GEOMORPHIC EVOLUTION OF SALINE DEPRESSIONS NEAR POKARAN, RAJASTHAN, INDIA

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ABSTRACT

The paper deals with the origin and geomorphic evolution of the ranns around Pokaran. It is suggested that the ranns represent discontinuous depressions developed along the contact of hard and compact basement rocks with the soft ferruginous sandstones and shales carved out mainly due to the formation of a chain of cuestas by differential dissection along the margins of an ancient basin. These depressions were further modified by the process of deflation before attaining the present shape. The nature of the sediments present in of the ranns has also been discussed.

INTRODUCTION

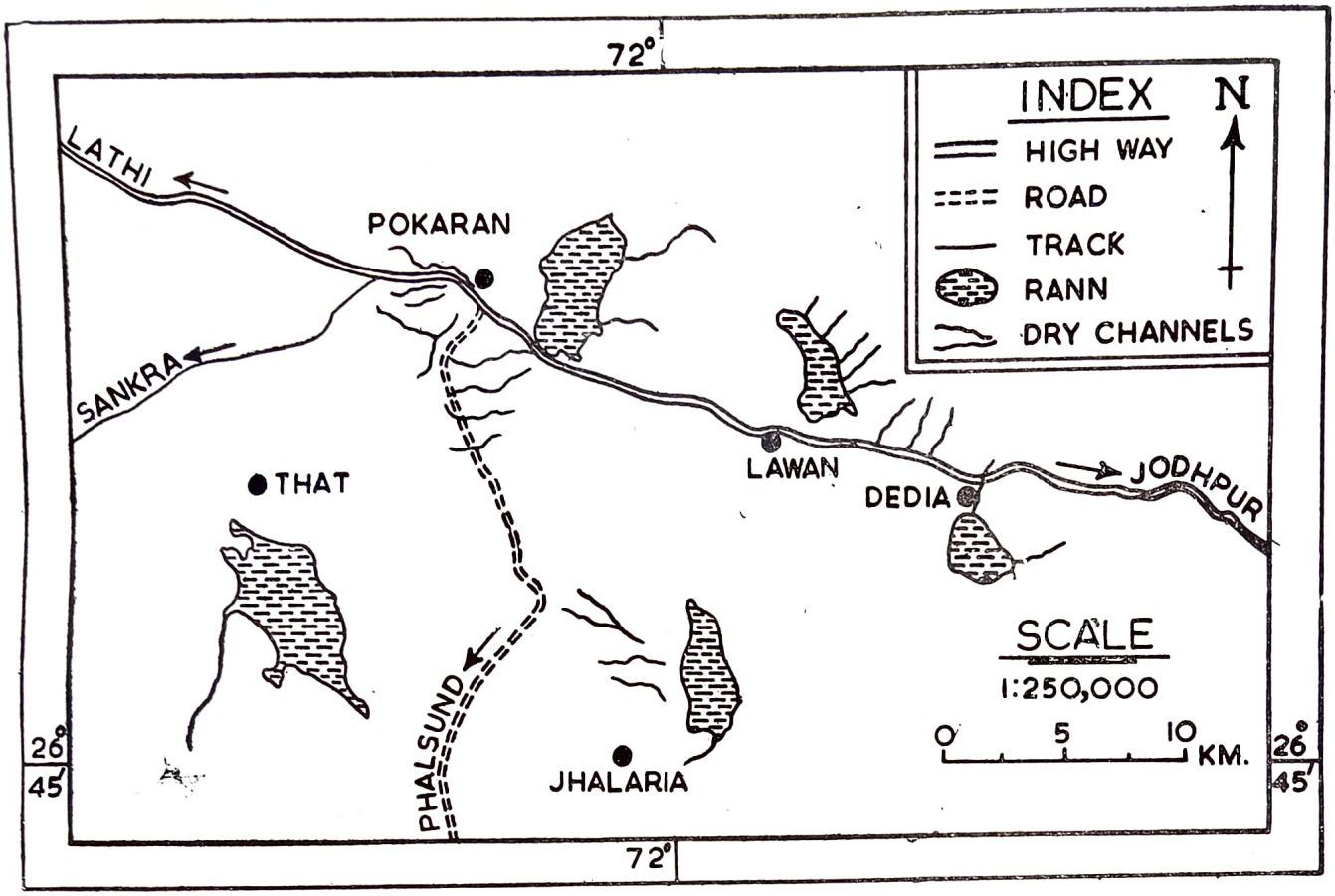
There are five saline depressions named after the local villages of Pokaran (26° 58′ : 71° 57′), That (26° 25′ : 71° 52′), Jhalaria (26° 45′ : 71° 58′), Dedia (26° 51′ : 72° 7′) and Lawan (26° 55′ : 72° 5′) in Pokaran area which falls in the Survey of India Topo Sheet Nos. 40N and 45B (Map 1). These ranns are shallow depressions in a rocky desertic country and are normally dry but filled only after sufficient rainfall. The thickness of the sediments in the ranns is only between 1.4 m to 3.5 m, deposited mainly over the basement of ferruginous shales and rhyolites. The brine is present in sufficient quantities only at Pokaran and That ranns, which is being utilized for the production of common salt. The rest of the ranns are almost completely devoid of brine.

Apart from the ranns the region is characterised mainly by the features like, low discontinuous ridges, sand dunes and flat erosional surfaces stretching up to considerably long distances, thus, presenting a typical desertic landscape. The area is thinly populated, represented only by few small villages. In general, the vegetation of the area is also typically desertic in nature.

GEOLOGICAL OBSERVATIONS

The area around Pokaran is characterized by the absence of an organised drainage system and the development of flat low mounds, small ridges, sand dunes, and flat erosional surfaces. These features are carved out on the basement granites, rhyolites and soft ferruginous sandstones and shales. The granites are the oldest rocks in the area exposed near Jhalaria village south of Pokaran in the form of big boulders succeeded by the rhyolites and sandstones (Jodhpur sandstone). Granites and rhyolites form the basement for the deposition of these sandstones in the region. The contact between these units represents the margins of the basinal sediments in the Western Aravalli region.

All the five ranns in the area are seen occupying the zone of contact between the sandstones and the older basement rocks. In profiles also, below the recent sediments the shaly sandstones and rhyolites have been recorded.



MAP 1—Showing the location of Pokaran, That, Jhalaria, Dedea and Lawan ranns, Pokaran, Rajasthan.

So far, the geology and geomorphology of Pokaran area has not been studied in detail as it forms a part of the main western Rajasthan Desert and is of not much economic importance. BLANFORD (1876 and 1877) described the physical geography and geology of the Rajasthan desert. LA TOUCHE (1902) presented the geology of western Rajasthan. HERON (1938) studied the physiography of Rajputana. RODE (1964) traced the evolution of Rajasthan Desert on the basis of his sheet movement hypothesis. NARAYANAN (1964) described the stratigraphy of the Rajasthan shelf. Recently, AHMAD (1969) studied the origin and geomorphology of the desert. PANDEY (1969) has dealt with the various aspects of the arid zone geomorphology. SINGH *et al.* (1971) described the geomorphology of the middle Luni Basin. SINHA (1977) described the Quaternary geology, aridity and desertification in Rajasthan, and ALLCHIN *et al.* (1978) presented the prehistory and palaeogeography of the great Indian Desert. These studies are mostly general and regional in approach. However, the detailed account of the smaller geomorphic units is important, in order to understand the various problems related with the origin and development of the Rajasthan Desert. Accordingly, PANDEY AND CHATTERJEE (1970) discussed the genesis of the ranns near Jaisalmer and ANAND-PRAKASH (1980a and 1980b) described the landforms around Jaisalmer and the gemorphic evolution of the Lik river south of Pokaran.

To the best of my knowledge, the detailed geomorphic evolution and origin of the Pokaran ranns is not known. Therefore, the author during the field seasons of 1978 and 1979 studied the geomorphology of the area with a view to understand the origin and evolution of these ranns which has been presented in the following account.

Geomorphic Description

The area around Pokaran, That, Dedia, Lawan and Jhalaria ranns is mainly characterised by the following landforms :

(i) Discontinuous ridges
(ii) Erosional surfaces
(iii) Saline Depressions or ranns
(iv) Drainage
(v) Sand dunes

(i) *Discontinuous ridges*

These low ridges have mainly been carved out in the rocks of rhyolites and sandstones. The top portion of the ridges is mostly represented by a flat erosional surface. The face of the ridges towards the ranns is mostly marked by the steeper slopes whereas, the other sides are represented by gentler slopes. In general the scarpment slopes mostly face towards the ranns. At the base of the slopes the debris has also been accumulated forming the debris slope which is covered up to a considerable part by aeolian sand mainly due to the formation of obstruction dunes. Therefore, the debris slope is seen only rarely at places. The area below the debris slope is characterized mainly by the development of another gently sloping erosional surface. These ridges almost everywhere represent the contact between the hard and soft rock units of the area.

(ii) *Erosional surfaces*

There are two erosional surfaces observed in the area, one developed at the top of the ridges and the other at the basal region. These surfaces cover a very large area and are characterised by the presence of sand dunes and gravel wastes almost uniformly distributed over the surface. The gravel is mostly coated with iron oxide presenting desert varnish. In general these surfaces can be described as very gently sloping plains rarely gullied only near the margins. The elevation of the surfaces is almost uniform wherever they are present and seems to be developed mainly due to the sheet flow of water, representing the periods of severe erosion and peneplanation.

(iii) *Saline depressions or ranns*

There are 5 ranns in the area, namely Pokaran, That, Dedia, Lawan and Jhalaria.

(1) Pokaran Rann

The Pokaran Rann is situated very close to Pokaran City towards east and is approachable by the Pokaran-Jodhpur highway. Up to some distance the highway runs almost along the southern margin of the rann. The shape of the rann is linear to oval with its longer axis running about 6.25 km and shorter about 2.5 km. It is flanked by the low mounds of ferruginous sandstones and rhyolites. The base of these mounds are usually characterised by the formation of a well developed sand dune area and an erosional surface slightly above the bed of the rann. Apart from these features a number of dry channels are seen joining the rann from almost all the directions. Eight prominent channels from west, four from east and two from north are seen feeding the rann. Some of the channels die out before actually reaching the rann.

The thickness of the sediments in the rann is only 4 m as at this depth the compact red shaly sandstone of the basement is seen in the profile, studied from the central area of the rann. This depth also forms the brine level as the brine seems to be trapped at the

contact of the sediments with the basement rocks. The compact clayey nature of the shales has actually provided an impervious trap for the storage of the brine, used in the manufacture of common salt.

The sediments in the rann are characterised by the presence of a 30 cm thick layer of gravel over the basement shales, overlain by a 70 cm thick layer of laminated green gritty sand and a 3 m thick layer of compact reddish clay. The presence of a thin gravel band at 50 cm depth from the surface has also been recorded in the clays (Fig. 1).

(2) That Rann

This is the largest rann, about 10 km in length and 3 km in width, in the area located about 15 km SW of Pokaran City near the That village. The shape of the rann is somewhat oval like that of Pokaran rann and is surrounded by low mounds mainly of rhyolites. The erosional surfaces observed near the rann are also developed over the rhyolites.

The feeding channels are almost absent excepting a prominent channel joining the rann from SW.

The thickness of the sediments in the rann is only 1.4 m as the hard basement rhyolites are seen in a profile from the central area of the rann at this depth. This depth is also the brine level as the rhyolite forms the trap for the accumulation of brine which is being utilized for the manufacture of common salt. A coarse gritty sand layer (30 cm) with a gravel fraction forms the basal part of the sediments deposited over the basement rhyolites. This layer is overlain by a 20 cm thick band of medium to fine grained sand and 90 cm thick green plastic clay (Fig. 1).

(3) Jhalaria Rann

Jhalaria Rann is about 5 km in length and 2 km in width located near Jhalaria village, 18 km south of Pokaran City. It is also somewhat oval in shape and surrounded by the low mounds of basement rhyolites and red sandstone. At places granite has also been observed south of the village. The extensive erosional surfaces are seen developed over these rocks. The channels feeding the rann are rare, only two prominent dry channels could be seen joining the rann from eastern and southern margins.

The rann is a shallow depression as only 1.5 m sediments have been observed in a profile studied from the central area of the rann. The sediments are characterised by a 5 cm thick kankar layer at the base lying over the basement red shales. It is overlain by a 40 cm thick coarse gritty sand layer. Overlying this layer a 40 cm thick band of medium to find sand with some gravel fraction has been observed. The upper most part of the profile is composed of a 65 cm thick clay layer with salt bands (Fig. 1). The notable feature is the absence of the brine in the rann up to the basement sandstones.

(4) Dedia Rann

Dedia Rann is subcircular in shape unlike all other ranns of the area located about 18 km east of Pokaran City. It is mainly surrounded by the low mounds of reddish sandstones and shales. The flat erosional surfaces are seen developed over these rocks around the rann. Channels feeding the rann are rare and only two prominent ones are seen joining the rann from eastern and northern margins.

This is a shallow depression as the basement sandstones are seen only at the depth of 2 m below the sediments in the central area of the rann. This depth also forms the brine level. Mainly clays are seen in the entire profile. Only the basal 10 cm clay con-

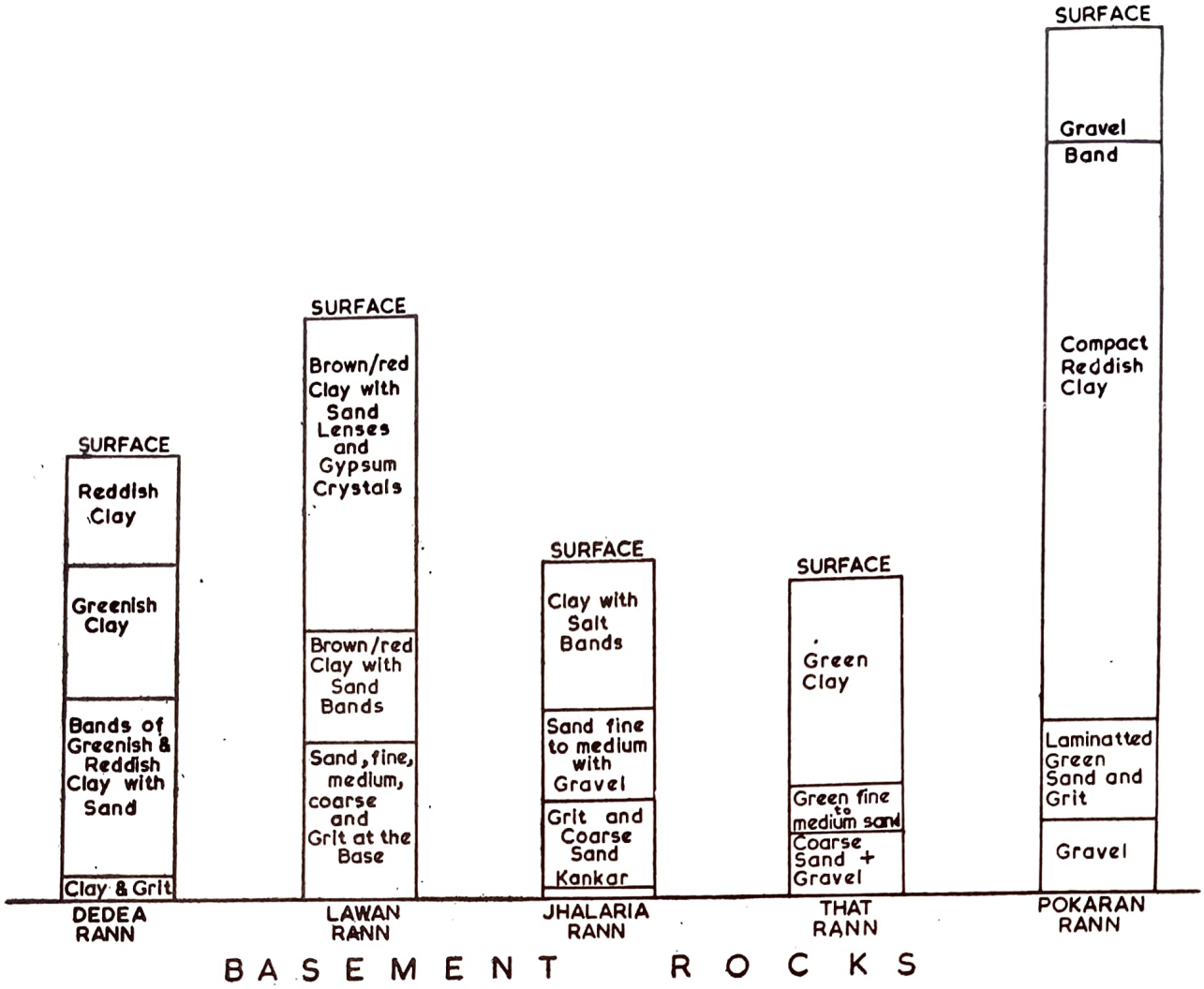


Fig. 1.—Profiles showing nature of the sediments in the ranns (Scale 5 cm=2 m)

tains some grit fraction. The clays can be divided only on the basis of its colour as the basal 90 cms clay is of green and red colour succeeded by a layer of 60 cm green clay and 50 cm red clay (Fig. 1).

(5) Lawan Rann

Lawan Rann is about 8 km in length and less than 1 km in width located near Lawan village about 12 km east of Pokaran City. It is linear in shape forming a shallow depression in an olive-red shaly sandstone basement. The low mounds of these shales are seen around the rann over which the erosional surfaces are developed. Number of small dry channels have been observed joining the rann only from the north eastern margins.

The basement sandstones and shales occur at the depth of 2.6 m in the profile studied from the central area of the rann. Sediments of the rann are characterised by a 70 cm thick basal fine to medium sand layer with some grit fraction. This layer is succeeded by a 50 cm thick band of brown-red clays with occasional thin sand layers. The rest of the profile is composed of brown-red clay with sand lenses and gypsum crystals up to the surface of the rann (Fig. 1). No brine is observed in the profile up to the basement.

(iv) *Drainage*

There is no definite and organized drainage system in the area. However, a number of channels are seen mostly flowing towards the ranns. These channels are shallow

in nature and usually remain dry for most part of the year. In general, these channels can be described as small streams originating from the ridges which terminate in the shallow ranns travelling short distances mainly over the erosional surfaces. Regionally, the drainage is directed towards south through the Lik Channel finally falling into the Luni river near Balotra. This is the only prominent river in the area, though its broad channel also remains dry and full of sediments.

(v) *Sand dunes*

The sand dunes are mostly seen over the erosional surfaces and at the base of the ridges. These are of various types, but most common ones are barchan and linear dunes. In general the dunes are of drifting nature, excepting near Bhaniana (26° 37′ : 71° 51′) and Dantal (26° 32′ : 71° 55′). Here the dunes occur across a channel and have become stabilized may be due to the availability of water resulting into the development of a few lakes.

GEOMORPHIC HISTORY

Before discussing the geomorphic history of the ranns the geological setting of the area needs proper consideration as the nature and behaviour of the rocks with various erosional agencies has remained the main factor in shaping the landforms. The oldest rock in the area is granite which remained exposed to the various erosional agencies for a considerably long time in geological past before its eroded surface has been covered by acidic lava flows forming the rhyolites. Since, the granites were covered and protected by the rhyolites the agencies started eroding the surface of the rhyolites and the portions of granites left uncovered by the lavas. This process continued for a very long time till some part of the area which was under severe erosion converted into a basin. In final shaping of the basin, the role of tectonic activity is also significant. Thus, the cycle of complete erosion of the rocks was interrupted by the deposition in certain parts of the area. The deposition in the basin then continued for a sufficiently long time till it became filled with sediments, whereas, the other parts of the area remained under the cycle of erosion.

After the filling of the basin, the area again suffered from the influence of severe tectonic activity which helped in the uplifting of sediments deposited in the basin. These sediments after the uplift were also exposed to the erosion. Under such condition the differential erosion of the hard and compact granites and rhyolites and the soft fragile sediments became an important factor in shaping the entire landscape of the area. The faster rate of erosion of the soft sedimentary rocks formed the valleys and depressions, whereas, the slower erosion of ancient hard rocks built the ridges. Further, the contrast in the development of the features became more pronounced near the contact of the sediments with the hard rocks or near the margins of the basin. This situation might have resulted in the formation of a chain of scarpment faces all along the marginal areas of the basin completing the history of the palaeogeomorphic features. At this point the stage became set for the development of Quaternary and recent landforms.

In due course of time, the continuous erosion almost peneplained the entire area resulting into the development of first erosional surface which later uplifted, possibly during Tertiary times. Similarly, the erosion again peneplained the area which was again uplifted resulting into the development of the second erosional surface (Anand-Prakash, 1980a) during early Quaternary.

On the second erosional surface these ranns and other recent features were carved out mainly due to fluvial action. However, while the process of erosion continued, the run off in the channels started becoming lesser and lesser due to the decrease in the rainfall which significantly changed the climatic regime into the arid condition. This resulted ultimately into the abandonment of the channels, as the streams could not maintain their beds due to the less availability of water to transport the excessive load of sediments which were poured into the channels due to the aeolian activity. Further more, the drifting sand filled the depressed areas and also burried most of the surface morphological features converting the narrow deeper areas into shallow flat depressions. Thus, whatever water was available mainly during torrential and storm rains started flowing in sheets over the flattened erosional surfaces which helped in the development of a thin cover of gravel on the plain surfaces giving it the present form.

Under these conditions the rock debris was transported over the slopes aided by gravity towards the shallow marginal depressions and deposited in the form of gravel and grits seen almost in all the ranns. The availability of water slowly became less and could not transport coarser material and therefore, only medium to fine sand reached the basins and deposited over the gravels, grits and coarse sands. Further, less availability of water could transport only the finest material into the basin resulting in the formation of clay under the closed basinal conditions.

On the basis of the above account it seems that the ranns were developed as asymmetrical discontinuous shallow depressions along the margins of an ancient basin currently represented by the soft sandstone and shales deposited over the granite and rhyolites basement due to the differential dissection of the rocks. The features contributed for the formation of the shallow depressions can be grouped into three different topographical elements, such as the elevated low ridges separated by the ranns by a gradually sloping marginal area, a depression like that of a valley developed at the base of the cuesta with gently undulating relief slowly ascending in the form of an inclined plateau and the region of the backslope of the cuesta. The basement massifs of granites and rhyolites represent the first element, whereas, the second and the third elements were mostly developed on the sandstones and shales. These sandstones form a possible material for the formation of the cuestas after erosion in which the crests are mostly represented by the harder units and the base by the softer bands. Thus, mainly due to the formation of the cuestas along the margins of the basin in the area the shallow depressions have emerged into existence. These cuestas were further worn down after the formation of the ranns as the present relief of the area is represented by somewhat flat terrain in general, and the region is presently in the process of peneplanation. Thus, the erosion has considerably modified the shape of the cuestas which need to be interpreted by understanding the interrelationship of the various landforms in the area. Similar evidences for the formation of such features have been mentioned by TRICART (1974) from Segovia in Spain and Lodeve Basin in France. Here it has to be mentioned that the features have been further modified due to desertic conditions as the deflation has also played an important role before the final shaping of the depressions. In due course of time, these depressions were filled with the sediments and became saline in nature due to the excessive evaporation under arid conditions as the salts could not be washed out from the ranns in the absence of an outlet.

In the light of the geomorphic history of Pokaran ranns, the following comparison between the various ranns and lakes of the Rajasthan Desert seems possible.

The desertic region of Rajasthan has a number of saline ranns and fresh water lakes

which can be grouped into three main types on the basis of their geomorphic evolution: (1) The ranns and lakes originated due to the natural blocking of the streams mainly by the sand dunes, (2) the ranns and lakes originated due to faulting, (3) the ranns and lakes originated due to the erosional pattern of the rocks. The first type is represented mainly by fresh water lakes and only a few ranns, namely, Budha Pushkar, Pushkar (Ajmer), Degana lake and small ranns near Pachpadra, respectively. The second type is mainly represented by large ranns of Jaisalmer, viz. Meetha, Kharia, Kanodwala and Khanowala (PANDEY *et al.*, 1970, and ANAND-PRAKASH, 1980a). The third type is mainly represented by the five ranns of Pokaran area. A large number of ranns and lakes have not been mentioned here, as so far their geomorphic evolution has not been worked out in detail. This comparison indicates that the Pokaran ranns are entirely different from the Jaisalmer ranns in their geomorphic origin. The faulted origin of the Jaisalmer ranns may also be taken as an indicative of their older age in comparison to the Pokaran ranns as the fault seems to be definitely older than these topographical features.

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