The Chambal Badlands

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Abstract

Chambal Badlands of central India are one of the most extensive badlands in the world, and are one of the four severely dissected landscapes within the Middle Alluvial Ganga Plains (MGAP). This extensive dissected landscape with labyrinth of winding gullies has offered refuge to outlaws for centuries. Badlands or ravines generally but not exclusively occur in semi-arid and arid areas with erodible rocks. These areas, dominated by surface erosion by overland flow and gullies, are characterized by heavily dissected terrains with steep slopes and channels separated by sharp ridges. The gullies rapidly incise and extend headward. Evidence suggests that the evolution of the badlands along the Chambal River coincided with the incision of the river as a result of the strengthening of SW monsoon in the early Holocene. Lineament controlled block uplifts might have also affected these areas causing the streams to rejuvenate, inducing widespread gullying in the region. Evidence such as ruins of former settlements, and remains of temple foundations suggests that these badlands were formed and/or rapidly extended during the recent historical period. The possibility of further expansion of the badlands in response to human interference is expected in the future.

Keywords

Chambal • Badlands • Ravines • Gullies • Tectonics • Rejuvenation • Lineament • Monsoon

1 Introduction

Breaking the monotony of the vast Indo-Ganga Plains, stunning the eyes of the onlookers, emerge the Chambal Badlands with their awe striking appearance and spell-binding notoriety. Cascading from the lofty mountains of Himalaya in the alluvial Ganga Plains of India, lay two of the holiest rivers of India, namely, Ganga and Yamuna. But there are also some southern tributaries that originate from the Indian Craton and join the Yamuna and the Ganga with equal magnificence and vigor. The Chambal River is one such cratonic river that joins the Yamuna (Fig. 1) and forms a large alluvial valley at the junction of the northwestern lobe of the Vindhya Plateau and the southeastern fringe of the Aravalli Hills. From the source to its confluence with the Yamuna, the Chambal River is about 1000 km long, with a catchment area of $\sim 140{,}000\ km^2$, which is larger than that of any Himalayan tributary to the Ganga or Yamuna. The river drains over both the Deccan Traps basalts and Proterozoic Vindhyan rocks and contributes significant amount of sediments to the foreland basin (Sinha et al. 2009). The Chambal Badlands, one of the most classic badlands in the world and comparable in their magnitude and extent only with the Dakota Big Badlands of North America, occur predominantly along this river (Fig. 2). In the Indian context, these badlands have been famous for centuries for all the wrong reasons, rather than for their

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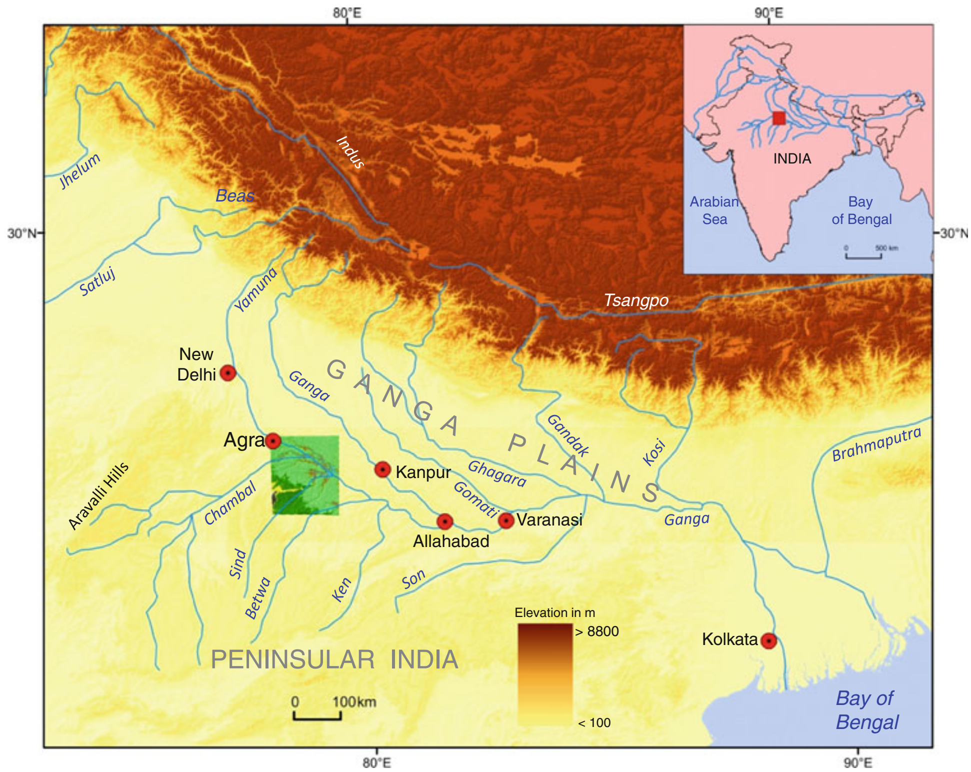

Fig. 1 Map showing the location of the Chambal River in central India. The *box* shows the location of Fig. 2. Circles represent major towns and cities

natural rugged beauty, dramatic landscape and rich faunal life. The name 'Chambal' is *synonymous with* banditry in the region. Some of the India's most infamous outlaws have operated from this region. But none of these can diminish the fact that the region is a display of nature's creative ability at its peak; a landscape so dynamic and spectacular, yet so difficult for the mankind to handle. That is the Chambal Badlands of India (Figs. 2 and 3).

Badland is a term applied to those landscapes, which are intensely dissected where vegetation is absent or sparse and is useless for agriculture. The term was first given to the arid, dissected plateau region of SW South Dakota by native Americans and fur trappers who found the area difficult to cross. Badlands develop in a wide range of materials and climate, but seem to be usually associated with arid and semi-arid environments and show a preference for unconsolidated and poorly cemented material or soft rocks (Harvey 2004). There are topographic variations in the badlands primarily due to differences in the sediment properties (Bryan and Jones 1997).

2 Geographical Setting

In India, ravines are found along many large alluvial rivers and occupy nearly four million hectares (ha) of land ($\sim$1 % of India's total land area) (Haigh 1984). There are four specific areas, known for severe ravine erosion in India: the Yamuna-Chambal Ravine Zone, the Tapi-Narmada-Sabarmati-Mahi Ravine Zone, the Chhotanagpur Ravine Zone, and the Siwalik-Foothills Ravine Zone (Sharma 1968). The largest among them is the Yamuna-Chambal Ravine Zone. The Chambal Ravines stretch for a length of 480 and 10 km wide belt along the banks of this cratonic river and occupy about half a million ha of land (Haigh 1984). These are deeply dissected ravines that spread extensively over the plain region.

The climate of the region is semi-arid, with an average annual rainfall of $\sim$900 mm with nearly 90 % of it occurring during the four monsoon months (June to September). Much of the summer precipitation is delivered with great intensity. Vegetation is mainly thorny acacia bushes which are very typical of such semi-arid landscapes (Fig. 4). Evergreen riparian vegetation is completely absent, with only sparse ground-cover along the severely eroded river banks and adjacent ravine lands.

The Chambal River passes through some of the most densely populated districts of three Indian states, namely, Madhya Pradesh, Rajasthan and Uttar Pradesh. The drainage area is rectangular in shape up to the junction of the Parvathi and Banas Rivers, while below the confluence the catchment becomes unusually narrow and elongated (Fig. 5a). Though the actual badland terrain supports very little population due to its ruggedness, there are several settlements within these badlands such as, Jiran, Kota, Bhilwars, Dholpur, Sawai Madhopur, etc. that carry large population.

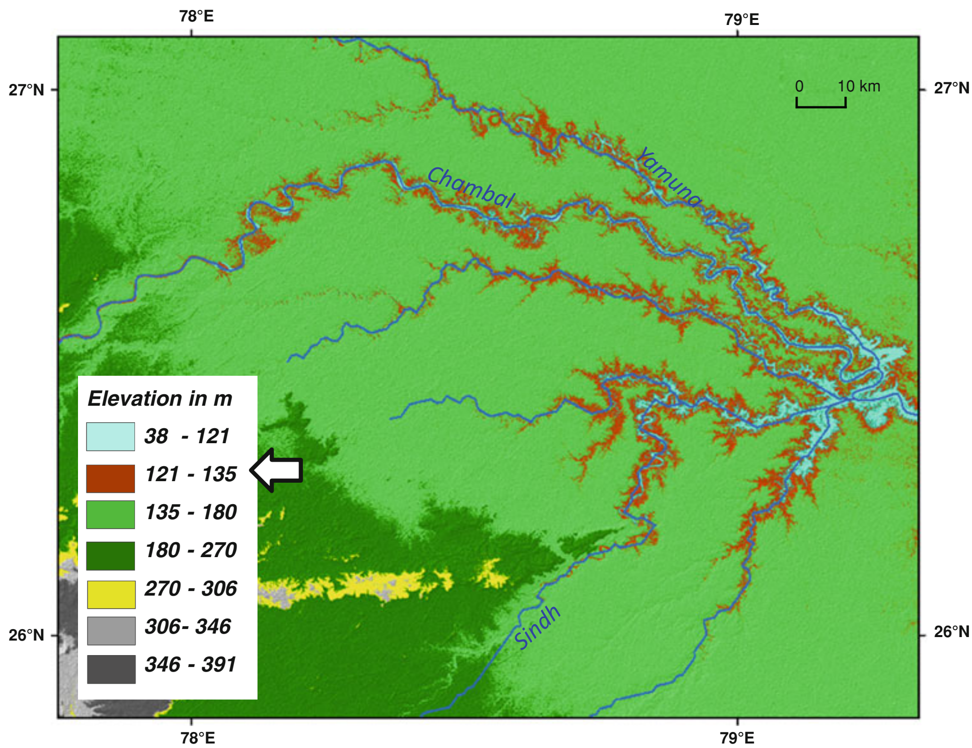

Fig. 2 Badlands along the Chambal and adjoining rivers. Near the confluence with Yamuna, the badlands developed along all these rivers coalesce to form an incredibly extensive ravine zone in this region. The *white arrow* represents the elevation category dominated by badlands

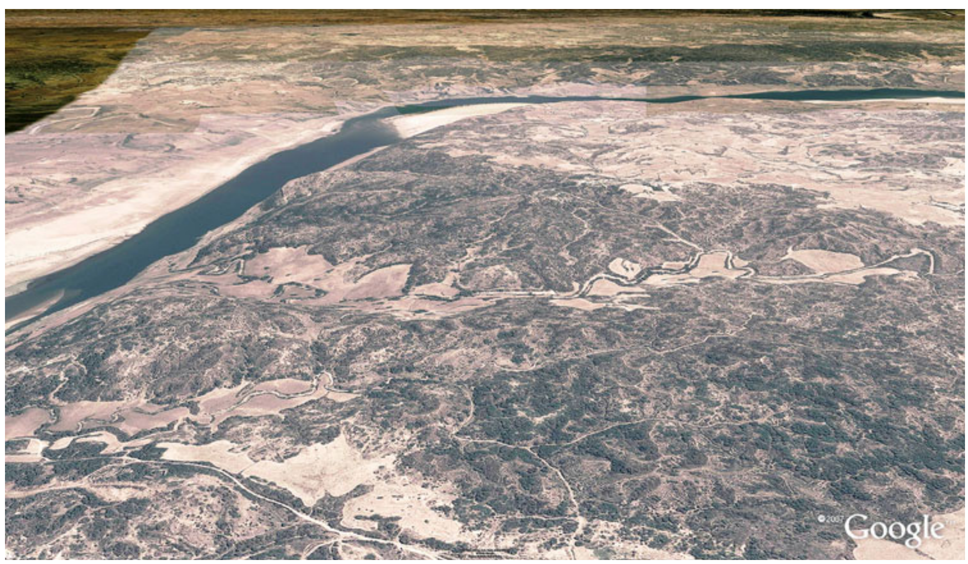

Fig. 3 Google Earth image of the Chambal Badlands (*dark* area). The Chambal River is seen on the *left*. The image covers approximately 40 km^2 area

The badlands are developed in ~50–60 m thick Quaternary alluvial deposits, which occur in a triangular-shaped area and are underlain by Bundelkhand Granite, the Gwalior Group, and the Vindhyan Supergroup rocks (Fig. 5b). The thickness of alluvium increases remarkably up to ~200 m near the confluence with Yamuna. The alluvial sequence consists of a highly oxidized polycyclic sequence of fine sands, silt and clay in varying proportions with occasional coarse channel sand and grit bodies. Calcrete (or *kankars*) and hardpan horizons are characteristically present in the sediment (Mishra and Vishwakarma 1999). These alluvial tracts exhibit remarkably homogeneous topography and the flatness of the surface is broken only by the ravine belts along the rivers.

3 Badland Morphology

The badland region is characterized by an intricate network of gullies and ravines that stretches for hundreds of kilometers not only along the Chambal River but also in the adjoining basins (Fig. 2). At many locations they attain a

Fig. 4 Two views of the Chambal Badlands. Gullies are v-shaped, very deeply incised, steep-walled and each channel is separated from the adjacent ones by sharp ridges. The difference in height between the gully *bottom* and inter-gully ridge *top* is between 20 and 40 m

width of as much as 10–12 km across. The entire badland zone demonstrates extensively and intensively dissected landscape having high drainage density; steep to sub-vertical scarps with narrow interfluves (Fig. 4). In the upstream reaches, gullies are narrow; depth is less than 1 m with a bank slope of between 45 and 80°. Further downstream, gullies change in their morphology and become wider (18–20 m), deeper with steeper bank slopes (>80°). Near the confluence with Yamuna, the gullies are of near-vertical slopes, very wide and deep with approximate width of 25 m and depth exceeding 45 m. Further beyond, the badlands of the Chambal, Yamuna, Kunwari, Sind, and Pahuj Rivers coalesce to form incredibly extensive badlands in this region (Fig. 2), the likes of which are very few in the world.

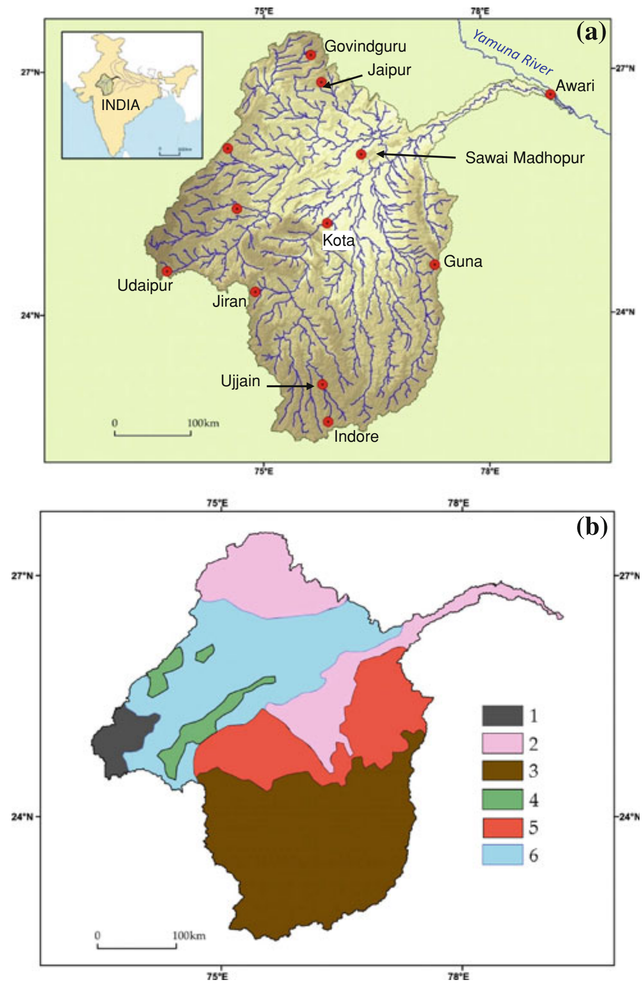

Fig. 5 **a** The rectangular-shaped Chambal drainage area. Note the remarkably narrower and elongated reach of the Chambal Drainage. **b** Geological map of the Chambal Basin *1* Aravalli Rocks, *2* Alluvium, *3* Deccan Traps, *4* Granite, *5* Vindhayan Rocks, *6* Gneisses

The badlands of Chambal resemble *Calanchi* landscape of Italy, except in its scale. A *Calanco* is a small hydrographic unit; horse-shoe shaped, with a tributary system in which each channel is separated from the adjacent ones by means of, more or less, sharp ridges with slope angles depending on the physical and mechanical properties of the bedrock. They often occur in colony to form *Calanchi*. These are heavily dissected terrain with steep, bare slopes and channels which rapidly incise and extend headwards (Alexander 1982). Chambal is the magnified version of *Calanchi*. Gullies are mostly v-shaped, very deeply incised and each channel is separated from the adjacent ones by sharp ridges (Fig. 4). The density of the gullies is so high that the interfluves appear like cones and the whole topography resembles unending colonies of hills. Morphology of the gullies varies from one location to the other and the variation is mainly attributed to the variation in their textural, stratigraphical and mineralogical properties. Wherever clayey horizon overlies the sediments, it gives rise to flat-topped hills with a steep scarp slope (Fig. 6).

The alluvial Himalayan Foreland exhibits the admixtures of sediments derived from two completely contrasting sources, namely the Himalaya and the Indian Craton. The Ganga and Yamuna Rivers bring down the Himalayan sediments and penetrate to distal foreland basin, whereas the cratonic rivers, especially Chambal and Betwa Rivers (Fig. 1), also transport huge volumes of sediments and deposit far north of the axial Yamuna River (Sinha et al. 2009). Himalayan sediments show high percentage of mica, illite and small percentage of chlorite and kaolinite but complete absence of smectite clays, whereas Chambal River transports high-grade metamorphic minerals from the Aravalli Hills and abundant smectite mostly derived from the Deccan Traps (Sinha et al. 2009). Both cratonic and Himalayan rivers have flooded over the entire region and reworked those sediments for prolonged period of time resulting in thorough churning and mixing of these sediments. The badlands have been formed on these reworked sediments from the two contrasting sources which eventually resulted in the variation in their morphological expressions. Smectite clays have high shrink-swell property and in sodium rich environment they disperse rapidly. Wherever the smectites are present in the alluvial sequence, the gullies have incised deeper and developed wider valleys and vice versa.

4 Evolution of the Badlands

Badlands are erosional forms that result from surface erosion by overland flow following heavy rainfall. Certain conditions favour the development of badlands, such as a semi-arid climate with a long dry season, available relief and easily erodible rocks (Harvey 2004). The climate over the Chambal Basin is semi-arid with a strong seasonal contrast. The Himalayan Foreland Basin stores much larger volumes of smectite rich sediments derived from the cratonic region than sediments derived from the Himalayan region (Sinha et al. 2009). Heavy monsoon rains for a short period and prolonged dry spells promote shrink-swell activity and crumbling of the alluvial sediments in the region. All these processes lead the area already vulnerable to badland formation.

Even though evidence, such as ruins of the former settlements, broken potteries and temples with their foundations almost entirely eroded away by the encroaching ravines, suggests that most of these ravines seem to have expanded rapidly in the last few centuries (Mishra and Vishwakarma 1999), there is neither documentary nor field evidence of a mass scale land use changes in this region in the historical and distant past that could have triggered the initiation and/or extension of badlands of such magnitude. Considering the

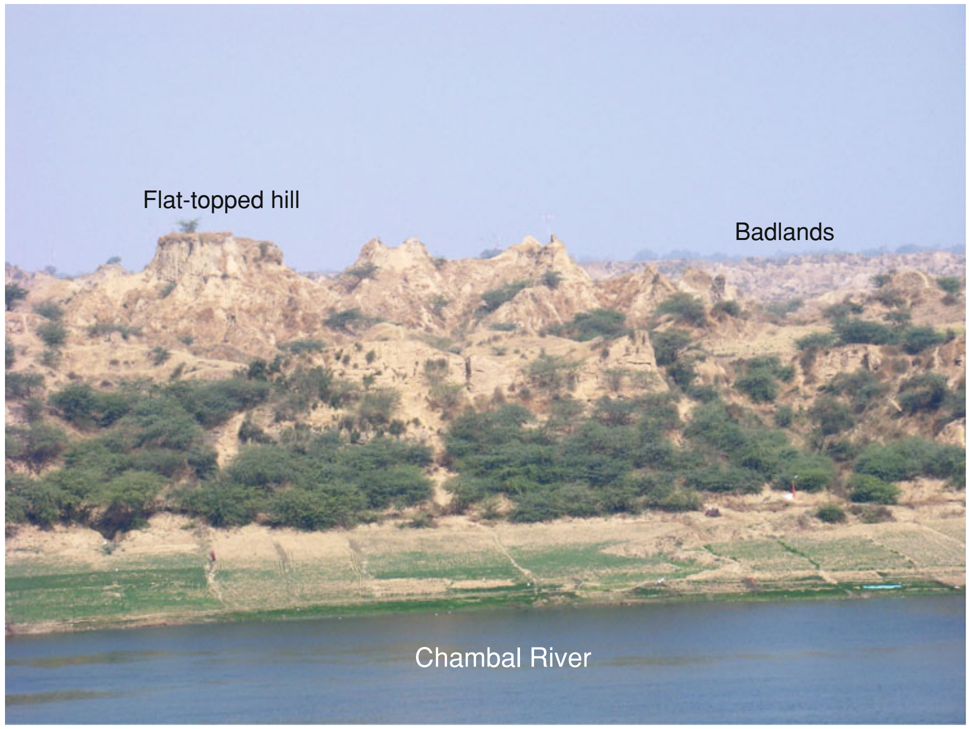

Fig. 6 When the clay horizon overlies the alluvial sediments, it gives rise to flat-topped hills with a steep scarp slope

scale and extent of the badland development along the Chambal River it appears that the process of badland formation has operated for a long time ($\sim 10^3$–10^4 years).

Base level is considered as one of the fundamental factors determining the badland morphology and development. The basally-induced incision and associated badland extension is generally goaded by climatic changes and tectonics.

Strengthening of SW monsoon during the early Holocene has been a well established fact that had left significant mark all across the subcontinent. As a response to the climate shift, the major rivers and their tributaries started incising their channels. Incision of the Yamuna River also began during this period, and the Chambal River which is a tributary to Yamuna responded without much time lag, leading to intensive bank erosion by bank gullies. The dispersive sediments readily collapsed and gully network expanded on the interfluves by further headward erosion. The badland formation, therefore, seems to have coincided with the intensification of the SW Indian monsoon at the end of the Last Glacial Maximum.

Although cratonic basins are considered to be tectonically relatively stable, one cannot completely rule out the possibility of tectonically-induced incision and dissection in the area. Abrupt shifting of the course of Chambal, as well as a prominent break along the longitudinal profile of the river, together with the dramatic increase in the thickness of alluvium have been attributed to a morpho-tectonic fault between Pinahat and Tikatpura by Mishra and Vishwakarma (1999). They have also inferred—(i) block uplift resulting in the sudden rejuvenation in relief and (ii) epeirogenic warping of the alluvial tract in the region. Although not well established, it appears that the evolution of the Chambal Badlands may be attributed to the combined effect of the strengthening of the southwest monsoon in the early Holocene and tectonic activity. Which of the two preceded the other or which of the two is really responsible for the badland development and expansion is difficult to ascertain? The debate will continue unless a good number of radiometric ages are acquired for this region.

5 Current Scenario

In the past few decades, the ravines of Chambal have become a national issue. The expansion of the ravines is causing serious threat to agriculture and irrigation projects in the lower Chambal Valley. The headward extension of the gullies constantly consumes the fertile agricultural land. The problem has worsened in the last few decades due to the reclamation of the gullied areas for agriculture at the peripheries of the ravines, which disturbs the surface and promotes renewed activities of gullies. Based on the analysis of the multi-date satellite imageries it has been demonstrated that between 1984 and 1998 there has been $\sim 17\ \%$ increase in the ravine area (Pani and Mohapatra 2001). The expansion of ravines is destroying not only the agricultural land but also posing other problems. Inadequate food and fodder as a result of degraded habitats is posing stress on wildlife leading to their encroachment towards the cropland.

6 Conclusions

Badlands are the landscapes where the dynamic forces of erosion has exceeded the resistive forces of the land surface by magnitudes, to create myriad sculptures of labyrinth of winding gullies that dazzles the imagination. A combination of semi-arid climate with long dry season, sparse vegetation due to lack of moisture and unconsolidated sediments rich in smectite clays promote the development of such landscapes. Chambal Badlands of India, that spread across an area of half a million hectares along the Middle Ganga Alluvial Plain of India, is one such feature that has been notoriously famous for centuries in the country for reasons strictly not for any desirable causes. These ravines are feeding on the fertile alluvial lands and this is causing concern to the nation. Present understanding is that the evolution and/or expansion of the badlands coincided with the incision of the rivers following the strengthening of SW monsoon as well as lineament controlled differential block uplifts that have affected these areas during the Holocene Epoch. Due to its ruggedness, the interior of the ravine is virtually inaccessible but the peripheral areas have been reclaimed by farmers for agriculture in the last few decades. There is high possibility of further expansion of the badlands in the future primarily due to increased human activity.

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