Late Quaternary drainage disorganization, and migration and extinction of the Vedic Saraswati

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Several lines of geological evidence confirm the existence of a high-energy fluvial regime in western Rajasthan during the Late Quaternary period. Geomorphic description of the extinct river system matches well with the Saraswati River described so vividly in the *Rig Veda*. The Vedic river which presumably flowed parallel to the Aravalli Mountains during its initial stages, migrated westward during neotectonic uplift of the Aravalli Mountains. The neotectonic movements, which brought about the down-sagging of the northern part of Aravalli Mountains also forced the Yamuna River to swap its original course to flow across the flattened 'mountain'. The river presumably pirated the Saraswati waters while it drifted eastward to join the Ganges.

SEVERAL lines of evidence confirm the existence of a high-energy fluvial regime in western Rajasthan during the Late Quaternary/Holocene period. The most significant evidence about the presence of a well-drained fluvial system comes from the riverine pre-history of all the saline lakes in western Rajasthan, including that of the Sambhar situated in the Aravalli Mountains[1–7]. In fact, suggestions have been made that the saline lakes are the segmented remnants of the disorganized river channels[8–10].

A number of palaeo-channels have been discovered in the Thar Desert region in recent years, through the use of satellite remote sensing data[8,11–19] (Figure 1). The studies by Rajawat *et al.*[20,21], who used more sophisticated pyramidal-processing techniques on the high-resolution IRS 1-C data, further confirmed the presence of a large number of segments of palaeo-channels in the region. All these palaeo-channels are presumed to be the relics of a river system that drained western Rajasthan at different times during the Quaternary. In addition to this, the presence of dry valleys (the Ghaggar, for example) in north-western Rajasthan, Haryana and also in the Sindh Province in Pakistan, attests the presence of erstwhile fluvial regimes in the Thar Desert region. The vast alluvial plains built up by these streams, and the high-energy nature of flows helped to link these river systems with the perennial headwater source of the Himalayan glaciers. Streams emanating from the Aravalli Mountains followed a north-westward trend across their newly developed pediplains, before merging with the Himalayan river systems further west.

The Luni River, which flows through the south-eastern part of the Thar Desert region once drained into this Himalayan system[22]. A number of palaeo-channels have been identified in the Luni Basin[3,4,14,15,23,24]. Based on the interpretation of Synthetic Aperture Radar Imageries, Kar[15] mapped several south-west to south south-west flowing palaeo-valleys in the alluvial plains between Jodhpur and Pali. He identified these as belonging to those of the Luni River. The discovery of palaeo-valleys indicates a number of easterly courses of the erstwhile Luni River. The points of deflection from the present course of the Luni River are located at places near Malkosni, Mortauka and Kankan (Figure 2). These, according to Kar[22], are the possible successive shifted courses of the Luni. Kar[25] discussed about the influence of NE-SW trending lineaments in controlling the present-day stream courses in the Luni–Jawai plains. A closer look at the lineament pattern in the region[26] on the other hand, indicated that the present-day drainage pattern is truly influenced by two conjugate sets of lineaments, trending NE-SW and WNW-ESE. The main course of the present-day Luni follows what has been described as the Luni–Sukri Lineament. The WNW-ESE lineaments on the other hand, have controlled the courses of the tributaries, which drain through the southwestern pediplains of the Aravalli Mountains. Kar[25] reported the presence of two fluvial terraces along many streams in the plains of the Luni drainage system. He related this feature to the movements along a number of NE-SW running faults that pass through the Aravalli foothills and further south. The author traced eight major faults (lineaments) in the Luni Basin, along which both vertical and transcurrent movements have taken place during the Late Quaternary. The movements caused drainage anomalies like channel-branching or obliteration, channel-incision and shifting of courses.

Ghose *et al.*[12], Kar and Ghose[13] and Kar[14] recognized three different stages of shifting of courses of the 'now-extinct' Himalayan river. The shifted river courses were roughly through (1) the vicinity of Rajgarh, Hardyal, Ratangarh and the present misfit valley of Jori; (2) Nohar, Surjansar and Samrau; and (3) Sirsa, Lunkaransar and

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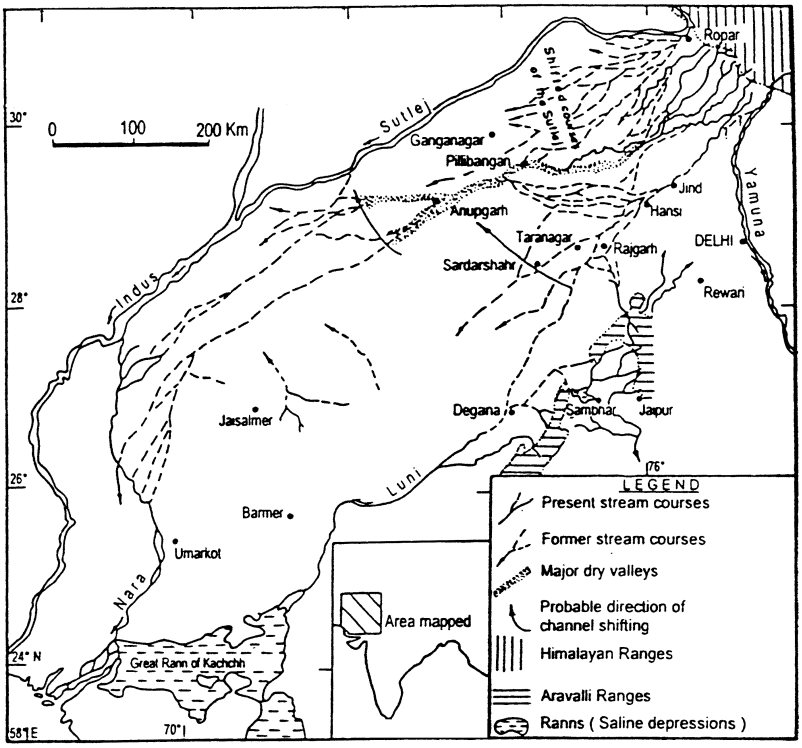

Figure 1. Map illustrating courses of the present and former streams passing through northwest Rajasthan (after Kar[22]).

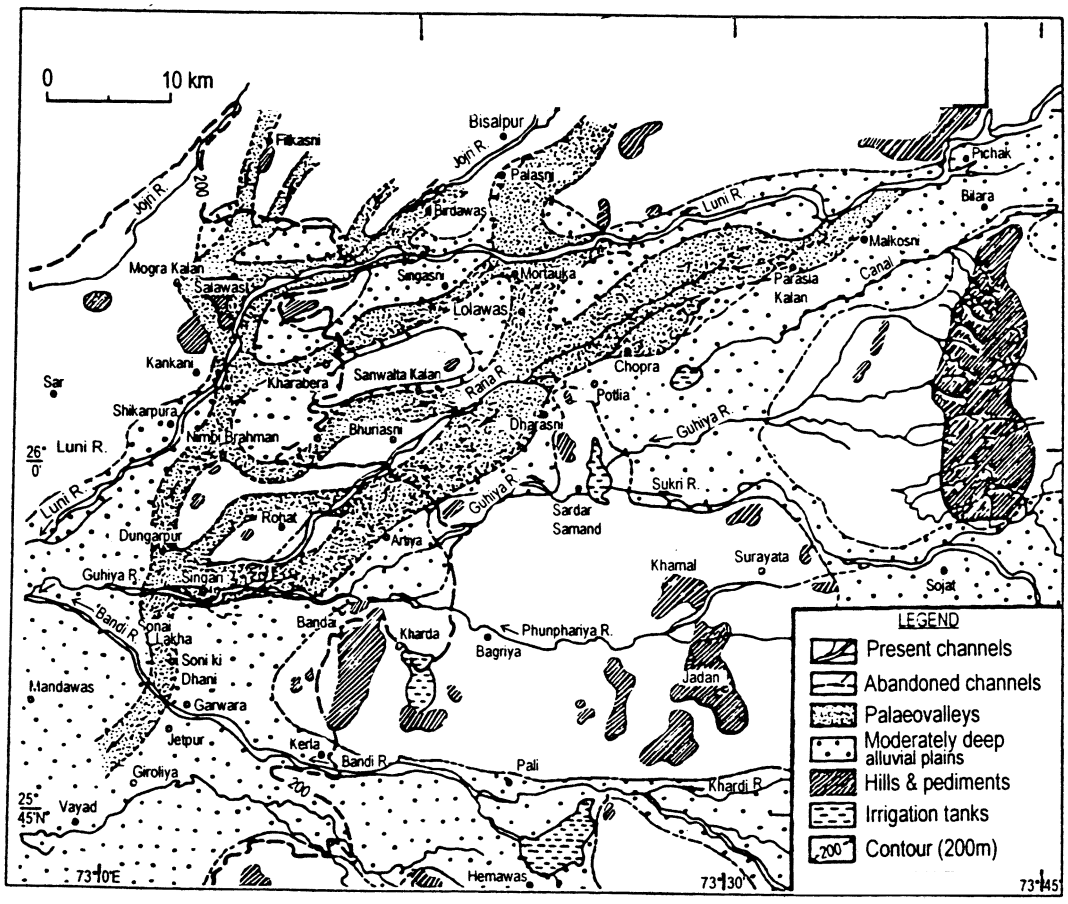

Figure 2. Map based on interpretation of radar imagery and field data illustrating the present and former drainage systems in the Luni–Bandi interfluves, west of Bilara–Pali (after Kar[22]).

east of Bikaner. The river seems to have shifted its course subsequently roughly through Nohar, Anupgarh, Sakhi, Khanpur (now in Pakistan), Ghantiali, west of Shahgarh and followed the lower courses of Nara (now in Pakistan). Further shifts took the Himalayan river through Raini and Wahinda and Hakra–Nara segment in Pakistan. In the final stage, the river met the Sutlej (*Satadru*) via Anupgarh to the west of Ahmadpur East in Pakistan. Analysis of remote sensing data also helps to recognize northwestward drifting of the course of a second important Himalayan river from the eastern margin of the Thar Desert[12].

According to Bakliwal and Grover[8], the Himalayan river initially followed a channel close to the foothills of the Aravalli Mountains. In the southern part, the river followed an easterly course than the present Luni, before its culmination in the Little Rann of Kachchh. These authors proposed a number of stages in the shift of river courses in the northwesterly and westerly directions before merging with the present-day dry beds of the Ghaggar. It may be pointed out that the shifting of river courses suggested by these authors is somewhat different from those suggested by Ghose *et al.*[12], Kar and Ghose[13] and Kar[14]. Nonetheless, all these studies, including those by Mehta *et al.*[16], Sahai *et al.*[18] and Yashpal *et al.*[19] not only helped in confirming the course of a mighty Himalayan river, but also indicated its migratory nature, implying northwesterly and westerly shifts in its course. The apparent differences in the suggested trends of palaeo-channels ascribed by all these authors could be because of the difficulties in piecing together of different segments, due to lack of records on the ages of their formation.

The discovery of three large delta complexes in the northern part of the Great Rann of Kachchh[27,28] further strengthens the view about the operation of a high-energy fluvial regime through Rajasthan. The delta complexes (Figure 3) stretch westward up to the mouth of Indus and eastward up to the mouth of the Luni River. Southward, the delta complexes extend up to the rocky mainland of Kachchh. The eastern and western delta systems are at the mouths of the present-day Luni and Nara rivers, respectively. The middle one, looking at its size and complexity, appears to be associated with a mighty river system. The authors associate this relict delta system with the Vedic Saraswati, which has now disappeared from the scenario. Dissection of these delta complexes was arguably caused by a number of neotectonically active faults, such as the Nagar Parkar Fault, the Luni Sukri Fault/ Lineament, Island belt Fault, the Allaband Fault and the Kachchh Mainland Fault[27,29,30]. A critical analysis of the satellite images of the region reveals that the deltaic deposits were much more extensive in the past, made up of complex intertwined channels or distributing drainage network of three different rivers. Malik *et al.*[27] consider the submergence of the deltaic system and its subsequent replacement by a tidal regime during historical times.

The geological records from western Rajasthan and Kachchh region of northern Gujarat, therefore, strongly suggest the presence of a well-drained fluvial system in

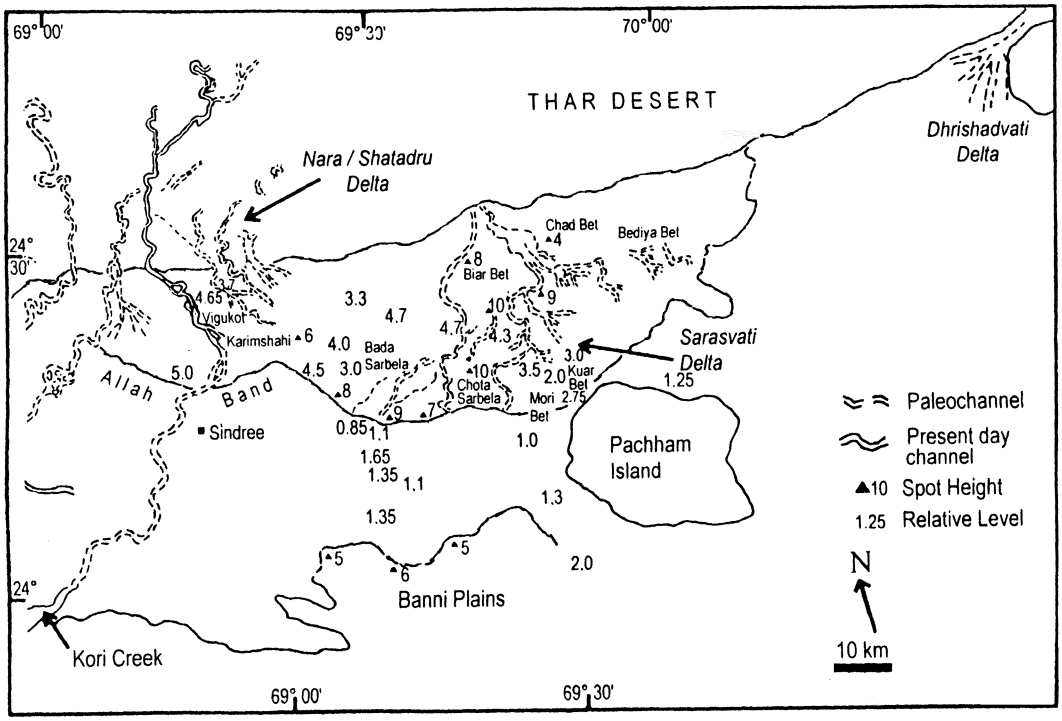

Figure 3. Map showing the bird's foot palaeo-delta complex representing the mouths of three rivers identified as Shatadru (Hakra), Saraswati and Drishadvati (after Malik *et al.*[27]).

the past. The territory now presents a different scenario, characterized by arid climate and the presence of a thick sand sheet comprising dune deposits and ephemeral and essentially centripetal drainage pattern. Many scholars and earth scientists now believe that the extinct river system was none other than the River Saraswati, which has been extolled in superlative terms in the *Vedic* and *Puranic* literatures.

A number of workers pointed out that the aridity was the main cause of extinction of the Vedic river. From the description of the Saraswati River in *Vedic* literatures, it is apparent that the river in question was indeed a very forceful one, having perennial flow of glacial water. Extinction of such a glacial-fed river purely due to aridity, would be highly unlikely. It may be worth comparing the case of the River Nile, one of the very large rivers in the world today. The river is flowing gloriously through the highly arid region of the eastern Sahara Desert. We would also like to emphasize the fact that there is absolutely no scientific basis for the belief that River Saraswati plunged underground and is now having subterranean flow of water. Perhaps this was at the back of the mind of some of the earth scientists who were engaged in the drilling operation, with the hope of tapping the flow of the '*Vedic* River'. Contrary to the view of subterranean flow of Saraswati, Nair *et al.*[31] argued against any direct headwater connection of the groundwater (sampled from some palaeo-channels in Jaisalmer and Ganganagar districts) with the present-day Himalayan sources. While we reject the theory of aridity or the subterranean flow of Saraswati as the cause of its extinction, we are left with the only alternative, which suggests migration of the river either to west-southwest direction to join the Indus River system or to mingle with the Ganga River system in the east.

Although there is no unanimity on the actual process of migration of the Vedic river, it is now known with certainty that the neotectonism during the post-Vedic period was the cause for such geomorphic changes in western Rajasthan. In this connection, two different geomorphic features need critical analysis. These relate to the great water-divide of the Himalayan rivers, and the easterly deviation of Indus and Hakra–Nara rivers in the southernmost parts of their courses.

Spectacular polarity of the Himalayan rivers into easterly-flowing Ganga River system and the southwesterly flowing Indus River system (Figure 4), is in spite of the fact that presently there is hardly any geomorphic high in the region, particularly between Delhi and the Himalaya in the north to cause that. The difficulty in assuming the Aravalli Mountains as a water divide is because of the fact that presently, the mountain does not extend up to the Himalaya. The peninsular mountain appears to be a quite subdued feature around Delhi, which gradually merges with the alluvial plains north of Delhi. Geophysical data (based on gravity modelling), however, prove the existence of a subterranean ridge, described in the literature as the Delhi–Hardwar Ridge. We, therefore, interpret that the Delhi–Hardwar Ridge, which now exists as a subsurface feature must have been a topographic high and acted as the water divide to polarize the drainage into easterly and southwesterly flowing systems in the past. The present-day geomorphic scenario, therefore, entails subsidence of the positive topographic feature due to regional down-sagging of the territory that faces the Himalaya. Because of such a geomorphic change due to the neotectonic movement, two plains on either side of the topographic high became amalgamated into one single plain. It may be tempting to conceive *Govardhan Parbat* mentioned in the *Mahabharata* as one of the hills that once constituted the northern extension of the Aravalli Mountains, north of Delhi. If we presume the existence of these hills as real, then the date of subsidence of the region could be contemporary to the *Mahabharata* Period.

The course of the only river, which clearly is a misfit stream in the above mentioned geomorphotectonic setting, is the Yamuna. The river, which begins its course in the plains west of the 'submerged' Delhi Hardwar Ridge, flows across the territory to join the easterly-flowing Ganga, further east at Allahabad. We may venture an interpretation that the proto-Yamuna was initially a southwesterly-flowing river like the other rivers of the Indus system. Its subsequent turn to the east to join the River Ganga must have followed the subsidence and flattening of the topographic high, which earlier existed as the northern continuity of the Aravalli Mountains. The down-sagging and subsequent flattening of the northern extension of the Aravalli Mountains can be related to the Late Holocene neotectonic movements in this part of the Indian Shield (see Valdiya[32] for a similar interpretation). Besides the mythological reference to the hills known as the *Govardhan Parbat*, no other age data are available for dating such an important geomorphotectonic event.

Another significant feature relating to drainage patterns of the southwesterly-flowing river system is the conspicuous parallelism between the part of the Sindhu River south of the confluence with five rivers, and the channels known as the Nara and Hakra, east of the former. The strict parallelism between the two river channels continues even beyond the points west of Umarkot (in Pakistan). From this point onwards, these rivers take a sharp southeasterly turn and flow in a southeastward direction up to the river mouths at the Arabian Sea (Figure 5). Such a spectacular feature in the river courses leaves little doubt about the control of lineament tectonics in the drainage evolution. The sharp angular deflections in the courses of rivers, particularly where the rivers flow through a flat sand-covered territory, are quite an unusual feature. We may logically presume, agreeing with Bakliwal and Grover[8], that the courses of rivers which flowed along the western parts of the Aravalli Mountains, had essentially linear NE-

SW trending channels subparallel to the trend of the Aravalli Mountains. The deflections that we note in the river courses may be explained as due to shift of a part of these river courses in response to the westerly tilt of the rectangular block bounded by two sets of lineaments. It is possible to identify the southernmost lineament as the NW-SE trending Jaisalmer–Barwani Lineament. The northern lineament could possibly be Raisinghnagar–Tonk Lineament. Tilting of the block which caused westerly shifts of the west Aravalli pediments, is linked with the uplifts of the Aravalli Mountains as a fault-bounded horst.

Credit goes to Oldham[33] for focusing our attention to the Saraswati River, the lost river of the Vedas. He was the first to prepare a drainage map of a region (Figure 5), which presumably was drained by the Saraswati River system. Many other earth scientists[19,34] and scholars firmly believe that the river course now represented by the dry beds of Ghaggar and its southern counterparts, Hakra and Nara basins, constitutes the channel of the Saraswati River referred to in the *Vedic* and *Puranic* literatures. This is notwithstanding the possibility that the Ghaggar–Harka–Nara channel could even be the left-out channel of the Sutlej. The idea that the Ghaggar–Hakra–Nara course

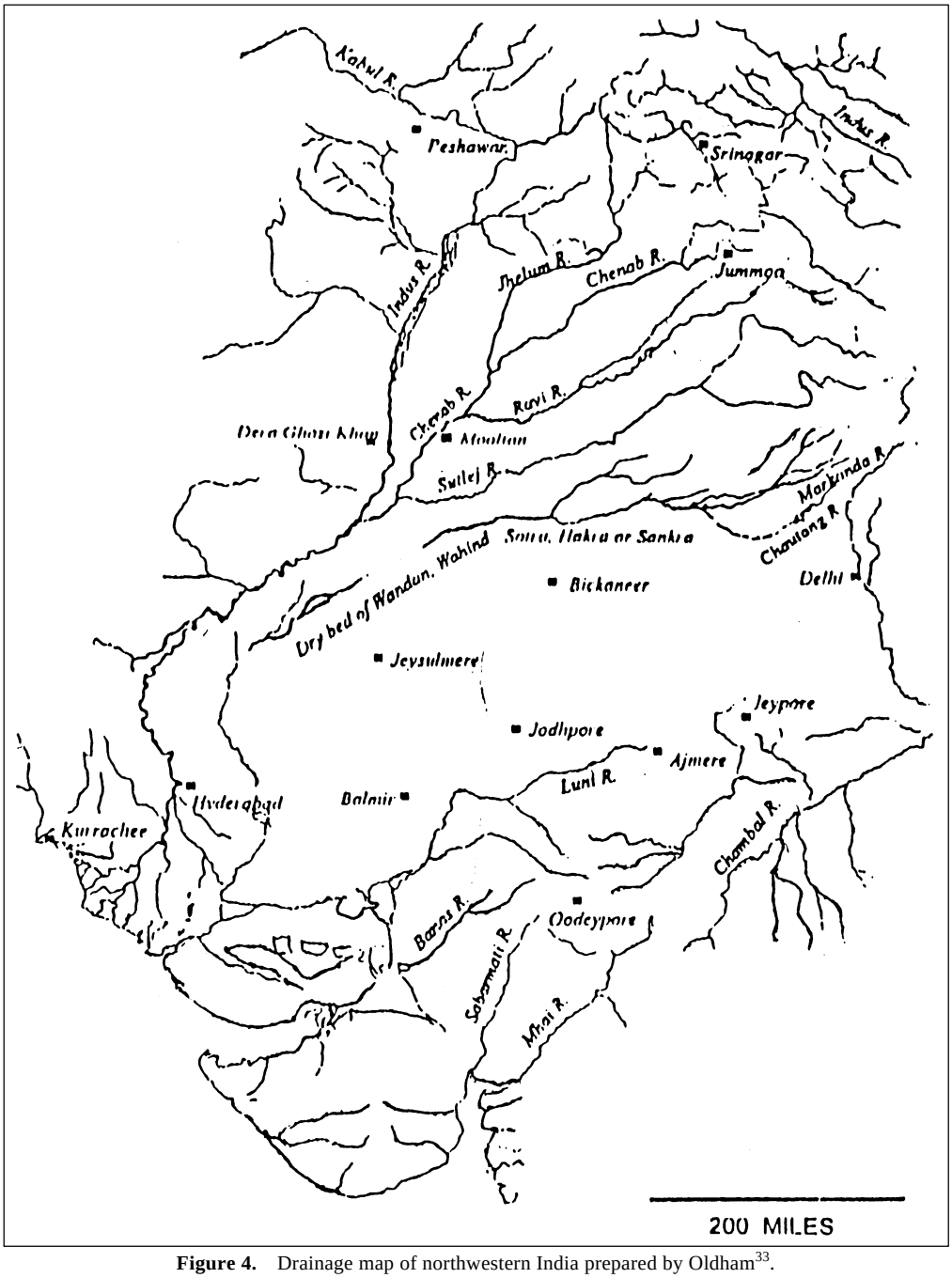

Figure 4. Drainage map of northwestern India prepared by Oldham[33].

represents the Vedic Saraswati channel, although attracted attention of a large number of workers, is not in conformity with the fact that the mythical river has been conceived as the greatest river of ancient India. In the *Rig Vedic* hymns the river has been referred to as *naditamé saraswati*, meaning the 'best of rivers' (*Rv. 7.95.2*), which surpasses 'in majesty and might all other river' (*Rv. 7.95.2*) and 'swifter than other rapid streams'. 'It comes onward with tempestuous roar (*Rv. 6.61.8*) bursting ridges and hills with its strong waves (*Rv. 6.61.2*). These descriptions of Saraswati do not appear compatible in any way with any of the dry ephemeral beds of Ghaggar, Hakra and Nara. Even if we assume that the mighty Himalayan river flowed through Rajasthan only during the Middle and Late Holocene times, and was later shifted westward or northwestward, the flow of the river must have been reduced drastically when its course merged with those now followed by the Ghaggar, Hakra and Nara. None of the tributaries of the present-day Ghaggar River system has any headwater source connection with the Himalayan glaciers, and survives only on monsoon rains. The Ghaggar, according to Rajaguru and Badam[35], was never a mighty river during the Harappan times. There is also no proof to suggest that Ghaggar ever had a flow pattern matching with that of the Vedic Saraswati. The present width of the Ghaggar has been overemphasized[36]. It is a common phenomenon that the ephemeral beds are generally wider, as these have to compensate the lack of depth in river-beds to carry huge volume of flood waters. Even the delta that now occurs at the mouth of the River Nara is relatively small compared to that which occurs further east in the Great Rann of Kachchh, and assigned to the River Saraswati[27,28].

There is hardly any doubt about the presence of a mighty river system flowing close to the foothills of the Aravalli Mountains. Occurrences of gravel spreads in pockets, as at Jayal and its neighbourhood (near Didwana; Figure 6) over the rocky pediplains along the western slopes of the Aravalli Mountains, may be considered as the initial products of palaeo-drainage of a mighty Himalayan river[37]. The palaeo-channel recorded a little to the east of the present Luni[15] could represent the course of an early river. Some significance must be attached to the name Lavanavati (the name distorted to Luni subsequently), attributed to the only river system existing in western Rajasthan. It appears possible that Luni turned into pools of saline water after the withdrawal of the Himalayan river, hence its name. Presently, Luni is an ephemeral stream, which carries rainwaters from the Aravalli Mountains. The Himalayan river might have been shifted to a new channel which flowed through Pachpadra. Based on interpretations of aerial photographs, Ghose[2,3] suggested that Pachpadra was the confluence of two flourishing rivers that flowed as the proto-Luni in the south. Existence of five perennial rivers is implicit in the undistorted name of the place, Panchbhadra (*panch* means five, and *bhadra* stands for five flowing rivers; cf. *Sonbhadra*, *Tungabhadra*). Thus, concealed in the name of the place (now known for vast saline deposits) is the reference that it was a confluence of five generously

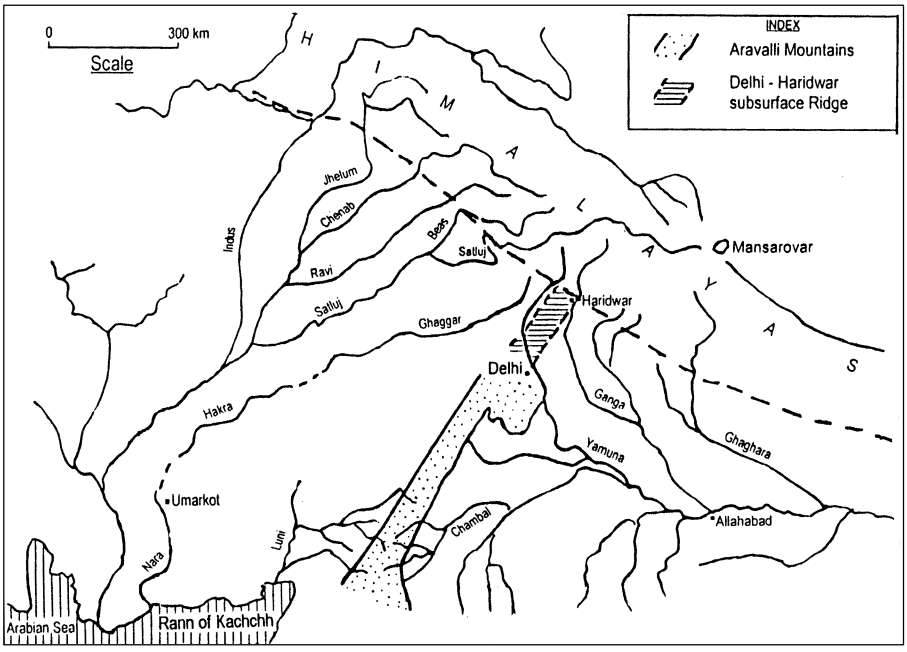

Figure 5. Map showing the bipolar drainage pattern of easterly-flowing and southwesterly-flowing Himalayan rivers. Probable northward extension of the Aravalli Mountains as the subsurface Delhi–Hardwar Ridge is shown schematically.

Figure 6. Spread of cobbles and gravels at Jayal, near Didwana (District Nagaur) presumably deposited by the proto-Saraswati.

flowing rivers (the *bhadras*); and that this geomorphic phenomenon was witnessed by the civilized man, most likely by the Vedic people. We are tempted to speculate that the terrain north of Pachpadra could have been the revered land of *Brahmawarta*, referred to in the Vedic literature, bounded by two rivers, Saraswati and Drishadvati. Geomorphologically, the *Brahmawarta* would have had features similar to present-day Doab in Punjab.

Finally, the location of the Saraswati River on the western side of the Aravalli Mountains is implied in the fact that there is not even one single separate verse in praise of the Ganga[38], while the rivers of the Indus system along with the Saraswati and Drishadvati received repeated mention in the *Rig Vedic* hymns. Nevertheless, we have no reason to presume that Ganga did not exist as a major river during the Vedic times. On the other hand, the information helps to confirm the regional association of the Vedic Saraswati with the river systems that drained the plains to the west of the Aravalli Mountains. Casual mention of the Yamuna in the *Rig Veda* possibly reflects its subdued significance during the Vedic times.

The apparent consensus amongst different workers and scholars on the recognition of dry beds of the Ghaggar, Nara and Hakra as the relic courses of the Vedic Saraswati may represent a case of mistaken identity. As one of the earliest to be on trail of the legendary Vedic river in this terrain, Oldham[34] assumed that a small stream, named 'Sarsuti', presently a small tributary of Ghaggar, could be the possible relic of the Saraswati referred to in the *Rig Veda*. We wonder if this view is based on the fact that the name 'Sarsuti' sounds similar to Saraswati. If etymological consideration could really be the basis of such a suggestion, it may then be worth mentioning that a number of present-day or even the supposedly extinct rivers in different parts of northern India are also known as Saraswati or Sarsuti River. We would like to emphasize here that a part of the Luni River in the upstream side is also known as Sarsuti. We strongly feel that viewing from geomorphologic angle, the Sarsuti in the upstream side of Luni must have a better claim as the relic of the Vedic River Saraswati.

Unlike the names that are generally associated with the river systems in this part of Rajasthan (Panchbhadra or Lavanavati), those associated with the presumed Saraswati channels in the western Thar Desert, such as Ghaggar, Hakra, Nara, etc. sound quite exotic, at least not associated with Sanskrit etymology. This could be an indirect logic against the assumption of the Ghaggar–Hakra–Nara beds as the palaeo-channels of the River Saraswati.

Summarizing, we suggest that the Vedic River Saraswati during the initial stages of its migratory evolution (*following the drainage reversal as an aftermath of the Himalayan collision*) flowed close to the foothills of the Aravalli Mountains. The river migrated westward with westerly shifting of western pediplains of the Aravalli Mountains, because of its sharp uplift as a horst. At a certain stage of its migration, the mighty Himalayan river followed the course of the Luni River. The rise of the Vedic civilization could have coincided with the further westerly shift of the Saraswati and its tributary, the Drishadvati. We speculate that the terrain north of Pachpadra was the celebrated land where the Vedic people lived. The river at that time built up a large delta in the Great Rann of Kachchh, which did not turn into a mere shallow depression by then. Further, westerly shifts of the Vedic river were accompanied by major neotectonic movements, which might have destroyed the most ancient civilization on Earth. The neotectonic movements in the northern part of the Aravalli Mountains led to its subsidence and virtual flattening of topographic high that had earlier acted as the Great Water Divide. We fully agree with the suggestion of Valdiya[32] that the River Yamuna 'pirated' the Saraswati waters when it changed its course from southwesterly to easterly, to become a part of the Ganges river system.

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