# 24 The Typical Badlands Landscapes Between the Tyrrhenian Sea and the Tiber River

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**Abstract**

A mixture of special geomorphological conditions and extraordinary cultural interests is collected in the country between the Tyrrhenian Sea and the Tiber River. In the Holocene severe erosion processes shaped Plio-Pleistocene marine claystones, highly uplifted during the Quaternary, producing spectacular badlands landscapes with *calanchi* and *biancane* landforms. C*alanchi* show a resistant caprock, driving a parallel-retreating evolution of rugged steep slopes; *biancane* are rounded landforms, related to clayey outcrops in low-relief areas. Badlands have been greatly modified by anthropogenic activity: most of *biancane* and some *calanchi* were smoothed in the twentieth century, mainly to the widening of sowable land. For these reasons, a very peculiar badlands landscape is recognizable today.

**Keywords**

Badlands • *Calanchi* • *Biancane* • Volcanic caprock • Central Italy

Ogni valle è fatta dal suo fiume e tal proporzione è da valle a valle, quale è da fiume a fiume
*Each valley is shaped by its river, and the same proportion existing between a valley and another is found between their rivers*
Leonardo da Vinci

## 24.1 Introduction

Some clayey terrains present in many parts of Italy are affected by accelerated erosion processes, producing badlands landforms known as *calanchi* and *biancane*. Badlands landscapes are frequently considered to be typical of dryland areas. Semi-arid badlands are present throughout the Mediterranean region, the better-known examples being located in various parts of Spain and southern Italy. Nevertheless, they also occur in wetter areas, as in central Italy, where high topographic gradients, bedrock weakness and high intensity rainstorms coexist.

Central Italy has an unbelievably wide variety of landscapes in relation to its extension. Between the Tyrrhenian Sea to the west and the Adriatic Sea to the east, there are about 200 km, along which the traveller crosses coastal, hilly and high mountain landscapes. The structure of the Apennine chain consists mainly of ridges of carbonate rocks of Mesozoic age, elongated in the NW–SE (Apennine) direction and increasing in elevation from the Tyrrhenian to the Adriatic sector, where tectonics raised the highest summits to almost 3000 m a.s.l., with thrusts, faults and crustal deformation still in progress (Fig. 24.1). The great complexity of the geometric relationships between the various formations is derived from the geological history of the Apennines. The orogenic wave has spread from west to east; during the Miocene, it has mainly focused on the Tyrrhenian sector, that in the Pliocene was then subjected to crustal

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thinning and horst and graben construction. For the same reason, on the Tyrrhenian coast belt, between the Pliocene and Quaternary endogenous activity formed several volcanic complexes, some of which are still active. The recent geological evolution is therefore responsible for the uplift of the Plio-Pleistocene marine deposits to several hundred metres above sea level. During this period, on the Tyrrhenian side of central Italy geodynamic processes have caused differential uplift, volcanic eruptions and the origin of horst ridges. The variety of outcropping lithotypes and the tectonic processes have influenced the development of structural landforms. The major ones are represented by morphostructural ridges bounded by NW–SE trending fault scarps, dipping towards the graben depressions (Fig. 24.1). Minor morphotectonic features (e.g. straight channels, saddles and straight ridges) are aligned along the other structural patterns. In the areas in which the main morphostructures are located and/or where harder rocks crop out, landforms are more rugged and valleys are deeper. However, the landscapes between the Tyrrhenian Sea and the Tiber River are mostly characterized by hilly landscapes, with elevations rarely higher than 1000 m, as a result of the widespread outcrops of soft sediments. The Plio-Pleistocene clayey lithotypes recently uplifted are now modelled by very strong exogenous processes and in some areas give rise to characteristic landscapes, with dramatic and very widespread erosion landforms: *calanchi* and *biancane*.

## 24.2 Geographical and Geological Setting

Several areas in northern Latium and southern Tuscany, between Siena and Rome, have been modelled by fast erosion processes and include typical badlands landforms.

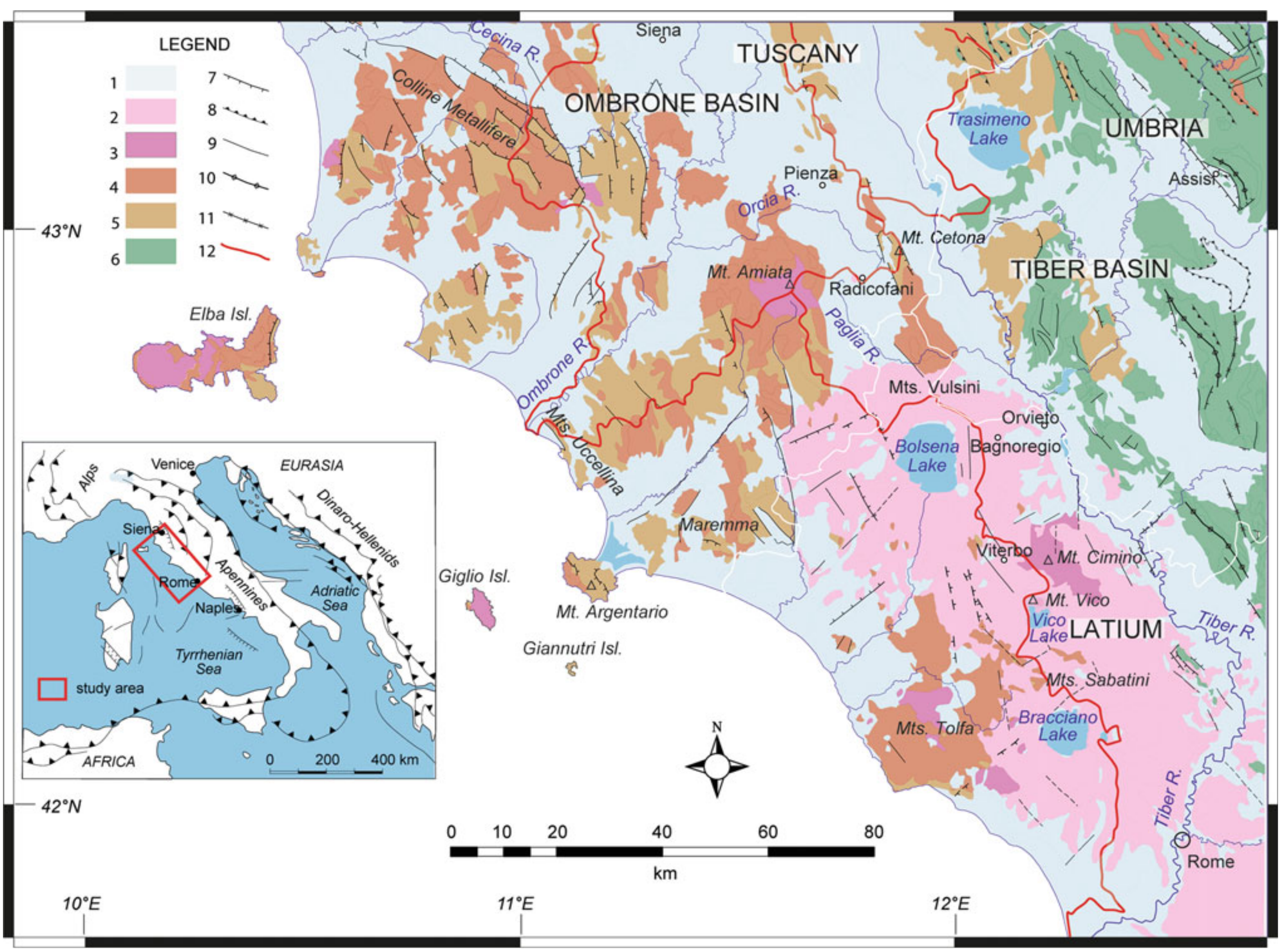


**Fig. 24.1** Geological sketch of the study area. *1* Plio-Quaternary undifferentiated marine and continental deposits (and subordinate Messinian evaporites); *2* Pleistocene basic to intermediate volcanic rocks; *3* Plio-Pleistocene (and subordinate Miocene) acid volcanic rocks; *4* Ligurian and sub-Ligurian nappes sedimentary and metamorphic units (Trias to Lower Cretaceous); *5* Tuscan nappe sedimentary and metamorphic units (Paleozoic to Miocene); *6* Umbria-Marche sedimentary sequence (Trias to Tortonian); *7* Normal faults; *8* Overthrusts and reverse faults; *9* Other faults; *10* Axis of anticline; *11* Axis of syncline; *12* Main fluvial basin boundary

A smooth hilly landscape marks the northern portion of the area, where *biancane* slopes are frequent, although often reshaped due to local crop-growing activities. The *biancane* landforms are small clay domes up to approximately 15–20 m high, mostly bare of vegetation on steeper south-facing slopes, where sheet and rill erosion is very strong. *Biancane* are often located near the footslope or at the summits, and their existence is always associated with gentle slopes.

Moving towards the south, the landscape becomes much rougher, and the typical landforms on clayey slopes are represented by *calanchi*, that is systems of rills and gullies separated by sharp and steep ridges (from “*calans*” Latin for “dropping” or “downhill”). They occur particularly in places where horst structures and/or volcanic caprocks are present and slope steepness increases. These areas are concentrated in the eastern and northwestern parts of the Ombrone and Tiber fluvial basins, respectively (Fig. 24.1). *Calanchi* are sometimes bevelled by human activities; overall, the *calanchi* slopes are less reworked than those in the *biancane* zones.

The geological history has contributed to widespread outcrops of lithological units prone to denudation (Fig. 24.1). The building phase of the Apennine orogenic wedge (Oligocene to Tortonian) led to the formation of the major horst-and-graben morphostructures in the study areas. These are mainly NW–SE oriented and composed of sedimentary sequences (Umbria-Marche sequence, Tuscan Nappe, Ligurian and Subligurian Nappe) overthrust towards the NE (Fig. 24.1). The nappes include some metamorphic units (Paleozoic to Trias). The orogenic wedge began collapsing in the Late Miocene. Extensional tectonics, affecting the Tyrrhenian margin of the Italian peninsula, activated several NW–SE striking normal faults, which define the system of horst and graben cut by SW–NE transfer faults (Liotta 1991). A marine transgression led to the deposition of a Plio-Pleistocene sequence of clay, sands and conglomerates within the major depressions. Moving inland, the extensional basins are filled with lacustrine to fluvio-lacustrine continental deposits.

During the Quaternary, the Plio-Pleistocene marine deposits were uplifted by several hundred metres. This strong uplift is related to pluton emplacement and widespread volcanic activity along the Tyrrhenian margin (Acocella and Rossetti 2002), evidenced by the distribution of several volcanic complexes (Fig. 24.1). Quaternary uplift has been particularly strong along a NW–SE elongated zone, which extends from the Colline Metallifere Area towards the Latium volcanoes (Mts. Vulsini, Mt. Vico, Mts. Sabatini), going through Mt. Amiata, Radicofani and Mt. Cetona, where marine deposits crop out at 800 m.

Therefore, the altitude of Plio-Pleistocene marine deposits reaches several hundred of metres above the present sea level; together with the high value of relief amplitude, this underpins a very fast geomorphological evolution in this sector of central Italy.

## 24.3 Landforms and Landscapes

Fluvial erosion, together with slope denudation, contributes significantly to the morphogenesis of the Tyrrhenian side of central Italy. Many slopes are rapidly evolving and rivers carry high volumes of suspended sediment load.

Mass movements contribute to slope denudation along with water erosion. Apart from some rock falls, slides often occur on steep slopes. However, the influence of gravity is also evident on gentler slopes, where mudflows, soil creep and shallow soil flow are widespread. Due to these prevailing morphogenetic processes, gently undulated slopes typify the regional landscape.

Human impact has significantly affected the landscape of the area for a long time (Amici et al. 2017). Deforestation, grazing and farming are among the most important triggers for accelerated water erosion, tillage erosion and gravitational movements on slopes. Moreover, the effects of farming may become stronger if land-use changes determine cropland abandonment. Water erosion is pervasive on many slopes, due to extensive clayey outcrops, human activities, current climatic conditions and rapid uplift. Sheet erosion is responsible for exposure of roots and colluvium deposition at the footslope. As the slope gradient increases slightly, rill and gully erosion prevail, contributing significantly to badlands development and soil degradation. Ephemeral gullies are often recognizable in croplands and grow rapidly as a consequence of concentrated rainfall. Water erosion on natural slopes leads to typical badlands with *calanchi* and *biancane*. These landforms, in the belt between the Tyrrhenian Sea and the Tiber River, are similar to the badlands of the United States or many other areas, but have their own distinct characteristics.

A *calanchi* slope may seem a reduced model (by one thousand or ten thousand times) of a fluvial system. Thus, on the whole, they appear as “concave” landforms. As described by Alexander (1980), *calanchi* are systems of rills and gullies, connected in thick small networks evolving headwards and separated by sharp and steep divides (Fig. 24.2). In central Italy, some *calanchi* show knife-edged features, shaped as a system of narrow but deep cuts separated by thin and articulated ridges (Fig. 24.2), as to reproduce a drainage network in miniature. On the slopes, the effects of both strong runoff processes and subsurface erosion processes

**Fig. 24.2** *Calanchi* on a southward facing slope (Tyrrhenian Sector, Tiber River basin, Latium). A volcanic caprock is recognizable on some slope tops

(tunnelling or piping) can be observed. Many other badlands are made of larger incisions, with a trough-floored aspect, separated by smaller convex ridges, sometimes overgrown and characterized by less intense surface runoff phenomena.

The important role of wash denudation in the area is mainly due to local structural conditions. *Calanchi* morphology is associated with clayey outcrops, alternating with sandy and gravel levels, and frequently with counter-dip slopes, that allow the development of steeper slopes. This type of slope evolution is even more related to the presence of a volcanic caprock, especially in northern Latium, or a more or less cemented sand and conglomerate caprock. If a caprock is absent, slope steepness decreases quickly and the parallel-retreating evolution stops, as described in Scheidegger's evolutive model (1961; Figs. 24.3 and 24.4).

In the Tyrrhenian sector, aspect does not seem to greatly influence the distribution of badlands, but important morphological and vegetational differences can be observed on slopes with different aspect. Wash processes shape the south-facing slopes into very thin and sharp ridges, "blade" crests (Fig. 24.5). At the bottom of these slopes, in parallel-retreating evolution, small pediments can be observed, as already described by Schumm (1962). The north-facing slopes are much more overgrown and characterized by frequent mass movements that give a trough-floored aspect to the incisions, especially during winter.

In other areas of central Italy, like those located in the Adriatic sector, the presence of *calanchi* is even more closely linked to south-facing slopes, where higher insulation restrains vegetation growth; however, in this sector the south-facing slopes are almost always inclined opposite to the dip, which helps to hold a higher slope.

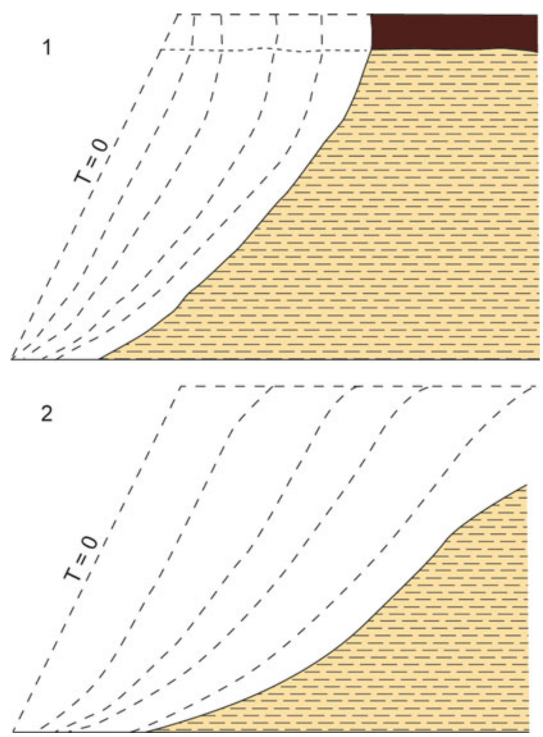


**Fig. 24.3** Scheidegger's slope evolution starting from $T = 0$ (initial time): *1* clayey slope with caprock; *2* clayey slope without caprock

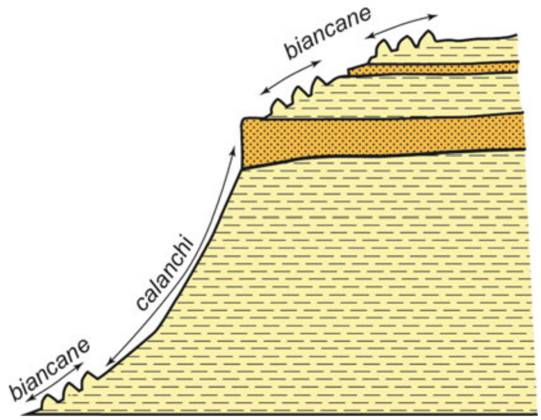


**Fig. 24.4** Distribution of *calanchi* and *biancane* on a typical slope of the upper Orcia River Valley (southern Tuscany)

*Biancane* are typical dome-shaped features a few metres in height and usually found in groups (Torri et al. 1994) to form a "convex" morphology on the whole. These rounded landforms can reach 20 metres in height without a vegetation cover on the steeper south-facing slopes, which are characterised by intense slope wash (Fig. 24.6). The term "biancana" (from "bianco" Italian for "white") probably comes from the presence of a thenardite ($Na_2SO_4$) crust on their surfaces, due to precipitation from capillary waters. Micro-pediments usually develop at the foot of the *biancane* retreating slopes (Fig. 24.6). They show thin layers of materials transported by runoff, deposited on low angle surfaces and often affected by mud-cracking.

The *biancane* are closely related to areas with low relief. In southern Tuscany, they are found either on the flat tops of ridges, and in the valley floors, next to the lower part of convex slopes (Fig. 24.4). Along the valley bottoms, *biancane* may be residual "inselbergs" related to slope retract. Those present on low-relief summit surfaces cannot be interpreted in the same way; they are due to runoff effects in interfluve areas, where steepness is low and gully erosion is still in the initial stage.

Italian badlands have, often, more vegetation if compared to badlands in other areas of the world (Figs. 24.2, 24.5 and 24.6). Their existence is linked to a series of

**Fig. 24.5** A watershed between two small basins in the badlands of northern Latium. The knife ridge has been used for centuries as a passage to cross the Calanchi Valley. A few decades ago it has become too narrow and unsafe, and the trail has been abandoned. Note, on the *top* (*red frame*), the remnants wooden boards of the old path hanging on the verge of falling

**Fig. 24.6** Group of *biancane* (Orcia Valley, southern Tuscany). At the foot of the southern slopes, evolving by parallel retreat, some micropediment are growing

favourable factors, dependent on the geological, geomorphological and climatic conditions. The climate of central Italy, especially that of the piedmont and coastal areas, is a basic influencing factor for badlands development. Hot and dry summer followed by a rainy autumn, with heavy rains on several consecutive days, enhances runoff action. During winter, the soil does not dry in depth, and spring rains (although less intense than the autumn ones) often cause an increase of mass movements rather than of runoff intensity.

Both *calanchi* and *biancane* result from the same geomorphic processes and are influenced by some common factors. Impermeable bedrock (clay or marly clay) is a necessary condition to produce strong runoff, where weathering can increase susceptibility to erosion. Thus, aspect generally plays an important role in badlands evolution by conditioning the vegetation cover distribution. However, *calanchi* and *biancane* have significant morphological differences (Ciccacci et al. 2003).

Moretti and Rodolfi (2000) outlined several environmental components that interact in the development of the *calanchi* landscape. Other factors being equal (e.g. aspect, lithological and climatic conditions), slope steepness strongly influences the erosive power of runoff in rills and gullies. In general, *calanchi* are more frequent on scarp slopes and their growth is favoured by sandy, gravel, conglomeratic or volcanic caprocks at the summit, helping to maintain slope steepness (Fig. 24.3).

Noticeable slope steepness favours diffuse mudflows, which strongly contribute to the removal of considerable volumes of sediment (and deposition, generally at the gully bottom), while caprocks are often subject to rock falls at the steep summits of *calanchi* slopes. Since *calanchi* on north-facing slopes are generally less developed and more vegetated, the runoff power is less effective, but may make earth sliding more likely (Fig. 24.7).

Deep piping is widespread at many *calanchi* sites, especially in northern Latium where *calanchi* are more extensive.

**Fig. 24.7** Calanchi Valley, with distinctive asymmetry of relief and vegetation cover (Tyrrhenian sector, Tiber River basin, NW of Rome). The north is on the *left*

According to Romero-Díaz et al. (2007), this process is favoured by land-use changes (i.e. cropland abandonment) and by steep hydraulic gradients. In particular, hydraulic gradients increase at the intersections between sub-horizontal bedding and vertical fractures. Deep pipes probably contribute significantly to denudation and evolve rapidly due to collapse.

Ephemeral gullies develop on cultivated or grazing lands, where they create very important paths of sediment movement. On slopes, several small earth pillars are present (with vegetation cover, stones or fossil gastropod shells on the top), whereas other minor landforms are caused by piping processes. Some very high pillars are residual landforms, resulting from demolition of sharp ridges due to falls (Fig. 24.8). On the footslopes, parallel retreat leads to the development of landforms similar to small pediments, as it has already been suggested in previous studies (Schumm 1962; Torri et al. 1994).

Summarizing, in central Italy rill erosion on *biancane* is more significant on south-facing steeper slopes, while the north-facing ones are gentler and generally exhibit a thin, continuous vegetation cover. The N-S *biancane* profile is typically asymmetric (Ciccacci et al. 2003), with the uncovered slopes showing weathered "popcorn surfaces". According to Farifteh and Soeters (2006), *biancane* are likely to develop on originally gentle slopes, while *calanchi* development is probably favoured by initial slope steepness, due to strong fluvial deepening in response to the lowering of sea level or to regional uplift. Moreover, as outlined by Torri and Bryan (1997) and confirmed by Farifteh and Soeters (2006),

**Fig. 24.8** High pillar in the Calanchi Valley (Tiber River basin, northern Latium)

structural factors, such as intersecting fracture patterns, probably control *biancane* formation and evolution.

In addition to runoff, piping and gravitational movements act together in shaping *biancane* slopes, but with some differences with respect to *calanchi* slopes: (a) unlike *calanchi* slopes (where deep piping is more frequent), *biancane* are widely affected by shallow micro-piping, developing at the boundary between the weathered layer ("popcorn surface") and the undisturbed bedrock; (b) *biancane* are less affected by gravitational movements (mainly mudflows along major rills and gullies) compared to more unstable *calanchi* slopes.

## 24.4 Geomorphological Evolution of *Calanchi* and *Biancane* Landscapes

Results of hillslope-scale monitoring and many field surveys showed the relationship between denudation rates and morphoevolution of the two badlands types. X-ray diffraction analyses performed on samples from the marine Pliocene and Pleistocene sediments of ODP Hole 653A in the Tyrrhenian Sea indicated an acceleration of the uplift/emergence of the areas here described at about 1.6 Ma BP (Della Seta et al. 2009). It is likely that, as a consequence, the landscape has been strongly dissected by fluvial deepening. In particular, as a result of the coupled effect of uplift and shifting from relatively dry to humid climatic conditions in the Early Pleistocene, valley deepening was favoured. Alternating cold/dry and hot/humid climatic phases during the Pleistocene probably determined the discontinuous preponderance of areal denudation or fluvial deepening, respectively.

During the Holocene, under conditions of general post-glacial warming, short-term climatic oscillations occurred in the mid-European region, as deduced, e.g. from lake-level fluctuations (Magny 2004). Recent works outlined the strong relationships among climate, fire, vegetation, and land-use and attested to the paramount importance of fire in Mediterranean ecosystems (Drescher-Schneider et al. 2007; Vannière et al. 2008). As evidenced by these authors, humans started to affect fire regimes since the Neolithic (8000 cal years BP), but during the Bronze Age (4000–3800 cal years BP) a significant increase in using fire as a tool determined considerable changes in fire regime. In addition, human impact increased noticeably since the Roman Age through deforestation, leading to considerable environmental modifications (Buccolini et al. 2007); as a result of human-induced rhexistasy, steep valley slopes and gentler interfluves, together with footslopes, have become the ideal sites for *calanchi* and *biancane* development, respectively.

After deforestation, grazing and farming have become important factors responsible for accelerated water erosion, tillage erosion and gravitational mass movements. Torri et al. (1999) put forward a hypothesis and provided evidences of progressive deterioration of the soil and land condition between 1840 and 1870, which increasingly transformed arable lands into pasture, and eventually, badlands. More recently, land-use changes due to cropland abandonment have amplified the power of water erosion on slopes.

The hypothesized formation and evolution of *calanchi* and *biancane* in the area between Tyrrhenian Sea and Tiber River is substantially in agreement with the model developed by Farifteh and Soeters (2006) for *calanchi* and *biancane* in Aliano (southern Italy), although some differences exist. On the Tyrrhenian side of central Italy the development of *calanchi* and *biancane* is strictly connected to the original slope steepness, which is one of the major factors influencing their distribution (Della Seta et al. 2007). Moreover, the occurrence of *biancane*, even at the summit of *calanchi* slopes, allows one to exclude the possibility that they could represent just residual products of *calanchi*, as proposed by some authors. Observations on present embryonic *biancane* confirm the leading role played by reticular systems of joints in the dissection of original, gently dipping surfaces (Torri and Bryan 1997; Farifteh and Soeters 2006).

*Biancane* initially grow as small bare symmetrical domes, whose north-facing slopes start to undergo shading as their heights increase. On the 20 years monitored *biancane* (Vergari et al. 2013), vegetation cover is likely to have developed on these shaded, thus moister, north-facing slopes, rather than representing a remnant cap, as stated in the evolutionary model by Farifteh and Soeters (2006), since it wraps the north-facing slopes of the evolved *biancane* from top to bottom. From this perspective, the evolution of *biancane* leads to a progressive increase of the aspect-induced asymmetry typical of evolved *biancane*. Moreover, strong retreat of south-facing bare slopes leads to the formation and rapid widening of micro-pediments at their foot (Fig. 24.6).

Therefore, the evolution of many *biancane* sites in the Tyrrhenian side of central Italy can be summarized as to occur in four main stages (Fig. 24.9). Initially, severe runoff processes affect a gentle slope on fractured clay, cut by intersecting systems of joints. This may take place in response to abandonment of agricultural activities, increase of fluvial deepening, and climatic changes (like those at the end of the Little Ice Age). Many rills and some gullies develop along the joints (Fig. 24.9a). Then, rill and gully networks grow, while under the surface tunnelling processes

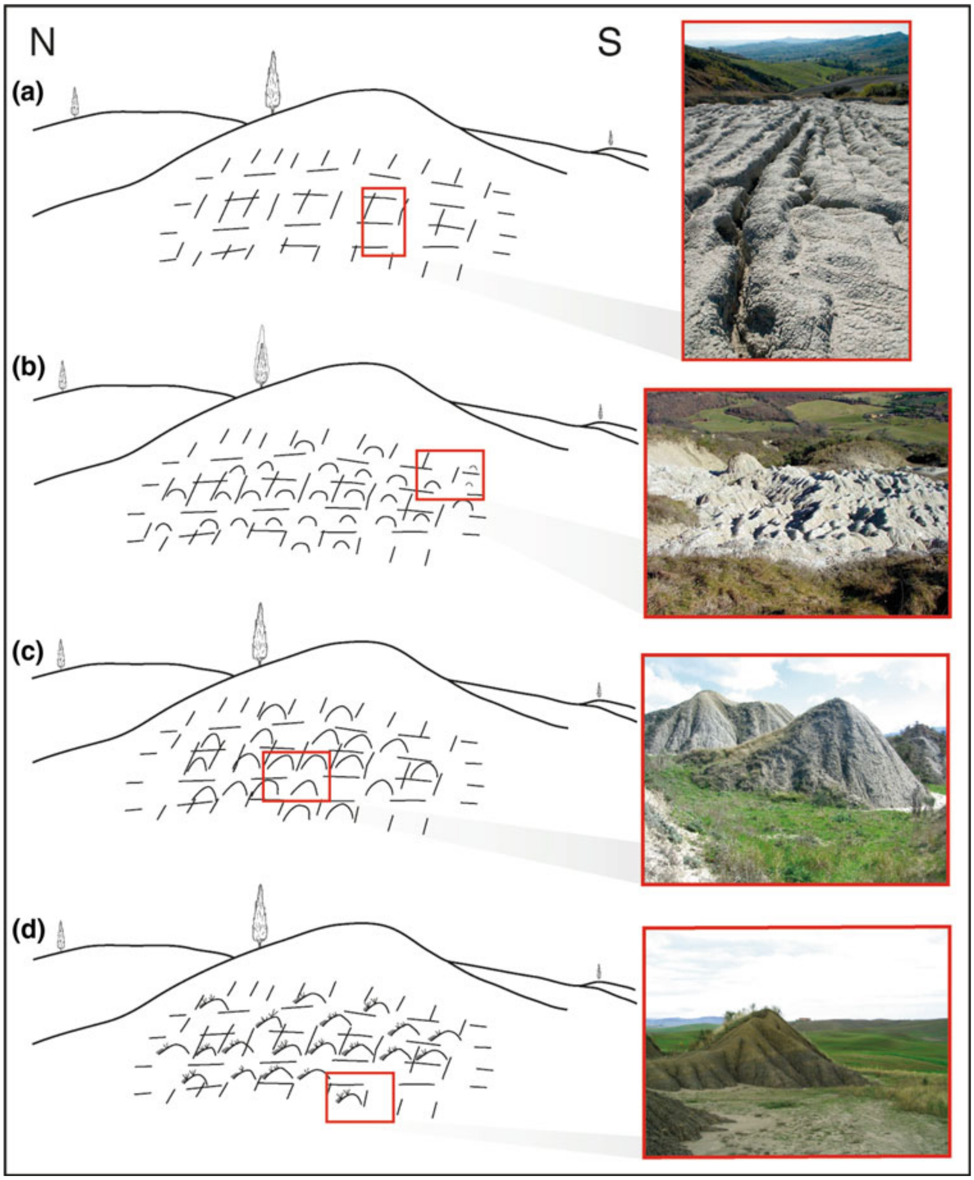


**Fig. 24.9** *Biancane* morphoevolution. **a** A gentle slope on fractured clay cut by intersecting systems of joints is undergoing severe runoff processes. **b** Development of embryonic symmetrical *biancane*. **c** *Biancane* hight increases up to 15–20 m. Vegetation on shaded north-facing slopes covers them and prevents further erosion. The south-facing hillsides continue to increase its own slope, then evolve by parallel retreat. *Biancane* become asymmetric. **d** Fast erosion lowers the small domes and leads to the widening of micro-pediments

form a pipe network. Selective rill erosion shapes embryonic symmetrical *biancane* (Fig. 24.9b). When the *biancane* height increases, vegetation on shaded north-facing slopes covers them and controls the progress of erosion. Thus, the power of rill erosion decreases on north-facing slopes and *biancane* evolve asymmetrically; hereafter, the south-facing slopes evolve by parallel retreat and some micro-pediments appear at its foot (Fig. 24.9c). Finally, the south-facing slope parallel-retreating preserves the asymmetry of *biancane*, but fast erosion lowers the small domes and leads to the widening of micro-pediments (Fig. 24.9d).

Regarding *calanchi* evolution, their slopes probably evolve by substantial parallel retreat as long as caprock is present, according to the Scheidegger's model (Fig. 24.3). Some outliers with volcanic caprocks hold ancient villages (i.e. Orvieto, Civita di Bagnoregio) and picture suggestive landscapes (Fig. 24.10). When caprock remnants finally disappear, parallel retreat ceases and slope steepness rapidly decreases, unless the fluvial systems are rejuvenated. This evolution is accompanied by changes in denudation rates, as a function of the increasing mudsliding from the rill and gully heads.

**Fig. 24.10** An outlier with volcanic caprock. On the top, the ancient settlement of Civita di Bagnoregio lies (Calanchi Valley, Tiber River basin, northern Latium)

## 24.5 Conclusions

In the Mediterranean region, soil erosion or, more broadly, severe slope denudation, is one of the most important environmental problems, both for its noticeable impact on human activities and for its consequences in natural environments. In the western sector of central Italy, geomorphic processes produce typical water erosion landforms, such as *calanchi* and *biancane*. These landscapes are very sensitive to land use changes that have occurred in recent times: from natural slopes affected by badlands, the trend has been firstly towards low-impact croplands, then to over-exploitation during the last 50 years, and finally to cropland abandonment. The present modifications are mainly due to an increasing contribution of mass movements to the erosional processes, previously driven mainly by surface running waters.

Anyway, slopes have very degraded soils or bare unstable surfaces, rapidly evolving due to strong wet-dry seasonal contrasts and widespread outcrops of erodible bedrock. However, these strong erosion processes have also created spectacular and rugged landscapes, alongside the cultural landscapes shaped by people over many centuries. Nowadays, the badlands landscapes in central Italy represent an additional resource for the territory, and not just “Bad Lands”. Tourists visiting the monuments and cultural landscapes between Rome and Siena are also increasingly attracted by the natural aspects of the landscape, especially the most picturesque ones: *calanchi* and *biancane* landforms.

## References


Acocella V, Rossetti F (2002) The role of extensional tectonics at different crustal levels on granite ascent and emplacement: an example from Tuscany (Italy). Tectonophysics 354:71–83

Alexander DE (1980) I calanchi, accelerated erosion in Italy. Geography 65(2):95–100

Amici V, Maccherini S, Santi E, Torri D, Vergari F, Del Monte M (2017) Long-term patterns of change in a vanishing cultural landscape: a GIS-based assessment. Ecol Inform 37:38–51

Buccolini M, Gentili B, Materazzi M, Aringoli D, Pambianchi G, Piacentini T (2007) Human impact and slope dynamics evolutionary trends in the monoclinal relief of Adriatic area of central Italy. Catena 71:96–109

Ciccacci S, Del Monte M, Marini R (2003) Denudational processes and recent morphological change in a sample area of the Orcia River Upper Basin (Southern Tuscany). Geogr Fis Dinam Quat 26:97–109

Della Seta M, Del Monte M, Fredi P, Lupia Palmieri E (2007) Direct and indirect evaluation of denudation rates in Central Italy. Catena 71:21–30

Della Seta M, Del Monte M, Fredi P, Lupia Palmieri E (2009) Space–time variability of denudation rates at the catchment and hillslope scales on the Tyrrhenian side of Central Italy. Geomorphology 107 (3–4):161–177

Drescher-Schneider R, de Beaulieu JL, Magny M, Walter-Simonnet AV, Bossuet G, Millet L, Brugiapaglia E, Drescher A (2007) Vegetation history, climate and human impact over the last 15,000 years at Lago dell'Accesa (Tuscany, Central Italy). Veg Hist Archaeobotany 16:279–299
Farifteh J, Soeters R (2006) Origin of calanchi and biancane in East Aliano, southern Italy. Geomorphology 77:142–152
Liotta D (1991) The Arbia-Val Marecchia line, northern Apennines. Eclogae Geol Helv 84:413–430
Magny M (2004) Holocene climate variability as reflected by mid-European lake-level fluctuations and its probable impact on prehistoric human settlements. Quatern Int 113:65–79
Moretti S, Rodolfi G (2000) A typical "calanchi" landscape on the Eastern Apennine margin (Atri, Central Italy): geomorphological features and evolution. Catena 40:217–228
Romero-Díaz A, Marin Sanleandro P, Sanchez Soriano A, Belmonte Serrato F, Faulkner H (2007) The causes of piping in a set of abandoned agricultural terraces in southeast Spain. Catena 69:282–293
Scheidegger AE (1961) Mathematical models of slope development. Geol Soc Am Bull 72:37–50
Schumm SA (1962) Erosion on miniature pediments in Badlands National Monument, South Dakota. Geol Soc Am Bull 73:719–724
Torri D, Bryan RB (1997) Micropiping processes and biancane evolution in Southeast Tuscany, Italy. Geomorphology 20:219–235
Torri D, Colica A, Rockwell D (1994) Preliminary study of the erosion mechanisms in a biancana badland (Tuscany, Italy). Catena 23:281–294
Torri D, Regüés D, Pellegrini S, Bazzoffi P (1999) Within-storm soil surface dynamics and erosive effects of rainstorms. Catena 38:131–150
Vannière B, Colombaroli D, Chapron E, Leroux A, Tinner W, Magny M (2008) Climate versus human-driven fire regimes in Mediterranean landscapes: the Holocene record of Lago dell'Accesa (Tuscany, Italy). Quatern Sci Rev 27:1181–1196
Vergari F, Della Seta M, Del Monte M, Barbieri M (2013) Badlands denudation "hot spots": The role of parent material properties on geomorphic processes in 20-years monitored sites of Southern Tuscany (Italy). Catena 106:31–41