides of fault scarps.

DISCUSSION AND CONCLUSIONS

The terraces of Hell Canyon and its tributaries clearly have a long and complicated history, which remains to be figured out. Details will need to be based on more than 10- and 40-foot contour maps and poor exposures in most reaches. The dynamic shifts in stream entrenchment and episodic terrace formation have taken place during the past million years, ending up with the present incised drainage of Hell Canyon. One can not simply use the "finger method" of counting terraces backward to correlate with the climatic signal recorded by marine oxygen-isotope stages because repeated motions on several faults have affected the terraces, the valley border sediments change downstream, and because the terraces appear to be time-transgressive in part, or at least in their upstream preservation. The upstream preservation and disappearance of terraces imply either incomplete adjustment of the drainages to episodic changes in climate and tectonism (threshold and process-duration phenomena) or dynamic shifts in sediment transport within the upper contributory parts of these small drainages. Is it possible for the small, ephemeral tributary drainages arising on piedmont slopes to generate enough water and sediment discharge within one climatic regime to create a complex response to form more than one terrace in a short period of time, or to generate more than one terrace longitudinally at the same time? Stay tuned.

REFERENCES

- Bull, W. B., 1991, *Geomorphic responses to climatic change*: New York, Oxford University Press, 326 p.
- Jackson, J. A., 1997, *Glossary of geology* [Fourth edition]: American Geological Institute, 769 p.
- Leopold, L. B., Wolman, M. G., and Miller, J. P., 1964, *Fluvial processes in geomorphology*, San Francisco, W. H. Freeman, 522 p.
- Schumm, S. A., and Hadley, R. F., 1957, Arroyos and the semiarid cycle of erosion, *American Journal of Science*, v. 225, p. 161-174.
- Schumm, S. A., and Parker, R. S. 1973, Implications of complex response of drainage systems for Quaternary alluvial stratigraphy: *Nature, Physical Science* (London), v. 243, no. 128, p. 99-100.
- United States Department of Commerce, 1973, *Precipitation-frequency atlas of the Western United States*, v. IV, New Mexico: National Oceanic and Atmospheric Administration, National Weather Service, Atlas 2.