CHAPTER - VI

GENESIS AND PATTERN OF RAVINES

The foregoing analysis of geomorphic and hydrological factors provide a sound basis for understanding the problem of ravine genesis. These features make it evident that ravine formation is an important geomorphic phenomena which is related to the recent upliftment of the Lower Chambal Valley. Besides, the deposits in which the ravines are developing, constitute a major zone of agriculture. Thus the devastation of these recent deposits through the formation of ravines poses a serious problem in the agricultural and irrigation planning of the Valley.

In the past few decades the problem of ravine and gully erosion with consequent loss of agricultural lands has received much attention in tropical and mid-latitude countries. Within the Indian subcontinent the studies of Rizvi (1941), Gorrie (1938, 58), Bharadwaj (1960), Abuja (1956) and Kaul (1962) reveal that the magnitude of ravine erosion is most critical on the hill slopes of the Himalayas, Siwaliks, Hazaribag and Chotanagpur plateaus, and along the Yamuna and its major tributaries like the Chambal. But the ravines found along the Chambal are of most severe type. It is estimated by the Planning Commission
(1965) that about 3 million hectares of agricultural lands are affected by the ravines in India and out of which 0.5 million hectares are found along the Chambal.

The ravine cuttings into the post-Tertiary alluvium are common and are the most striking features of the Lower Chambal Valley. The belt of ravines stretches from Kota city to the confluence of the Chambal with the Yamuna (Fig. 27) over a distance of about 482 kilometres. The ravines extend along the banks and are broadly separated by the watershed of the rivers on both sides. From Kota to Dholpur, the Bundi-Ranthambhor line of hills and beyond Dholpur the ravines of the Choti Parbati form the northern boundary of the Chambal ravines. The southern boundary fluctuates with the tributaries like the Kali-Sindhi and Parbati. Further on, the south eastern boundary of the Chambal ravines is well-marked by the ravines of the Kunwari river. Taking the average width of the ravine belt as about 10 kilometres, the total area dissected is thus about 4,820 square kilometres.

Starting from the Chambal gorge downstreams, one finds the intricate net work of the ravines of the Chambal and its tributaries, spreading on both the banks creeping into the rich alluvial soil. To the west of the Chambal in the Bundi district, the ravines of the Mej river and its major tributaries like the Talera, Ghorapacchar, and Kural form a narrow elongated belt of the ravines along the piedmont of the northern Vindhyan hills. To the east
of the Chambal, Kali-Sindh, Parbati and Kunu and their tributaries such as Parwan and Banganga flowing over the Harwati plain, have narrow ravine belt along their banks. The rivers of this triangular tract are characteristically narrow V-shaped and are parallel to each other. They are 3 to 4 metres deep.

Proceeding from the confluence of the Banas near Pali with the Chambal, one finds that with the increasing depth of the alluvium the depth of the ravines increases considerably. Consequently the shape changes from V to open V-shape. From Pali to Dholpur on the left bank of the Chambal there is a country of badlands stretching over the southern part of the 'Dangland'. The whole country between the foot of the Chambal scarp to the river bank exhibits a intricate net work of the ravines.

From Dholpur downwards, the ravines are more destitute and are bare of vegetation. They are characteristically U-shaped with vertical walls and flat bottoms. The depth varies between 30 to 60 metres. This dissected tract is a long narrow strip between the Chambal and the Yamuna, and about half the area is occupied by the deep and far extending ravines of the Yamuna. They eat their way from the banks into the adjacent areas along the Chambal, dissecting into numerous plateforms, knolls and flood plain bluffs. Towards west (Fig. 27) width of ravines is nearly 3 kilometres on either sides of the Chambal but on the east they almost unit with the ravines of the Yamuna.
The whole country between Bhind and Etawah is mostly dissected, irregular and is made up of steep ridges, low sloping hills, deep trenches and broad cut incised meanders. During the rainy season these streams become flooded and are a formidable barrier to crossing. The area in the neighbourhood of the junction of the Yamuna and the Chambal represents perhaps as wild and picturesque a view as is nowhere to be found in the plains. As far as eye can reach one can see here labyrinth dissected ravines and green valley of accasia trees. Besides, the ravines in this zone comprise so large a area of the total land that little area fit for agriculture has been left out.

DEFINITIONS AND CLASSIFICATION

Normally the gully is a current word for ravine. But as the present study reveal that it is not so. Neither all ravines may be considered as gullies nor all gullies to be ravines. Field observations in the Lower Chambal Valley show that a ravine always has steep side scarps, and immediate drop of 3 to 4 metres of head scarp, while a gully has a gently sloping head scarp and 40° to 80° inclined side scarps. Furthermore, a gully initiates along the animal trails, roads and paths on the agricultural uplands. On the contrary, a ravine forms along the river side and encroaches upon the catchment areas of the banks by headward erosion. Therefore, it may be suggested that the ravine formation is a process of the catchment area
View of Chambal ravines - a process of headward extension of ravine
View of V-shaped ravine. The subsoil is underlain of fine grained clays.
Alluvial knolls in the midst of ravines of the Mej river

View of the ravines of the Mej at Khatkar village, Bundi.
along the banks. Here in this study gully and ravine
cannote the following meanings: "A gully is a recently
extended drainage channel that transmit ephemeral flow,
has steep sides, and head scarp a width greater than
1 feet and depth greater than 2 feet" (Brice 1966). A
ravine is a channel of ephemeral flow, denuded and guided
essentially of rejuvenated streams, has steep sides and
head scarp, a width and depth always greater than a gully.

The definitions of other topographic forms which were
identified in the field are the following:

A gully initiating from the catchment area and a ravine
from the river meet at a zone which may here be termed
as a ravine-gully zone. Such features are not common.

The sides and heads of the ravines are steep and
abrupt in profiles, that are here called as alluvial scarps
(Plate 9). The inclination of the scarp ranges from 50°
to 90°, and the height ranges from a few metres to more
than 50 metres.

The scarps that forms the sides of a ravine along
its length are here called side scarps (Plate 10).

The triangular shaped deposits at the base of side and
head scarps of a ravine is termed as alluvial fans.

In the courses of ravines rounded knolls form a typical
features of the scenery and are here called as alluvial
knolls (Plate 11).

Small depressions along the creaks of soils on the
View of back flooding in the Chambal.

Swallow holes and tunnels in the ravines - a process of ravine approach.
flat ground, which are formed by the mutual action of meteoric water and soils, may be termed as *alluvial swallow holes* (Plate 12).

In order to have a better appraisal of the problem of formation and reclamation of the ravine from the agricultural point of view, it would be useful to classify ravines. In India, much attempts have been made to classify ravines by Tajwani and Ahuja (1956) in Madhya Pradesh, Gorries (1958) in Punjab and by the Forest Department of Rajasthan. Gorrie (1958) classified gullies into two broad classed as Chotanagpur or D.V.C. type and Siwalik type.

The Chambal ravines are of varying depth and thus for bringing them into productive use these ravines should be classified on the basis of their form, size, depth, width and head characteristics into three grades.

<table>
<thead>
<tr>
<th>Dimensions of ravines</th>
<th>Description of ravines</th>
<th>Symbol of ravines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth in metres</td>
<td>1</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Bed width metres</td>
<td>Upto 18</td>
<td>18 - 25</td>
</tr>
<tr>
<td>Slope of side scarp</td>
<td>45°-80°</td>
<td>50°-90°</td>
</tr>
<tr>
<td>Slope of head scarp</td>
<td>Gently</td>
<td>Varies</td>
</tr>
<tr>
<td></td>
<td>sloping</td>
<td></td>
</tr>
</tbody>
</table>

Note: G 1 type of ravine is gully according to above definition.
GEOMORPHIC AND HYDROLOGIC FACTORS OF RAVINE GENESIS

The integrated account of geomorphic and hydrologic factors which are pertinent to ravine genesis have been described in the previous chapters. At this instance, to avoid repetition only the essential features of these factors are given as the following:

Nature of the Chambal and its tributaries

Downstream from Kota city the Chambal enters into the Pleistocene surface and flows over 480 kilometres in the north eastern direction. In this course incised meanders led to the conclusion that before the recent upliftment, the river had attained mature condition and was meandering freely, over the wide flood plain formed by its own deposits. But the recent upliftment of the region gave new power to the stream to revert back in the cycle of erosion. So inspite of the previous open and broad valley the Chambal has again acquired renewed power for vertical erosion and as a result, meanders are now incising where they were at the time of upliftment. Furthermore, the exposition of the older alluvium, repeated clay layers in the bed rock profile (Fig. 7) and boulders in its course again suggest the rejuvenation of the river.

The above view is also supported by the fact that the depth of the Chambal from its alluvial plain increases considerably from Kota downstream to its confluence with the Yamuna. The river is 20 metres deep near Kota while
beyond Dholpur the depth increases to 40 - 50 metres. Similarly, the depth of ravines also increases in the same proportion. On the contrary, in the normal cycle of erosion the depth of the rivers decreases and devides widen as one proceeds downstream.

However, combining various features of the Chambal it may be concluded that the only process in the Valley development seems to be the deepening of the Chambal and other tributary valleys and ravines.

**Character of rainfall**

The climate of the Valley is sub-humid with low rainfall, hot summer, cold winter and large variation in rainfall and temperature from year to year.

As has been discussed earlier that in the Valley a large fraction of the total rainfall occurs during the monsoon period i.e. from June to September. Winter and summer seasons are generally dry, except some rain in winter. Due to the concentrated rain in the monsoon period the average intensity of rain is 2.18 centimetres (0.86") at Kota to 2.28 centimetres (0.90") at Dholpur. The intensity during summer and winter seasons is only 1.04 centimetres (0.45") at Kota and 1.06 centimetres (0.46") at Dholpur. Furthermore, because of the high intensity of rainfall during the wet season the Chambal like other peninsular rivers, discharges considerable volume of water, whereas
the flow in the dry seasons dwindles down to trickle.

Combining various features of rainfall it may be concluded that the torrential rainfall with such an intensity is mainly responsible for washing away the soil cover from the hill slopes and gives helping hand to the ravine formation.

Character of sediments

In order to understand the ravine genesis it is necessary to determine and correlate the characteristics and properties of the recent deposits in which the ravines are forming.

Broadly, soils of the Valley have been classified as clayey loams to clayey and sandy loams to loamy sands (Fig. 5). In the course of geomorphological study it was observed that loamy sands to sandy loams are comparatively more erodible than clay loams to loamy clays.

Generally the erodibility of soils is dependent on some inherent properties like dispersion ratio, ratio of colloid to moisture equivalent and erosion ratio. Mehta, et al (1958, 1963) have also classified soils of Kota and eastern Rajasthan as erodible and non-erodible considering erosion ratio, dispersion ratio, clay ratio and noncapillary porocity. He fixed the highest value of dispersion ratio for non-erosive soils as 20 and erosion ratio as 15%.

The analysis of soil profiles of the Valley as has already been referred to, suggest that in all the profiles
of sandy loams to loamy sands the erosion ratio is above 20%. So they may be classified comparatively more erosive than clayey to clay loams. It is substantiated by the field study that the ravines are most severe in the sandy loams and less in clayey loams to clayey soils.

RAVINE GENESIS

Two theories have been put forward on the genesis of ravine or badland topography in the tropical and the mid-latitude countries. Advocates of the first theory such as Bennett (1955) followed by Brice (1966) attribute gulling exclusively to land use or misuse, the chief cause amongst is overgrazing. Advocates of the second theory such as Bryan (1941), Antevs (1952) and Yi Fu Tuan (1966) consider that gullies are the result of climatic changes wherein degradation occurs in dry periods and aggradation in wet. Bryan (1941) concluded that a slight change in climate from dry towards the less dry is adequate to convert ephemeral streams from a condition of erosion to alluviation. Schumm (1956) has also discussed the formation of rills in badland formation, pointing out that they develop due to the channelling of water on steep slopes during rapid runoff.

The conclusions of the above authors do not go a long way to explain the excavation of 40 to 50 metres deep ravines. These neither can be produced by the unwise use of land nor by cyclic changes in the climate. The genesis of the ravines in such an extensive zone and on a gigantic
scale can be explained by another cause, i.e. the lowering of the local base level caused by the upliftment of the region. As has been mentioned earlier that the Chambal and its tributaries have been rejuvenated and due to this phenomenon they are engaged vigorously in the downcutting of their courses. Furthermore, it also becomes evident from the fluvio-geomorphic evidences that the ravines of the Lower Chambal Valley are essentially a type of mature dissection with a drainage pattern of fine texture or unusually high stream frequency and thus are process of the rejuvenated streams.

The above view is also supported by the fact that ravines are highly localized phenomena and are confined to the narrow and alongated belt along the Chambal and its tributary streams. It has been observed that similar type of dissected area is also found along the Yamuna neither upstream Mathura nor downstream Etawah. In this way the ravines of the Chambal and the Yamuna form an integrated and compact zone of ravines on the south western part of the Ganges basin which further brings to the conclusion that the cymatogenic upwarping of this Pleistocene surface seems to be localized and these ravines are the outcome of such phenomenon.

CAUSES OF UPLIFTMENT OF THE VALLEY

Another problem concerning the genesis of the ravine is that of ascertaining the various causes for the upliftment
of the Pleistocene surface of the Lower Chambal Valley.

It is very difficult to trace exact causes of the upheaval of a land-mass and therefore this aspect of structural geology is still controversial. In general, upliftment may be due to contraction of the earth's crust, thermal changes in the lower part of the crust, isostatic balance, or convection currents in the substratum.

As regards the Lower Chambal Valley, the author would like to suggest that since the area is fairly close to the Himalayas, the intermittent upheavals of the Himalayas particularly the post-Pliocene (Wadia 1952), have had a profound influence on the Pleistocene history of the region under study. Due to the tectonic movements in the Himalayan region the Valley experienced upheaval sometime in the middle Pleistocene and as a result the Chambal and its tributaries were rejuvenated. The symptoms of upheaval in the Valley are so clear that one is tempted to consider cymatogenic upwarp as the main cause of excessive ravine erosion.

The study of ravines in field and on maps has shown that the shapes, size, areal pattern and rate of encroachment are mostly related to soil characteristics and depth of soils. In the Valley where the soil is underlain by fine grained clays which are usually resistant to rapid erosion, ravines are essentially V-shaped (Plate 10). U-shaped ravines develop where the soil and sub-soil are commonly friable and easily cut by the flowing water. These ravines have steep sides and scarps. V-shaped ravines usually
develop less rapidly than the U-shaped ones but they frequently present an equally serious hazard.

AREAL PATTERN OF RAVINES

Frequency of the ravines per unit of area was worked out according to Strahler's method (1952, 58). The ravine frequency refers to the number of ravines per unit area of the Valley. As ravines are directly related to the Lower Chambal Valley and are found neither in the adjoining uplands of Kota or Bundi - Sawai Madhopur hills, except along the edges of the Chambal scarp. Thus, the frequency has been calculated only for the ravine infested areas of the Valley.

The ravine frequency map (Fig. 23) shows that the frequency varies from Kota to the Yamuna. In Kota area it is minimum and is from 1 - 5 per unit area. In Mangrol, along the Parbati, it is between 5 - 10 with an exception of some patches where it ranges from 10-15. From Kota downstream the frequency increases, thereby suggesting the advanced and critical development of ravines (Fig. 28).

The frequency worked out according to the classification of ravines shows the interesting areal pattern. The frequency of C I type of ravine in the area between Kota and Banas water, gap is maximum and downstream from the Banas the

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1 This map has been prepared on quarter inch toposheets and one unit represents 16 square miles of area.
frequency is minimum. On the contrary, the frequency of G 3 type increases downstream from the Banas water gap. Downstream Dholpur all ravines fall under G 3 type. The following data worked out district wise on the percentage basis and they give clear picture.

**Table VII**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G 1</td>
<td>25%</td>
<td>24%</td>
<td>14%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>G 2</td>
<td>39%</td>
<td>52%</td>
<td>27%</td>
<td>12%</td>
<td>2%</td>
</tr>
<tr>
<td>G 3</td>
<td>36%</td>
<td>24%</td>
<td>59%</td>
<td>85%</td>
<td>27%</td>
</tr>
</tbody>
</table>

It is evident from the above table that percentage of G 3 type of ravines increase as one proceeds downstream from Kota and vice versa. Two possible reasons may be suggested for this areal distribution of ravines.

1. When one cycle of erosion interrupts by the cymatogenic upwarp, the new cycle generally initiates first on the mouth of the rivers and proceeds slowly upstreams. In the case of the Chambal it may be concluded that after the termination of the Tertiary cycle, the Pleistocene cycle was initiated first in the lower reaches and now it is progressing upstream, thereby suggesting the mature and deep ravines in the lower parts and vice versa. Moreover, the rate of upliftment is directly proportionate to the intensity of ravine erosion that is to say that rate of upheaval is greater in the lower reaches of the Chambal.
Another possible reason can also be suggested that the ravines are mainly controlled by the depth of post-tertiary alluvium as well. The cross profiles of Chambal alluvium indicate that the depth of alluvium increases as one proceeds from Kota downstream. Due to this the rate of under-cutting of the Chambal is comparatively greater in the lower course than in the upper one, hence the ravines get deeper and deeper downstreams.

RATE OF ENCROACHMENT

In India the first attempt to determine the rate of ravine extension was made by Aitken (1956). At the present instance the rate has been assessed by comparing two sets of maps and by field measurements. The Survey of India Topo-sheets of 1922-23 have been superimposed on the aerial photographic maps of 1952-53. These two sets of maps indicate that ravines during the period of 30 years have engulfed nearly 122.00 hectares and 124 hectares of agricultural lands in Badoli village of Keshorai Patan tahsil and Barhi village of Shind tahsil respectively.

The two sets of maps also reveal unchanged positions of some of the portions of ravines near Berod on the bank of Kali-Sindh. Field verification has revealed that said position of ravines was due to the earthen bunds constructed along the periphery as early as 1921-22. The picture of ravines would have altogether been different had these bunds not been constructed.
A satisfactory approximation to the measured ravines enlargement was reached by another method, which is based on personal measurement of ravines and by farmer's interview. The results are given in the following table.

<table>
<thead>
<tr>
<th>Villages</th>
<th>Distance in metres</th>
<th>Approximate time of increase</th>
<th>Rate of encroachment in metres per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sagar pada village</td>
<td>15.24</td>
<td>50 years</td>
<td>0.530</td>
</tr>
<tr>
<td>2 Barhi village</td>
<td>12.19</td>
<td>30 years</td>
<td>0.371</td>
</tr>
<tr>
<td>3 Ater village</td>
<td>13.69</td>
<td>32 years</td>
<td>0.406</td>
</tr>
<tr>
<td>4 Pali village</td>
<td>8.55</td>
<td>20 years</td>
<td>0.406</td>
</tr>
<tr>
<td>5 Khatker village</td>
<td>12.19</td>
<td>40 years</td>
<td>0.3049</td>
</tr>
<tr>
<td>6 Kota village</td>
<td>4.81</td>
<td>15 years</td>
<td>0.3049</td>
</tr>
<tr>
<td>7 Mangrol village</td>
<td>9.75</td>
<td>40 years</td>
<td>0.2032</td>
</tr>
</tbody>
</table>

It would be clear from the above table that the average rate of a ravine extension in a year varies between 0.3048 metres to 0.406 metres, depending upon the local soil characteristics and the size of ravines. Combining various methods, the complicated nature of ravine extension is expressed as in equation:

\[ \text{Re} = \frac{\text{Di}}{\text{Te}} \]

where Re is rate of extension, Te is time of erosion and Di is distance increased.

The validity of the formula lies in the fact that the primary necessity in the ravine survey is to obtain
IDEAL STAGES OF RAVINE ENCROACHMENT

1. SWALLOW-HOLE STAGE

2. TUNNELLING STAGE

3. COLLAPSING STAGE

4. RECESSION STAGE

(BASED ON FIELD OBSERVATION)
data regarding the rate at which the additional land every year is coming under such condition. This equation will, however, give helping hand in measuring the rate of ravine encroachment not only in the Chambal area but also in the other parts of the country.

STAGES IN THE EVOLUTION OF RAVINES

The encroachment of ravines in the heavy clays follows a simple process which is characteristic of the Chambal and the Yamuna. Four stages of ravine extension have been recognized in the Lower Chambal Valley (Fig. 29). These are:

1. **Swallow hole stage**: In this initial stage parallel swallow holes form along the river on the flat ground by the mutual action of the meteoric water and soil particles (Plate 13).

2. **Tunnelling stage**: A further stage in the development is the deepening of swallow holes and formation of a tunnel from the swallow holes to the adjoining ravine. With the continuous corrosion of these tunnels they enlarge in size.

3. **Collapsing stage**: In this stage the roofs of tunnels collapse, thereby the ravine is shown on the surface.

4. **Recession stage**: The side and head scarps of the ravines recede
continuously. In the dry season side scarps widen and ravine bottom becomes shallower by the alluvial fans due to the action of soil creeps and gravity transfer of loose particles from the side and head scarps. Consequently with the continuous recession of side scarps alluvial knolls are disconnected or isolated and shattered into conical blocks. In this last stage maximum width of ravine bottom is attained. The same sequence of events repeat again and again.

**Head-ward erosion** is also responsible for the evolution of many of the deepest and widest ravines in the Lower Chambal Valley particularly where the sub-surface soil is soft and easily worn away. This phenomenon is also responsible for the branching of many ravines - the cutting out of tributaries, which have their beginning at Vulnerable points along the side scarps. The process of evolution of ravines by this phenomenon is very simple. Generally, a small vertical overfall beginning at the lower end of the eroding depression wears away the underlying material until the caves form in. Continuing by the same process the water-fall gradually carries the ravine upslope. As the point of overfall advances upslope, the height of side and head scarps increases usually since water cuts deeper and deeper, in its attempt to maintain a relatively flat grade of the bottom of the ravine channel. In this way the ravine starting at the banks of natural water courses often extends up the slopes, especially where the heavy
clays are underlain by sandy loams to loamy sands. In such areas ravines frequently attain depth of 15 to 20 metres or more. As they cut back they frequently cross lateral and oblique depressions or small waterways, thus favouring the development of tributary ravines. The process of branching may continue until a network of ravines dissects the entire area. The field study reveals that ravines formed by head-ward erosion and waterfall erosion may extend quite rapidly even through nearly level land. Their rate of extension often depends more on subsoil characteristics and the intensity of runoff than on the slope of the land. Since the cross sectional form of headward eroded ravines is U-shaped they may be commonly referred as U-shaped ravines, as has already been mentioned above.

The mudflow also gives a helping hand to the lateral encroachment of ravines in the agricultural land in a way that it supplies loose and unconsolidated material down slope, to be eroded off by the subsequent floods. It is common in the lower reaches around Bholpur, Barhi and Ater. In these parts during heavy rains, soil and loose rock particles are picked up and carried along by the runoff, usually in a deep trench and stream channel. Due to the clayey nature of soil the muddy flow is a pasty mass of fair viscosity and can transport boulders and boulders. During field study in the monsoon period it was observed that in the usual progress of such a flow the mass moves along until enough water has been lost by absorption or
evaporation for resistance to overcome the movement. The debris and kankers then temporarily dams the ravine channel in which it slopes until additional water accumulating behind furnishes the lubrication necessary for further movements. Thus by successive stages of flowage and damming, the mudflow moves down the ravine channel where it emerges from the ravine mouth, it spreads out and deposits its material in an alluvial fan consisting of a heterogeneous or poorly sorted mass of silt, sand, gravel and kankers.

EFFECTS OF RAVINE EROSION

The harmful effects of the ravine erosion in the Lower Chambal Valley goes far beyond the removal of the valuable top soil on which plants depend for their nourishment. One direct effect of course is gradual decline in crop yield which more than offsets any gains brought about by seed selection and manuring.

Due to the devastation of the ravine erosion million of hectares of the agricultural lands have gone out of cultivation. Although in India the magnitude of the ravine problem has not been correctly assessed so far, but it is estimated by the Planning Commission (1965) that about 3 million hectares of the agricultural land are affected by the ravine in the country and out of which 0.5 million hectares are found in the states of Madhya Pradesh, Rajasthan and Uttar Pradesh along the Chambal and its tributaries. In Rajasthan the total area under
THE LOWER CHAMBAR VALLEY

GEOMORPHOLOGICAL MAP

FIG. 30
ravine is estimated at 2.8 - 3.2 lakh hectares, out of which 4 lakh acres are found along the Chambal and its tributaries like the Kali-Sindh, Farbati and Banas.

In Madhya Pradesh the extent of the ravine area is mostly along the banks of the Chambal and its major tributaries. It was estimated by Subbaiya (1958) that 0.42 to 0.81 million hectares or 1 to 2 million acres of land must be under the deep gullies and ravines in Madhya Pradesh and out of this 2.43 lakh hectares or 6 lakh acres are in Morena and Bhind districts along the Chambal river.

It is estimated that about 1.23 lakh hectares of ravine areas are found in Uttar Pradesh out of this nearly 80,000 hectares are found along the Chambal river.

Thus the corresponding combined figures of the ravine along the Lower Chambal and its tributaries in three states are nearly 6 lakh hectares. Out of the total, 2.8 lakh hectares is in Rajasthan, 80,000 hectares in Uttar Pradesh and about 2.43 lakh hectares in Madhya Pradesh.

Consequently the aerial survey carried out for the purpose of the Chambal Valley Development Scheme in 1952-53, has also revealed that the area or ravines up to 4.6 to 6.1 metres (15-20 feet) depth is nearly 50,600 hectares in the Lower Chambal Valley. Besides, this, to assess the magnitude of the existing ravine problem, ravine survey has been taken by the State Forest Department,
Rajasthan and Agricultural Department of Uttar Pradesh and Madhya Pradesh. The details discussion about the ravine survey and reclamation will be given in the second part.

The forgoing analysis of physiography of the Lower Chambal Valley provides a basis for understanding the characteristics of agriculture and its related problems in the Lower Chambal Valley. A cogent account of geomorphological and hydrological features of the region would help in showing the relationship between landforms and agricultural development.

Soils of the Valley have been studied and classified into four major types (grey, brown, reddish and yellowish brown soils) on the basis of their textural characteristics, morphological features, occurrence of kanker layer and chemical properties. The analysis and distribution of various types of soils would help in studying the problems of water logging.

Various geomorphic processes including weathering, climate, and fluvial action have been discussed extensively because they have a bearing on the agricultural techniques and methods. Specially, fluvial morphology and climatic elements (as reflecting hydrological conditions in the various parts of the Lower Chambal Valley) were studied to show their influence on various crops, cultural practices and irrigation intensity.

Of all these, the nature of ravines was analysed
and they were classified not merely to understand their genesis, pattern and rate of encroachment towards the agricultural lands but to know how far agricultural efficiency, extent, cropping pattern and variation in the techniques of cultivation are one way or other controlled by the ravine formation. As the problem of the ravine erosion is the greatest menace for the agriculture in the Lower Chambal Valley, the quantitative analysis of ravine lands would help in solving the problem of soil erosion. The classification of the ravine lands into G 1, G 2, and G 3 types would further help in assessing their suitability for various methods of soil conservation.

Taking into consideration all aspects of physiography of the Valley in the proceeding chapters of the part two, land use pattern, agricultural methods and techniques, cropping pattern and regional analysis of agricultural pattern have been analysed.

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