Human use of landforms on the Deccan Volcanic Plateau: Formation of a geocultural region

Citation: Wescoat, James L., Jr. "Human use of landforms on the Deccan Volcanic Plateau: Formation of a geocultural region." Geomorphology 331 (April 2019): 175-190 © 2018 Elsevier B.V.

As Published: http://dx.doi.org/10.1016/j.geomorph.2018.08.044

Publisher: Elsevier BV

Persistent URL: https://hdl.handle.net/1721.1/122016

Version: Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

Geomorphology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Human use of landforms on the Deccan Volcanic Plateau: Formation of a geocultural region

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ARTICLE INFO

Article history:
Received 15 March 2018
Received in revised form 30 August 2018
Accepted 30 August 2018
Available online xxxx

Keywords:
Butzer
Historical geomorphology
Flood basalt
Rock cut caves
Deccan
Maharashtra

ABSTRACT

This paper takes its inspiration from Karl W. Butzer's course on the *Human Use of Landforms* at the University of Chicago. It builds upon that concept through an exploration of regional settlement patterns and landforms in the Deccan volcanic province of west-central India. The first section develops a conceptual framework for analyzing human adjustment to landforms on regional, settlement, and site scales. The second section employs that framework to analyze four major landform-settlement configurations in the Deccan from antiquity to the end of the eighteenth century. The Satavahana kingdom (ca. 100 BCE to 200 CE) had a strong southeast to northwest alignment along the Godavari River. Their capital city of Paithan was located at a navigable sacred ford across the river (*tirtha*), which was linked with upstream confluences (*sangams*), tanks (*kunds*), mountain passes (*ghats*), and port cities on the Arabian Sea. Subsequent Hindu dynasties (ca. 850–1300 CE) shifted from fluvial landforms to a north-south alignment along steep mesa escarpments and buttes in the central Deccan that provided defensive fortress and cave temple sites. Sultanate and Mughal forces expanded the urban footprint on nearby plateau lands at sites protected by surrounding mesas (ca. 1330–1700 CE). These cities were supported by local watershed runoff and long distance water channels. The final precolonial phase of Deccan settlement entailed a shift from the semiarid central plateaus to humid headwaters of the Western Ghats, whose buttes and scarps provided sites for scores of forts controlled by the founder of the Maratha empire Chhatrapati Shivaji in the seventeenth century. Maratha success led to development downstream at the capital city of Pune (1627–1803 CE), located at a river confluence flanked by mesas, which combined the strategies of previous periods. Over two millennia these four distinct, yet intersecting, patterns of human-landform relations have shaped an evolving geocultural region on the Deccan plateau that deserves comparison with other flood basalt regions.

1. Introduction

This paper takes its inspiration from a pair of courses taught by Professor Karl W. Butzer at the University of Chicago in 1980. His *Human Use of Landforms* provided a systematic treatment of topics in environmental geomorphology. It was shaped in part by his textbook on *Geomorphology from Earth* that surveyed major geological processes and provinces including volcanic landscapes (Butzer, 1976a). Curiously, a bibliographic search for the phrase 'human use of landforms' yields no publication titles in WorldCat, Web of Knowledge, or other indexes. The second course was *Environment and Culture in Early Prehistory*, which critically examined environmental models of societal formation, transformation, and collapse. It introduced ideas about the negative concatenation of environmental and social stresses. It was also a time of great debates about the role of water in complex societies, which Butzer (1976b) critically advanced in *Early Hydraulic Civilization in Egypt: A Study in Cultural Ecology*.

Some of his subsequent research projects advanced this combination of environmental and historical geomorphology in various ways, including his research on early modern irrigation societies in Andalusia (Butzer et al., 1985), an erudite review of 'Islamic traditions of Agroecology' (Butzer, 1994), and an article in this journal on 'Challenges for a cross-disciplinary geoarchaeology: The intersection between environmental history and geomorphology' (Butzer, 2008). The challenges identified include scaling, urban geoarchaeology, and spatial analysis. This combination of environmental and historical geomorphology generated excitement among a wide range of graduate students who sought to develop analogous approaches in related fields of historical geography and water resources (e.g., Wescoat, 1999, 2013).

As a contribution to this special issue honoring Butzer's scholarship, this paper begins with a brief introduction to the Deccan Volcanic Plateau region in Maharashtra, India (Fig. 1) and presents a conceptual framework for assessing human use of landforms at multiple scales. The main body of the paper then presents a historical geography of landform-settlement relations in the Deccan region over four major periods that span 2000 years. In the concluding section, we show how these four configurations have successively and collectively shaped a

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https://doi.org/10.1016/j.geomorph.2018.08.044
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Fig. 1. Perspective satellite image of the Deccan Plateau region of western Maharashtra, defined by the Sahyadri ghats on the west and dissected basalt plateau on the east. Source: Google Earth Pro, 2018.

dynamic geocultural region, defined here as a conjunction of geomorphological and settlement processes.

2. A perspective of the Deccan Volcanic Plateau

The geological region examined here is variously known as the Deccan Igneous Province, Deccan Volcanic Plateau, Deccan Basalt Province, and Deccan Traps. The word *trappa* is Swedish for steps and has been used in English from the mid-eighteenth century onward to refer to terraced terrain (OED Online, 2018). Here we will use the term Deccan Volcanic Plateau to refer to one of the largest igneous provinces on earth, covering an estimated 500,000 km^2 (Subbarao, 1999). The plateau was formed by massive basalt flows laid down in multiple strata some 67 million years ago during the Cretaceous-Paleogene boundary, events that contributed to extinction of the dinosaurs and laid the geological foundations for subsequent biozones (Bondre et al., 2004; Keller, 2014).

The initial Gondwana rift and subsequent processes of uplift of the western margin of the subcontinent produced plateau lands that tilt northwest to southeast along a 1500-km escarpment known as the Western Ghats or Sahyadri Range, which averages some 1200 to 1600 m above sea level (asl), with peaks as high as 2600 m (Kale, 2010). Depending upon the context, the word *ghat* refers to steps to water, a steep ascent, or a mountain pass. The Western Ghats separate a narrow coastal strip of land known as Konkan from the interior plateau region known as *Desh* (*country*).

The Deccan Volcanic Plateau extends from this core area northwestward into the Saurashtra peninsula of Gujarat State, northward beyond the Narmada River rift into the Malwa Plateau of Madhya Pradesh, and southward into Karnataka and Telangana states. Here we focus on the central Deccan plateau region of Maharashtra that lies east of the Sahyadris, south of the Narmada rift, and west and north of cratons of ancient rock. The Bastar-Bhandara craton defines the eastern boundary of the Deccan while the Dharwar craton establishes a southern boundary (Fig. 2).

The monsoon climate dates back to about 10 ma BP and yields three months of intensely erosive rainfall followed by 9 months of soil moisture deficits. The windward side of the Western Ghats receives monsoon rainfall of 3 to 4 m/y that cascades over waterfalls, cuts steep valleys, and drains rapidly into the Arabian Sea. Notwithstanding a rain shadow effect, the eastern face of the Sahyadris receives 1 to 3 m of precipitation that drain through long parallel river basins aligned from northwest to southeast, which in many cases follow structural lineaments that accelerate channel incision. These river basins are variably weathered and dissected, flanked by mesas and marginal buttes that have shaped human movement and settlement. The deep basalt bedrock has limited infiltration and storage capacity in its massive strata with greater but still variable storage in weathered, vesicular, and fractured aquifers, which contributes to chronic water shortages particularly in areas of the declining precipitation gradient from west to east across the Deccan (Mann, 1955; Adamson and Nash, 2014). Extensive black cotton soils (Ustert Vertisols) on weathered lower plateaus and floodplains have high fertility but slow drainage and high shrink-swell properties that affect building.

Large bodies of research are available on the geology, hydrogeology, and geomorphology of the Deccan Volcanic Province (e.g., Kale, 1990, 2010). Less research has focused on human settlement in relation to landforms of the Deccan Volcanic Plateau, i.e., the human use of landforms (though see Kale, 2014). This is surprising because the region has strong historical associations with concepts of Maharashtra (Feldhaus, 2003; Deak and Jasper, 2014). In linguistic terms, the Deccan is said to be derived from the word *Dakshina* meaning *south* or on the right-hand side of the subcontinent when facing east. The central Deccan Plateau region also has an association with the distribution of Marathi-speaking people. The Maharashtrian Prakrit language dates back to 500 BCE, became the court language of the Satavahana dynasty (ca. 100 BCE to 200 CE), and also flourished in the Seuna dynasty (ca. ninth century BCE). While the region has been politically fragmented in many periods, it has undergone periods of consolidation that constitute what we are calling here a geocultural region. As a step toward reconstructing these processes, the next section develops a conceptual framework for analyzing human use of landforms at multiple scales.

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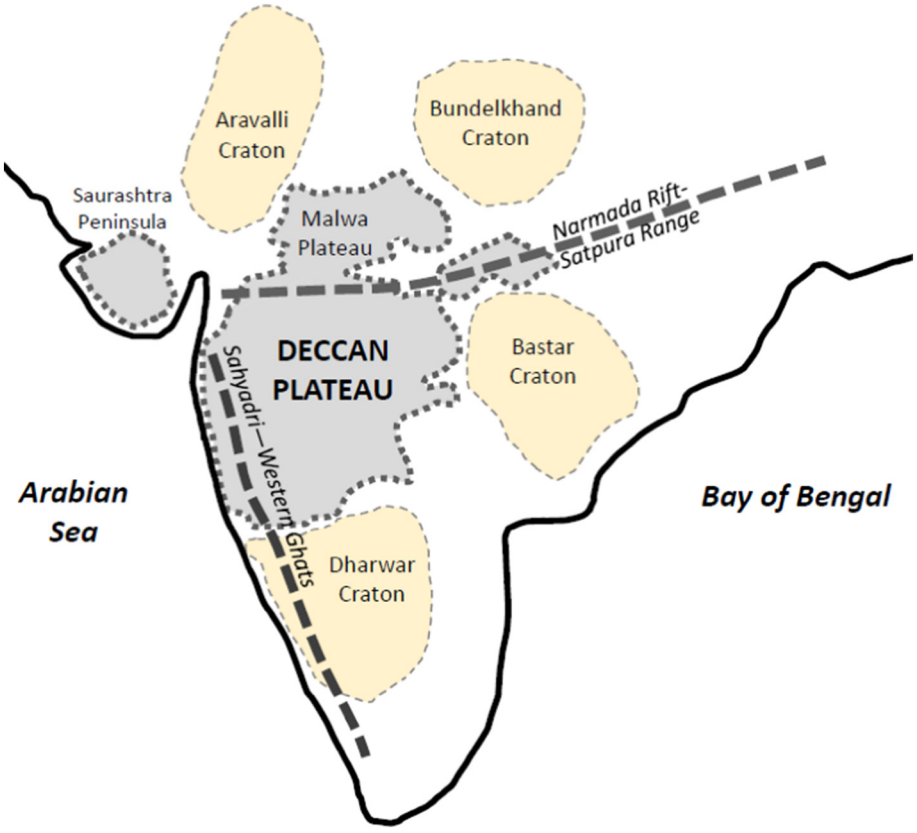

Fig. 2. Map of Deccan Trap, Sahyadri Western Ghats range, and surrounding cratons. (After Sheth, 2006).

3. Conceptual framework for analyzing human use of landforms in the Deccan

This section draws together key resources for constructing a conceptual framework and methodology for analyzing the human use of landforms in the Deccan (Fig. 3).

1. The first stage in this framework begins by compiling diverse historical, archaeological, geomorphological, and field studies relevant to the human use of landforms. Maharashtra district gazetteers compile such information but do not synthesize it. Important interdisciplinary collections of essays on the Deccan tend to focus on either physical or social processes (e.g., Mukherjee et al., 2016, and Subbarao, 1999, on physical processes; Attwood et al., 1988, and Deak and Jasper, 2014, on social processes). On the physical side, geomorphological research on the Deccan ranges from regional landscape surveys to analytical studies of tectonic and fluvial landforms (e.g., Kale and Rajaguru, 1988; Kale, 1990, 2010; Kale et al., 2016). A few studies consider the social dimensions of geomorphosites and geoheritage, along with increasing interest in anthropogenic geomorphology (Indian Institute of Geomorphologists, 2018; Kale, 2014, 2017). On the social side, excellent surveys of settlement history in the Deccan shed light on political, economic and demographic processes, but unfortunately give limited attention to physical phenomena (e.g., Kosambi, 1988; Smith, 2002). Historical geographies of specific periods and places give more attention to landforms and landscapes, but much more in the way of environmental synthesis is needed (e.g., Kennet et al., 2013; Morrison, 1995; Neelis, 2011; Ray, 1986; Sinopoli, 2001, for the Satavahana period).
2. The second step is to identify geomorphological and topographic maps to support a more detailed analysis. The Government of India has produced digital geomorphological maps for the country at 1:50,000, which is also the scale used for detailed topographic mapping. The National Remote Sensing Centre's (2010) *Manual for Geomorphological and Lineament Mapping*, employs five levels of description. The first three levels classify broad categories of terrain by structural origins. The Deccan falls largely under level 1 = hills and plateaus, level 2 = plateaus-Deccan traps, and level 3 = plateaus

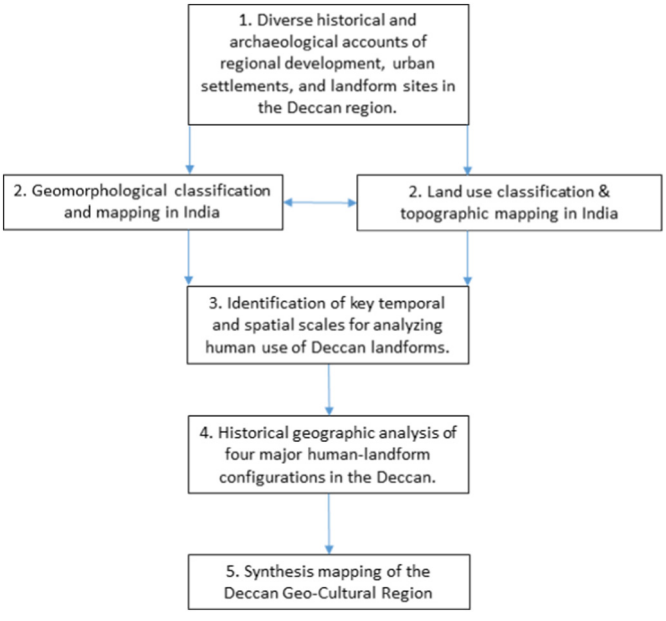

Fig. 3. Conceptual model for analyzing human use of landforms in the Deccan (author).

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(extensive) or alluvial valleys (limited). More significantly, levels 4 and 5 distinguish the plateau features and conditions listed in Table 1 and Fig. 4.

Although the geomorphological layer does not display other relevant parameters (e.g., slope, depth, aspect, or shape), lengths, areas, perimeters, and aquifer characteristics are listed in the GIS properties file, which is useful for analyzing their frequencies and distributions in the districts and region studied here.

Land use mapping is more challenging for a number of reasons. First, modern land use maps have limited relevance for premodern eras. Second, national land use classification in India does not include important human activities (e.g., transportation, pilgrimage, and defense). Modern digital land cover maps incorporate more information on physical conditions than on human activities. By comparison, urban land use maps distinguish residential, commercial, public, recreational, and transportation activities, which are of direct relevance for the human use of landforms. Most useful are Survey of India 1:50,000 topographic maps, which identify a range of cultural features in relation to contours and terrain that shed light on human use of landforms. Many features (e.g., roads, villages, religious structures, and archaeological sites) have historical roots that are relevant for studying the human use of landforms.

3. The third step is to identify temporal and spatial scales relevant for human-landform relations (cf. Allen, 2008) (Table 2). These include:
   - *Regional scale* movement and settlement patterns in which human activities adjust to landform opportunities and constraints over periods of centuries to millennia. For example, the Deccan geological region is ~500,000 km^2, which lies between Allen's second and third scales of shield and Sahel.
   - *Settlement scale* adjustment to and of stream channels, small watersheds, and plateau margins. This scale corresponds with Allen's individual mountains and small valleys in areas of 10s to 100 s of km^2 on time scales of decades to centuries.
   - *Site scale* modification of slopes, soils, and rock formations (e.g., in cave architecture, infrastructure, fortifications, foundations, and quarries on scales of meters to kilometers). The Deccan region relies heavily on basalt stone excavation, rock cut architecture, and masonry construction generally.

   These scales lie along a continuum of landform adjustments and modifications and are selected for their interpretive potential in this study as diagrammed in Fig. 5. Extra-regional influences such as international trade are also relevant in the formation of the Deccan geocultural region.
4. Analyzing these processes, maps and scales, we identified four major contexts and configurations of human-landform relations in the Deccan region.
   - Early historical use of fluvial landforms in the Godavari River basin (100 BCE–200 CE).
   - Medieval human use of scarp and butte landscapes in the central Deccan (850–1300 CE).
   - Early modern use of plateau landscapes in the central Deccan (1300–1700 CE).
   - Precolonial use of watershed landforms by the Mahratta dynasty (1600–1800 CE).
5. The last step is to compile these four historical geographies in ways that help visualize the formation of the Deccan as a geocultural region. The Deccan has undergone a remarkable coevolution of geomorphological and settlement processes. Over time, linguistic and political economic regions came into rough conformance with the Deccan volcanic province, followed by periods of fragmentation and reassembly, in what cumulatively may be called a geocultural region.

Table 1
Geomorphological classes in Deccan region (NRSC, 2010).

Level 4	Level 5
Under canal command	Butte
Highly dissected	Dyke
Undissected	Escarpment slope
Escarpment slope	Mesa
Weathered-canal command	Outer fringes of plateau
Weathered	Waterbody
Moderately dissected	
Weathered	
Slightly dissected	
Shallow	
Alluvial moderate weathered	

4. Human use of landforms on the Deccan Volcanic Plateau

Over 2200 years of history, the central Deccan plateau has witnessed dramatic sociospatial changes. We proceed through four major configurations of human-landform relations in this section. While each period has diverse patterns of settlement, we highlight a particular pattern in each section that originates with the capital cities of that period (cf. accounts by Kosambi, 1988 and Ray, 1987). We omit the long prehistoric period of settlement in the region, which is unfortunate given Professor Butzer's focus on that era, but our interest lies in the formation of a geocultural region that includes its linguistic identity.

4.1. Use of fluvial landforms in the Godavari basin during the Satavahana dynasty (ca. 100 BCE–200 CE)

The Satavahana dynasty is the earliest dynasty that arose within the Deccan, as compared with earlier but more distant Maurya and Saka kingdoms that established outposts in the Deccan. The Satavahanas established numerous settlements in the Godavari, Bhima, and Krishna river basins. Ray (1987, p. 95) noted the conformity between the Satavahana territory and '…the basaltic lava spread on the Deccan Plateau. Geologically and climatically, the western Deccan forms a unified region within the peninsula….' At the same time, the history of Satavahana settlement patterns, processes, and chronology are widely debated (Dhavalikar, 1996; Ray, 1987; Morrison, 1995; Sinopoli, 2001). Ray (1986, 1987) characterized Satavahana cities as a second wave of South Asian urbanization emanating from the Gangetic valley more than a millennium after the decline of Indus valley cities. That interior source and trade network may help account for the inland trade route locations of major Satavahana cities such as Junnar, Nashik, Paithan, and Ter (Fig. 6). These inland cities had long-distance connections with Roman trade centers via port cities of secondary stature such as Sopara and Kalyan.

As noted above, Deccan river basins trend from northwest to southeast following the plateau tilt and structural lineaments. The largest and most sacred is the Godavari River, regarded in past and present as the Ganga of the south (Feldhaus, 1995). Unlike the Ganga, however, the Godavari and its tributaries have less perennial flows and are less renowned for navigation than for their local water supplies and river crossings that have joint commercial and sacred significance as *tirthas* (Eck, 1981).

The Satavahana capital city of Paithan stands at the intersection of the Godavari River and an important trade route of central India (Figs. 6–8). 'The city [Paithan] gained eminence mostly due to its strategic location. It was situated on the ancient highway or track linking it with Broach, Ujjain and Mathura, connecting hinterland with coastal port Surparaka (Sopara) through Govardhana country (Nashik). The town is also referred to as a famous center of trade by foreign travelers in their accounts as the greatest city in the Dakshinapatha, i.e., the country south of Narmada' (Archaeological Survey of India, 2018).

There are three important geocultural aspects of Paithan's location. First, the city sits on low mounds adjacent to a relatively narrow (~0.2 km wide) rocky channel that has provided a stable crossing from antiquity (Kennet et al., 2013). Second, the channel is flanked by a

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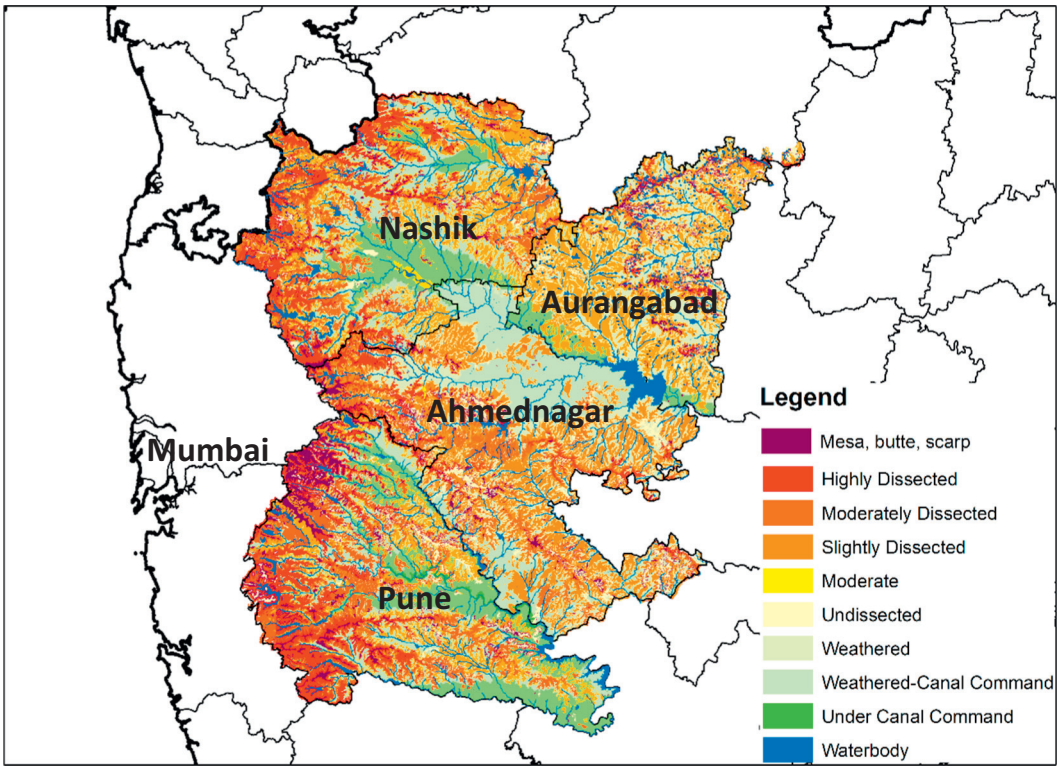

Fig. 4. Landforms in four modern districts of the western Deccan plateau (Ahmednagar, Aurangabad, Nashik, and Pune). Source: GSDA layers, author mapping, 2018.

broad and fertile floodplain (~15 km wide) that passes between the dissected plateaus and mesas. Third, Paithan is easily approached from all directions and is thus an ideal commercial vis-à-vis defensive location. It provided the main river crossing for inland commercial trade between Ter in the southeast and the coastal port of Bharuch in the northwest, and thus served as a hub for long distance overland and ocean trade.

To this day, settlement geography in the basalt region of western India is explained in large measure by road-and-stream crossings. Such crossings (*tirthas*) had deep cultural as well as economic importance. The word *tirtha* can refer to different types of sacred sites, but it refers most commonly to river crossings demarcated by a small temple and landing on one side and a major temple and riverfront *ghats* on the other (Eck, 1981). Although the original Satavahana river crossing is not extant, Paithan's development as a *tirtha* has deepened over time with later Jain and modern saints' temples constructed at riverfront sites.

Forty kilometers upstream, waters of the Pravara River enter the Godavari at a confluence (*sangam*) whose sacrality is marked by Shaivite temples of beautifully cut and carved basalt stonework, also associated with the goddess Ganga (Fig. 9). Twelve kilometers upstream

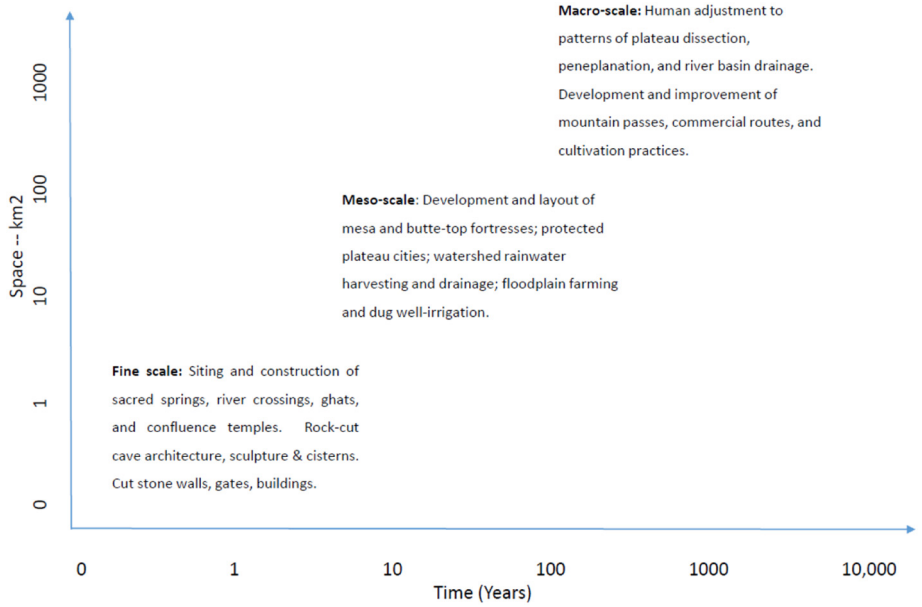

Fig. 5. Human use of landform scales.

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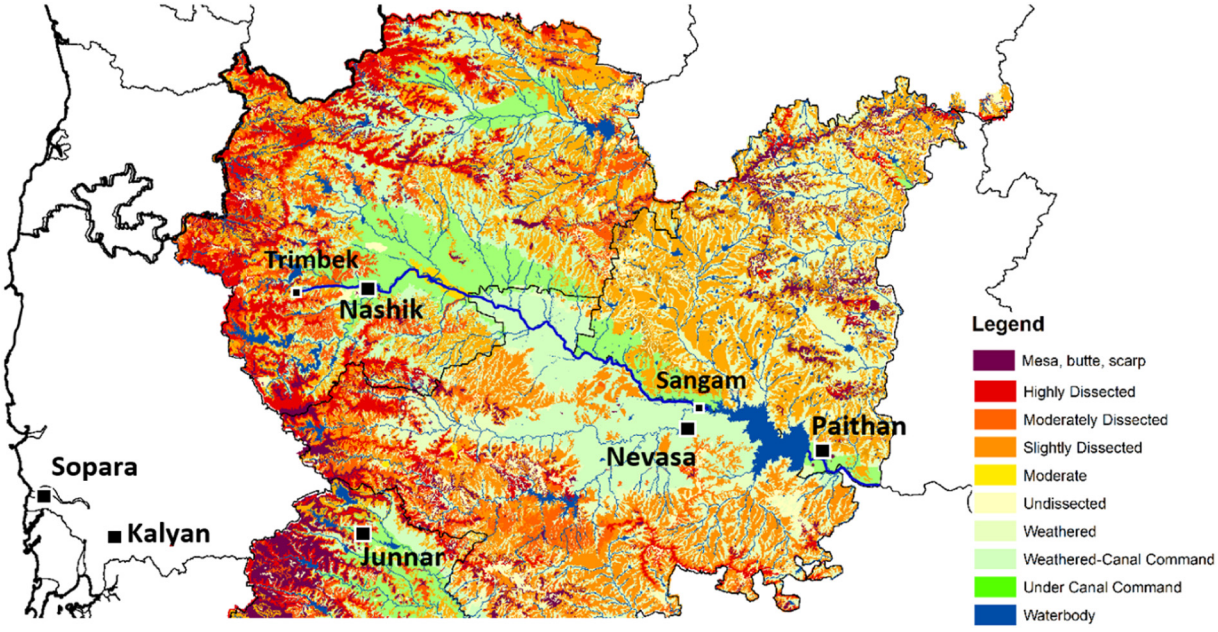

Fig. 6. Major Satavahana sites and linkages of Godavari River basin.
Source: author and GSDA, 2018.

from the floodprone *sangam* on the Pravara lies the major city of Nevasa, which had commercial and religious roles during the Satavahana period (Gupta, 1998), and 30 km beyond Nevasa lay an extensive Satavahana village settlement cluster in the fertile floodplain of Rahuri (Ray, 1986). These settlements were connected by road with the Satavahana city of Junnar (*old city*, which may refer to its status as an earlier capital), sited on a fertile weathered plateau below high mesas and buttes of the Sahyadri range. Junnar has the largest extant complex of Buddhist rock-cut architecture of more than 200 Buddhist caves sited in mesa and butte escarpments surrounding the city (Ray, 1986; Shinde, 2013). These cave complexes were accompanied by rock-cut channels and cisterns for water harvesting that served major passes and trade routes through the Sahyadri basalt range whose complex alignments were laid out during the Satavahana period.

Returning to the Godavari main stem and proceeding 180 km upstream, one arrives at the jointly sacred and commercial city of Nashik. Like Paithan, Nashik (*nine mounds*) was sited on low hills adjacent to a stable reach of the Godavari channel and developed ca. 100 BCE to 200 CE during the Satavahana period. Nashik has additional qualities of geocultural significance. It is strongly associated with the forest exile location of the deities Ram and Sita as well as the nearby birthplace of their devoted servant-god Hanuman nearby (Kulkarni, 1981), all of which have established it as a major *tirtha*. The citadel of Nashik flanks the Godavari, and the city's stone ghats step down to the water's edge

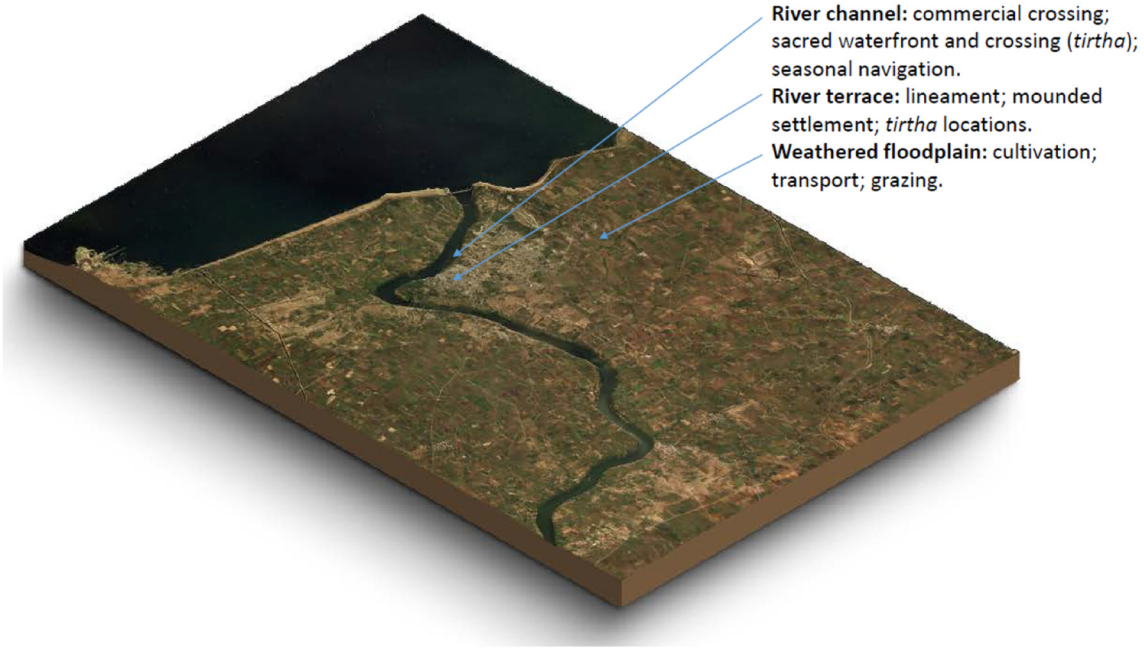

Fig. 7. Block diagram of Paithan area landscape. Three-dimensional model by Sera Tolgay.

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Fig. 8. Paithan mound from across the Godavari River. Author.

for bathing tanks (*kunds*) on both sides of the channel for daily worship and important festivals that culminate in the 12-yearly Kumbh Mela. Like Junnar, but on a smaller scale, Nashik has important Buddhist cave architecture known as Pandu Lena located in an escarpment 9 km west of the city along a trade route to the coast (Ray, 2013). The trade route runs southwest through the Thal Ghat pass to the inland

Fig. 9. *Sangam* of Pravara and Godavari Rivers. Author.

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port of Kalyan and coastal port of Sopara where a Buddhist stupa of burnt brick survives.

Another 25 km upstream from Nashik along the Godavari, near its source, is the Trimbakeswar (Trimbek on the map) *jyotirlinga* temple, one of the twelve holy *jyotirlinga* sites in India (*jyoti* = light, *linga* = stone column, and *jyotirlinga* = infinite column of light). This Shaivite complex marks the descent of Ganga to earth through the locks of Shiva's hair. Rain runs off from the top of Brahmagiri Hill, which is a narrow butte 200 m above the temple, past a set of stairs to Ganga *dwar* where the river can first be seen, and from there down to the sacred Kusavarta bathing tank (*kund*) close to the temple.

In summary, the processes of geocultural formation during the Satavahana period were (i) urbanization of the fertile Godavari floodplain, especially at fordable river crossings such as Paithan and Nashik; (ii) sacralization of fluvial *tirthas*, *sanga*ms, and sources; (iii) carving of cave temples, cisterns, and passes in the Sahyadri headwaters; and (iv) long distance trade relations from India to Rome via port cities of the Konkan region. These relationships were woven together in later texts like the *Godavari Mahatmya*, which associated *tirthas* along the river with different parts of the body, for example: Trymbakeswar with the head, Paithan with the neck, Nanded with the navel, and so on (Feldhaus, 2003, pp. 19–20).

The early historical period was also integrative in linguistic terms, as witnessed by the shift from Sanskrit to Prakrit, which influenced Marathi, and was also associated with the territorial name of *Maharashtra* (*great territory*). At the same time, landform and settlement patterns differed between the headwaters and plains of the Godavari. The number and area of buttes is much greater in the uplifted, humid, erodible upper basin. This helps explain the broad distribution rock cut cave temples in the upper basin. Conversely, heavily dissected terrain in the upper basin limited development of long distance trade routes and the availability of arable land, which helped account for Paithan's early prominence downstream. However, Paithan's lack of natural defensive terrain led to a different landform configurations in the medieval era.

4.2. Medieval use of scarps and buttes in the Central Deccan during the Seuna dynasty (ca. 850–1300 CE)

The Seuna (Yadava) territory, like those that preceded it, extended over much of the Deccan (Gokhale, 1970-72). It underwent a major shift during the ninth century CE, away from the northwest-southeast Godavari River channel and toward a north-south alignment along scarps and buttes that connected Paithan with major routes north to Maheshwar on the Narmada River and onward to the regional capital of Ujjain. The Seuna dynasty relocated their capital from Paithan's commercial *tirtha* 60 km north to an impregnable butte fortress known as *Devgiri* (*Hill of the Gods*) (Fig. 10).

Before focusing on Devgiri, it is important to consider the monumental Ellora cave temple complex, carved into a mesa escarpment during the sixth to tenth centuries CE, which lies 10 km north of the Devgiri butte fortress (Figs. 11 and 12). As with rock-cut temples in the Western Ghats, the Ellora caves had a long history of patronage by political, commercial, and religious leaders. Granoff (2013) reminded us that these features are cave temple architecture and not the cave dwellings of prehistoric times. The Ellora cave temples antedate the Seuna capital by several centuries and continued to develop under Seuna and other patronage (Dhavalikar, 2003). They involved concurrent as well as successive processes of Buddhist, Hindu, and Jain patronage; and some infer that cave patrons, artists, and their works developed in dialogue with one another (essays in Brancaccio, 2013). Cave temples constituted a different kind of *tirtha* at a sacred site, as compared with those constructed at river crossings.

Malandra (1993) characterized early Buddhist caves at Ellora as an unfolding *mandala* of rooms and iconography that revolve around a central space of worship (*chaitya*) or living spaces (*vihara*) (cf. Spink and Yaguchi, 2017, vol. 7, pp. 41–55, on the solstice orientation of some cave temples at Ajanta). Among the Hindu temples at Ellora, the most dramatic is Kailasanatha (cave 16), which was initiated under Rashtrakuta patronage in the eighth century. Its Shaivite architecture, iconography, and the very name of the cave, *Kailas*, indicates its appropriation of Shiva's Himalayan dwelling place, Mount Kailasa, recreated in the rock escarpment to recenter its religious and political power in the region. The Seuna rulers allowed earlier Buddhist and Shaivite temples to persist while carving new temples with Vaishnava iconography.

Methods of basalt cave temple carving shed light on processes of scarp landform use and deserve more detailed study (e.g., along the lines outlined in Law, 2016; Rockwell, 1993; Sinha, 2011). First, any brush, soil, and talus on the slope were cleared away. Apparently, slopes with limited fracturing were selected for scarping and excavation while more weathered slopes were used as drainageways between caves. The scarp was made vertical on the sides and notched deeply into the hillslope to reach solid rock faces tens of meters in height and depth. In some cases, major strata and faults influenced floor elevations and roof supports. In exceptional cases such as the massive basalt conditions at the Kailasanatha temple, solid blocks of stone were left within the excavated area to become interior temples and large figurative sculpture. Caves on either side of that central complex had more mixed strata of vesicular, amygdaloidal, and massive conditions (Law, 2016). Carving methods ranged from roughed out excavations and chiseled hatch-textured surfaces to fine sculptural detail and surfaces polished with abrasives, sometimes within a single sculpture or spatial composition as well as between adjacent caves. Dehejia and Rockwell (2011, 2016) interpreted these variable surfaces as a 'flexible concept of finish' (cf. Spink and Yaguchi, 2017, vol. 6, p. 41 on precise and imprecise carving at Ajanta). Some caves and sculptures are barely incised, while others are deeply carved spaces with variously chiseled surfaces. As observed along trade routes through the Western Ghats, the excavations at Ellora tapped small springs and incised channels on cliff faces that discharged into rock-cut cisterns and filled larger water tanks with monsoon runoff to fulfill annual and symbolic water needs (Mubayi, 2016).

The Archaeological Survey of India and Geological Survey of India collaborated to produce a volume of geoscientific papers on Ellora that provide a valuable exemplar for future research (Sinha, 2011). The book includes a 1:500 scale topographic base map (two orders of magnitude smaller than the Survey of India map series), which shows how cave siting and upper slope design directed water into drainageways on either side of the caves. Its ninefold landform classification distinguishes surface weathering conditions that help us understand the excavation depths, heights, and architectural strategies in different caves. However, this study lacks what we seek most, which is an explanation of why this scarp was selected for elaboration and how it was related to human settlement strategies at the base of and on top of the cave complex.

We gain insight into that question just south of Ellora at the dramatic butte fortress of Devgiri, which became the Seuna capital in the ninth century CE (Figs. 13 and 14). Stone carvers from Ellora shifted from sacred to defensive architecture at Devgiri. The butte is enclosed within an outer city wall and three levels of citadel walls and moats that created one of the strongest fortresses on the subcontinent. A Yadava palace of the eleventh-twelfth centuries CE survives on the middle level of the citadel. Just above the palace, tall sideslopes were cleared of talus and scarped vertically to a height of 50 m to repel invasions. A narrow stone bridge, followed by a labyrinthine tunnel snaked through the citadel with numerous blind alleys and turns along its path to confuse and trap invaders. As in the Ellora complex, rainwater harvesting, rock-cut cisterns, and dug wells were essential components of the Devgiri water system (Mubayi, 2016). Unlike Ellora, however, the masonry architecture and sculpture of Devgiri consists almost entirely of load-bearing structures built of finely cut stone blocks rather than rock-cut architecture.

In summary, scarp and butte landform use had widespread significance through the early historical period period that culminated in the medieval period. They reflected commercial prosperity as well as multisectarian piety that flourished in stable periods and lapsed during

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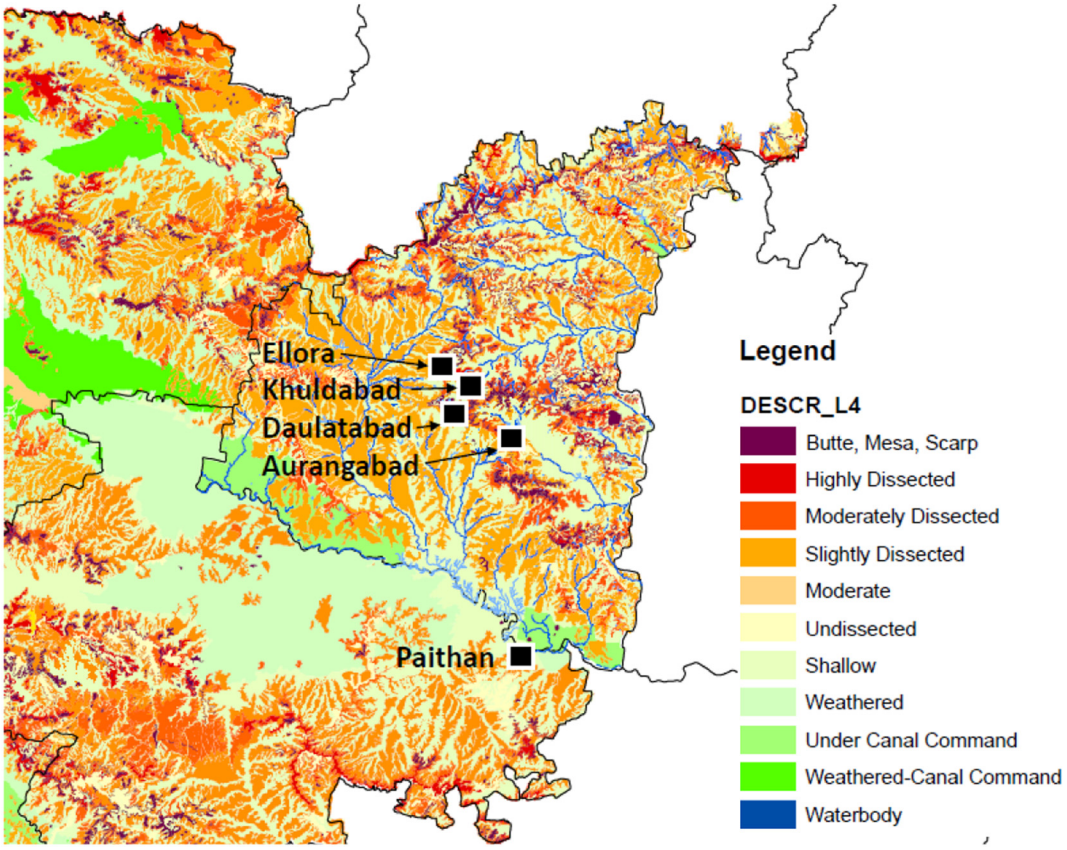

Fig. 10. Seuna period butte, mesa, and scarp sites, Aurangabad district. Author and GSDA, 2018.

dynastic transitions and military conflicts. They came together in the sacred cave temple complex of Ellora and the fortress capital of Devgiri, where the same masonry technologies used for sacred structures were adapted for military purposes. This evolution of human-landform relations expanded in geographic scope and scale during the Sultanate and Mughal periods in the fourteenth through seventeenth centuries CE.

4.3. Urban use of plateaus and mesas during the Sultanate and Mughal dynasties (ca. 1300–1700 CE)

In 1294 CE, Sultan Alauddin Khilji of Delhi conquered the Yadava army and introduced Muslim rule to the region. This set the stage for Sultan Muhammad bin Tughluq's conquest of the Chalukya army at Devgiri by deception in 1324 CE. This sultan renamed the citadel

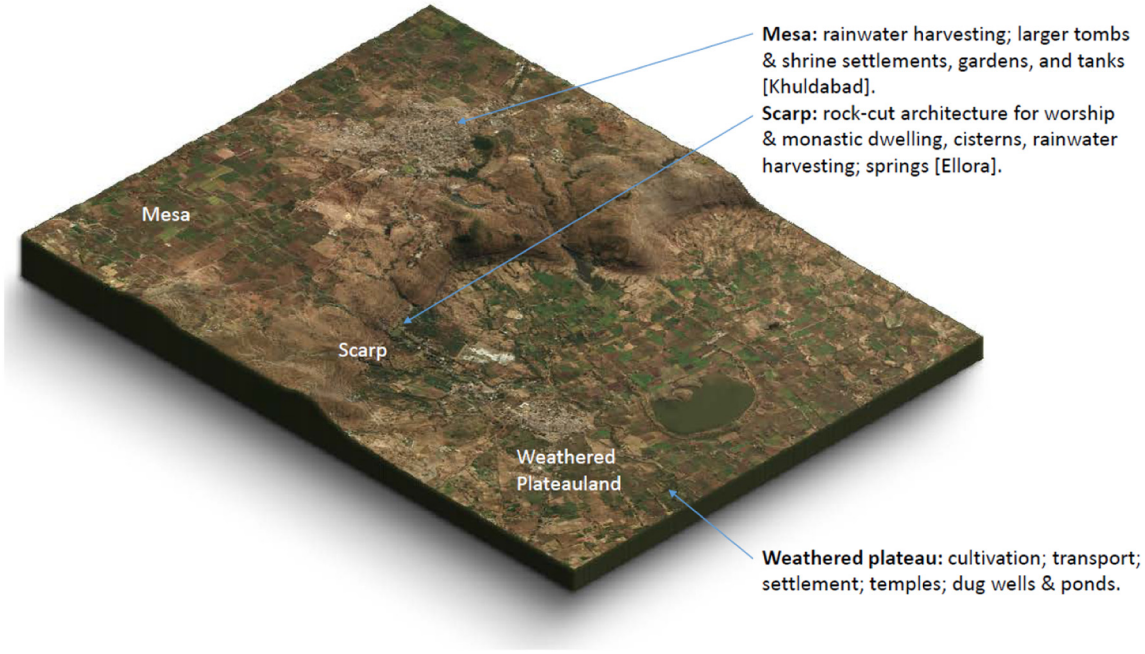

Fig. 11. Block diagram of Ellora landscape. Three-dimensional model by Sera Tolgay.

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Fig. 12. Ellora cave excavation and stone carving methods. Author.

Daulatabad (*City of fortune*) and decreed that the population of Delhi must relocate there. That policy proved disastrous, but subsequent Sultanate rulers continued to develop the citadel and walled city surrounding Daulatabad.

Much of the extant stone architecture and water infrastructure of Daulatabad dates to the Sultanate and Mughal periods. It features stone stepped tanks (*kunds*), mosques, and palaces with baths, pavilions, and gardens on each level that beautified the defensive complex. Significantly, the orientation of its upper pavilions and of the northern city gateway faced north toward the Sufi spiritual center of Khuldabad, initially known as *Rauza* (paradise or funerary garden) in the early fourteenth century CE, which is discussed later in this section.

The Sultanate period involved dynamic processes of territorial conquest, fragmentation, and consolidation that forged regional patterns of landform-settlement relations (Eaton and Wagoner, 2014, p. 277): '…the Deccan's unique topography with its many hilltops spiking up from an otherwise flat plateau… for centuries prior to the advent of gunpowder, Deccanis had taken advantage of the plateau's naturally hilly terrain by building forts on its many promontories.…hill forts enabled chieftains to control surrounding country sides and their rural populations.…' Competing sultans divided the plateau region into competing territories that complicated its identity as the *Deccan*. For example, the Bahmani sultanate based in Gulbarga broke the region into four territories centered in Ahmednagar, Daulatabad, Sholapur, and Bijapur (1350–1500 CE). Subsequently, cities were created outside but not very far away from defensive citadels (Sohoni, 2015c).

The Sultanate and later Mughal armies of the Deccan were huge with 10 s to 100 s of thousands of soldiers, and their administration required larger settlements than a butte like Daulatabad could provide. The major landform innovation was to establish large cities at Ahmednagar and Aurangabad on plateau lands at sites that were protected and provisioned by surrounding mesas (Figs. 15 and 16).

In 1494 CE, Nizam Shah Ahmed founded the city of Ahmednagar on the plateau where he defeated the Bahmani army some 90 km southwest of Paithan. Over the following century the central fort was surrounded by the city of Ahmednagar that served as the capital for the Nizam Shahi dynasty. Almost all of the structures in the fort and surrounding palaces, pavilions, and gardens were built of finely hewn basalt stone blocks. It was one of several circular fortress cities constructed on the Deccan that included Golconda, Sultannagar, Nauraspur, Bijapur, and Warangal (Sardar, 2014). While the circular city had access in all directions, surrounding landforms shaped the type of access intended for each direction.

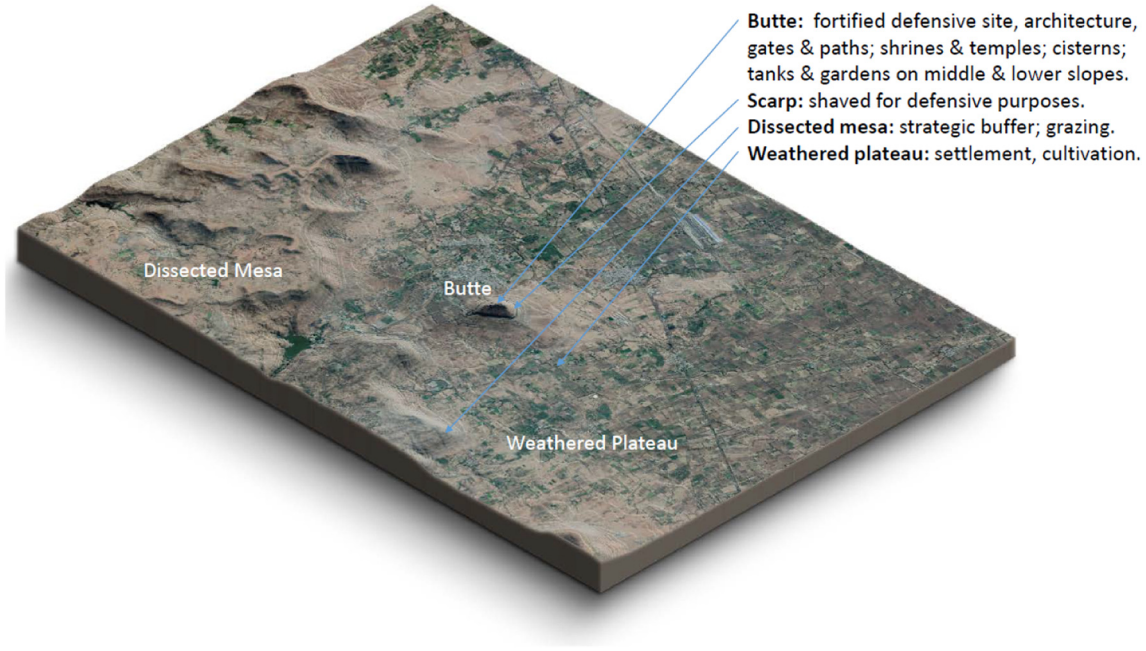

Fig. 13. Block diagram of Daulatabad landscape. Three-dimensional model by Sera Tolgay.

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Fig. 14. Devgiri-Daulatabad scarped citadel. Author.

That is, in addition to the spaciousness of its urban plateau location, Ahmednagar's landscape context provided three geomorphological advantages. It was surrounded by mesas and scarps that gave the city general protection. Its location gave direct access from the south from which Nizam Shahi reinforcements could arrive, protected by defensible passes (*ghats*) on the north. These surrounding landforms also

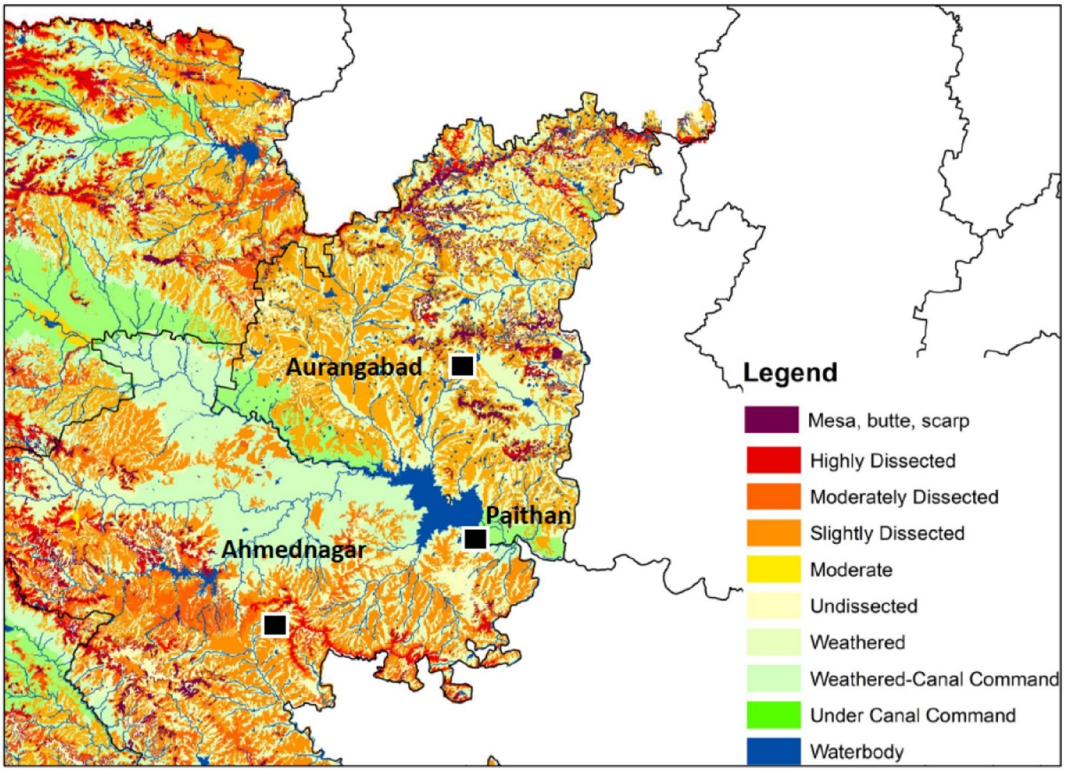

Fig. 15. Geomorphology of Aurangabad and Ahmednagar districts.
Source: Author and GSDA, 2018.

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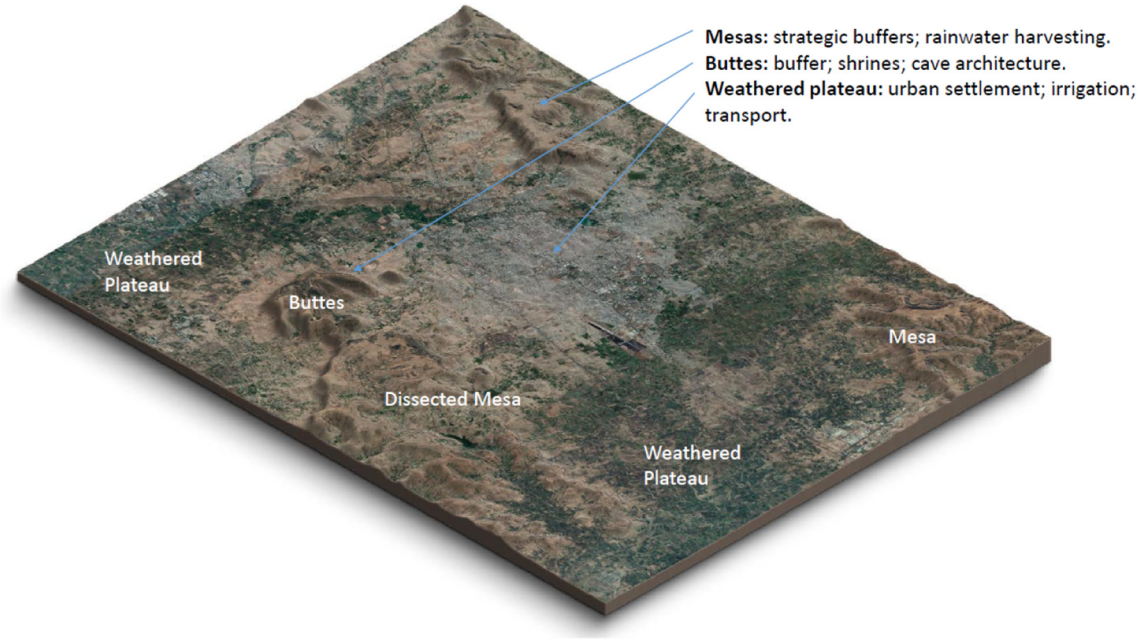

Fig. 16. Block diagram of Aurangabad landscape. Three-dimensional model by Sera Tolgay.

generated runoff into the local Sina River that flowed through the city, ultimately discharging into the Bhima River in the southeast. Small streams like the Sina were more manageable for water supply purposes than larger rivers like the Godavari, and they were less vulnerable to drought than seasonal channels on the open plateaus and mesa uplands. Nevertheless, the basalt bedrock posed serious constraints on groundwater storage, which contributed to regular agricultural droughts (Thomas and Duraisamy, 2017). A sophisticated system of weirs, pipes, and aqueducts brought water from 50 km away to mitigate drought and support urban gardens, orchards, fountains, and *hammam*s as well as domestic water needs (Sohoni, 2015a, 2010). Elevated mesas and buttes became the favored sites for shrines, temples, tombs, and pavilions that required little water. Although strategically located and commercially prosperous, large cities like Ahmednagar were not as defensible as a butte fortress like Daulatabad, and the city was variously lost to and recaptured from the Mughals during the seventeenth century (Anwar, 2007).

Aurangabad became the second city to adopt this pattern of strategic plateau urbanization, located between Paithan and Daulatabad. The African slave-ruler Malik Ambar established a new city at the village of Khirki in 1610, which was renamed Fatehbad (*City of victory*) by his heir in 1626, which became Aurangabad when conquered by the Mughal ruler Aurangzeb Alamgir in 1656 CE (Ali, 2016). In 1680 CE, Aurangzeb shifted the Mughal capital south from Delhi to Aurangabad in 1680 CE in a decision that echoed but was far more successful than that of Muhammad bin Tughluq in 1327 CE. The Mughal governor Khan Jahan Bahadur built protective basalt stone walls and purportedly 52 (a symbolically significant number) gates around the city (Sohoni, 2015a, 2015b). Sohoni (2015c) noted that by this point, city gates and walls had more administrative than defensive significance, due to advances in artillery power vis-à-vis military architecture and to Mughal open field vis-à-vis urban warfare.

Like Ahmednagar, Aurangabad is sited on a spacious, gently sloping, plateau surrounded by scarps and mesas on three sides (north, west, and south), from which it could divert and collect substantial water supplies. Hirsch (2018) showed how the layout of Aurangabad and its gates, and major Mughal buildings nearby such as the Bibi-ka-Maqbara, relate to this topographic setting. Waterworks that supplied the expanding cities of Aurangabad and Daulatabad included underground *nahars* built by Malik Ambar (Rotzer, 2010). In addition to rock-cut tunnels, the city's waterworks employed terracotta pipe, stone channels, and siphon towers. These waterworks drained into the Kham River, which ultimately discharged into the Godavari. Aurangabad was thus separated from its rival Ahmednagar by a major river and by a mesa drainage divide.

A third major plateau and mesa settlement during this period developed at the Sufi funerary landscape of Khuldabad located 8 km northwest of Daulatabad, in this case on top of a broad mesa (Ernst, 2003). Beginning in the 1330s, prominent Sufi saints were buried on the mesa, and their graves became places of *ziyarat* (pilgrimage) originally known as *Rawda* (funerary garden). The African slave-ruler Malik Ambar (d. 1630) was buried nearby in a beautifully carved two-storey, single-domed basalt masonry tomb (Fig. 17). By comparison, his rival (the last powerful Mughal emperor Aurangzeb; d. 1707) was buried in the courtyard of his Sufi *pir*, in a conservative grave that had no stone marker or structure in a grave open to the sky. The spatial significance of Khuldabad as a funerary landscape stems in part from its vista across the mesa, amplified by its symbolic location almost directly above the Ellora cave escarpment.

Just as we compared the distribution of upstream and downstream landforms in the Godavari basin, we may also compare the landform frequencies and areas of Aurangabad and Ahmednagar districts. Here we would expect no difference in the frequency and proportion of different landform types, as they cut across the plateau in similar climates and distances from the area of maximum uplift and had similar settlement strategies. And indeed that is the case. Strategically sited plateau cities of the Sultanate period were anticipated by ancient Satavahana cities of the western Deccan, like Junnar and Nashik, which also relied upon surrounding scarps and runoff. However, the Sultanate and Mughal cities were located in dryer areas of the Deccan, which drove innovations in water collection, storage, and distribution (Chakravarty et al., 2006).

In cultural terms, Pushkar Sohoni (2015b) argued that the Ellora caves, Khuldabad shrines, and the Shaivite Ghrishneswara temple in Ellora town (renovated by the grandfather of the Maratha hero Chhatrapati Shivaji) evolved to become a coherent cultural complex in the fourteenth through seventeenth centuries CE. To that we may add that they shared a coherent geomorphological context and logic that contributed to the formation of the Deccan region. These cultural relationships have been a subject of contrast as well as continuity. Historian

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Fig. 17. Finely shaped and carved basalt tomb of Malik Ambar at Khuldabad. Author.

of religion Carl Ernst (2000) compared different cultural interpretations of Ellora's significance in seventeenth century travel accounts. Likewise, historian of religions Nile Green (2005) discusses competing Brahmanical and Sufi interpretations of Daulatabad and Khuldabad. With their inclusion as listed protected monuments and World Heritage Sites in the twentieth century, subject to changing conservation strategies, their joint geological and cultural significance continues to evolve.

4.4. Synthesis of butte, plateau, and sangam in Pune district during the Maratha Empire (ca. 1600–1800 CE)

Mughal dominance of plateau cities and countryside was a formidable force in the late seventeenth century, but the final phase of precolonial settlement of the Deccan volcanic region developed an even more effective combination of landform-related defensive and offensive strategies under the Maratha ruler Chhatrapati Shivaji, his descendants, and followers. Shivaji's father Shahji (b. 1594) held land grants (*jagirs*) in Pune, which became the basis for shifting the dynastic center to that location. However, that did not occur quickly. Shivaji was born on the butte-top fortress of Shivneri Fort just outside the ancient city of Junnar where our narrative began (Fig. 18). The Shivneri butte has a thin cap rock and steep slopes (and cave temples) on all sides that provided an effective defense. Abundant monsoon rainfall was captured and stored in numerous rock-cut cisterns that greatly reduced the vulnerability of hilltop fortresses to siege (Gordon, 2005). Shahji's uncertain position in the Bijapur court coupled with hostile Mughal attacks led Shivaji and his mother to take refuge and sometimes flee from one butte fortress like Shivneri to another in the Sahyadri range during his childhood. Sohoni (2015c) showed how this shift in settlement strategy from cities to fortified hilltops also withstood increasing artillery power of the larger Sultanate and Mughal empires.

This mobility later became an effective defensive strategy, as scores of butte fortresses straddling the divide between the Desh and Konkan regions enabled guerrilla war tactics against the large Mughal armies. The Mughal army was so large and logistically complex that it was unable to defeat the early Maratha guerilla forces, for whom the heavily dissected plateau lands proved an advantage during Shivaji's lifetime (d. 1680). Offensively, Maratha forces would circle behind Mughal armies to attack supply chains, effectively driving them to plunder the surrounding countryside for supplies until they had so exhausted those resources and oppressed the population that they were forced to retreat. The Maratha's decentralized administration also contributed to territorial expansion through the eighteenth century CE.

Many buttes were topped with stone temples and flanked by hundreds of cave temples that gave these forts joint religious and military use and signification. These frontier forts, in Rotzer's (2010) terminology, rimmed the upper *watershed* of the Bhima and Krishna river basins. In a manner analogous to earlier empires, the Marathas moved down from butte fortresses to protected plateau locations. The largest and most important of these was the Maratha capital city of Pune, which had mesas to the south and west, along with a strategic and sacred *sangam* of the Mula and Mutha rivers on its northern side that ultimately discharged into the Bhima River (Figs. 19 and 20). In these respects, it echoed human uses of landforms in the chain of cities that developed along the humid eastern flats below the Sahyadri range – Nasik, Junnar, Pune, Satara, Sangli, and Kohlapur – which themselves became connected via a north-south route analogous to that which connected Daulatabad, Aurangabad, and Ahmednagar in the drylands of Marathwada farther east (Kosambi, 1988).

We would expect Pune and Nashik districts, as headwaters of their respective river basins, to have similar frequencies and areal distributions of landform types, as observed in Aurangabad and Ahmednagar. However, that is not the case. The Pune region has more protective mesas and fewer buttes, than Nasik district. The Pune region has more moderately dissected and less undissected plateau land than Nashik and environs, which may have reduced its arable area, although water more than land was a limiting resource in this period.

What further distinguished Pune from Nashik and other centers in the western Deccan was its geopolitical and water resources context. Like Junnar, and more than Nashik, Pune had the string of upper watershed forts. Runoff from its upper basin buttes and mesas collected in larger perennial rivers whose confluence (*sangam*) became the site of Pune city. The region is flanked by two other perennial rivers, the Ghod-Bhima River on its northern side and the Nira River on its south, which join at the eastern boundary of the district near Indapur. Pune's hinterland had a wider and more abundant range of water resources than other urban centers of the Deccan.

This final period of landform-settlement relations added a vital set of commercial and political corridors to the region. The first was the Bhor Ghat pass through the Sahyadris that connected Konkan ports with the Desh region via Pune, which became the most important east-west trade route over time. Second, multiple north-south axes developed among Sahyadri forts and plateau cities such as Junnar and Nashik. And third, Pune developed a strong northeast corridor connection with the Ahmednagar, Paithan, and Aurangabad alignment of the ancient and medieval periods. These connections synthesized the major landform and settlement processes of the precolonial Deccan plateau.

5. Synthesis and conclusion

When we plot the four periods and patterns of settlement on a map of regional landforms, we observe that the fluvial, escarpment, plateau, and watershed configurations have a distinct and coherent logic (Fig. 21). Human use of fluvial landforms has engaged from headwaters to *ghats*, *sangams*, and *tirthas*. Human use of buttes, scarps, and mesas served jointly spiritual, commercial, and defensive purposes. Plateau cities were strategically located with respect to mesa protection, water

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Fig. 18. Shivneri Fort near Junnar, Pune district, Maharashtra. Author.

supply, and trade. The Marathas effectively combined all three patterns of fluvial, butte, and plateau strategies in a regional pattern that might collectively be called watershed urbanism. Each pattern also reflected exogenous forces and influences, from ancient Roman and Indic trade centers in antiquity to Sultanate capitals in northern and southern India, and ultimately in the early nineteenth century with colonial Bombay on the coast. While the regional capitals waxed and waned, their associated human uses of landforms endured as repeating strategies through space and time, which collectively helped shape the geocultural region known through history as the Deccan.

Karl Butzer's writings and his courses conveyed a vision of and prospect for historical geomorphology that connected the development of landforms and human settlements at multiple spatial and temporal scales. This paper has sought to elaborate his ideas about what research

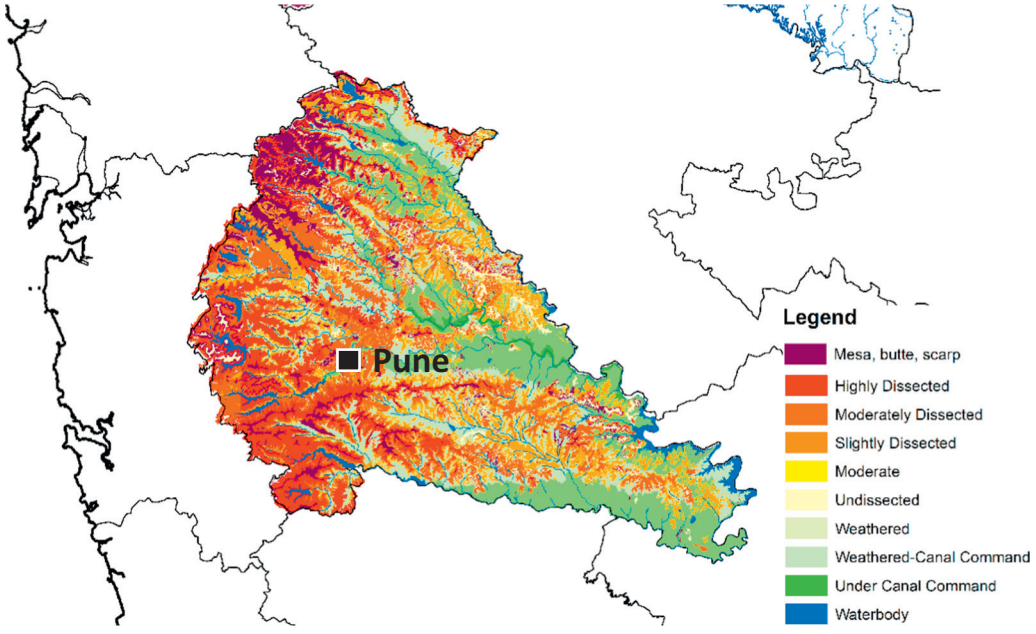

Fig. 19. Geomorphology of Pune District.
Source: Author with GSDA GIS, 2018.

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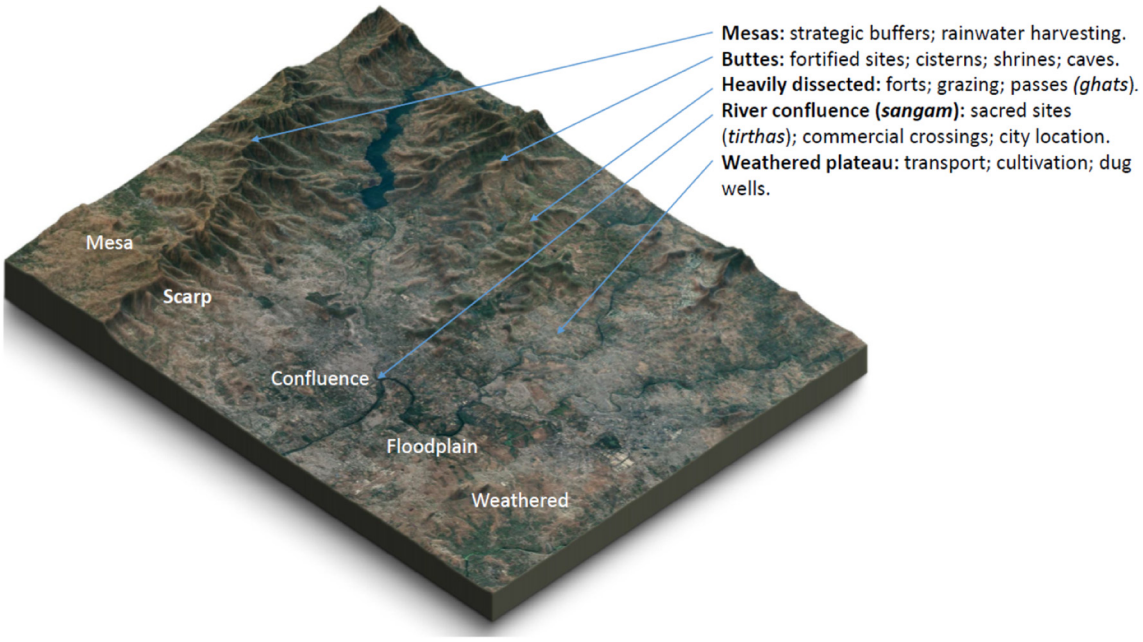

Fig. 20. Block diagram of Pune landscape. Three-dimensional model by Sera Tolgay.

on the human use of landforms can entail. It rigorously analyzes human modification of earth surface processes and resultant landforms as is increasingly well established in the discipline. As Butzer demonstrated throughout his work, it focuses on historical processes of human adjustment to terrain that reflect opportunities and risks associated with commercial, defensive, and settlement strategies. And as exemplified in the Deccan, historical geomorphology also embraces the manifold levels of human meaning ascribed to processes of modification and adjustment, which collectively comprise the human use of landforms.

Acknowledgements

I am grateful to the Aga Khan Program for Islamic Architecture at MIT and the MIT-Tata Center for Technology and Design for funding travel in the region. Leaders of the Indian National Trust for Art and Cultural Heritage in Aurangabad and Pune introduced me to many of the sites discussed here. Officials in the Government of Maharashtra Water Supply and Sanitation Department, Groundwater Surveys and Development Authority, and World Bank Jalswarajya II program generously

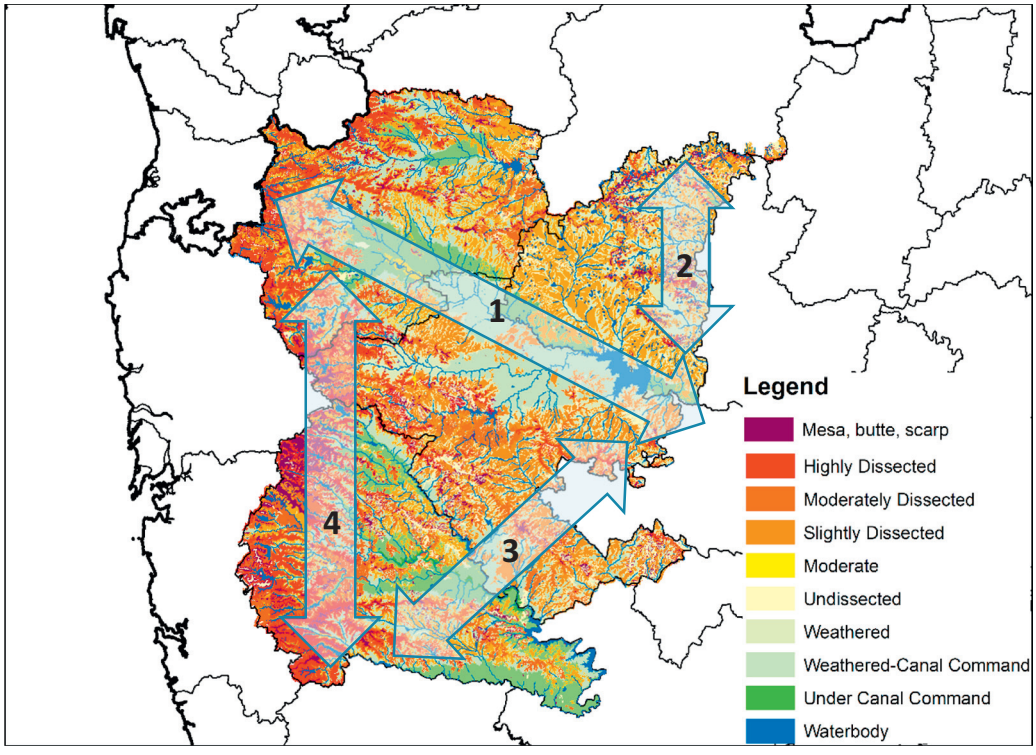

Fig. 21. Major spatial patterns of landform and settlement development on the Deccan Volcanic Plateau. Author and GSDA, 2018.

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shared ideas and information about district water resources and groundwater prospect mapping. I received helpful feedback from presentations of earlier versions at the 2017 Association of American Geographers meeting, Dr. BNCA University in Pune, and AURO University in Surat, India. Sera Tolgay developed the landscape models for visualization, and Ranu Singh helped with image editing. Professor Karl Butzer provided the inspiration and Professors Sheryl Luzzadder Beach, Timothy Beach, Carl Ernst, Richard Marston, Pushkar, provided encouragement for my pursuit of these ideas, which along with helpful feedback from reviewers and editors greatly improved the paper.

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Please cite this article as: Wescoat, J.L., Human use of landforms on the Deccan Volcanic Plateau: Formation of a geocultural region, Geomorphology (2018), https://doi.org/10.1016/j.geomorph.2018.08.044