Chapter 8

Evolution Of The Imphal Valley

Every valley shall be exalted, and every mountain and hill shall be made low: and the crooked shall be made straight and the rough places plain

Isaiah (40:4)
EVLUTION OF THE IMPHAL VALLEY

Imphal Valley which is also known as the Manipur Valley lies in the central part of the state extending approximately between 24°18'N to 25°00'N latitudes and 93°48'E to 94°07'E longitudes. This valley has a distinct geomorphic and/or geologic features, for it occurs within the surrounding hilly terrain of the region. It is approximately an oval (irregular rectangle/rhomb) shaped valley having a width of about 30-35Km (E-W) and a length of about 60-65Km (N-S). It has an area of about 2000 Km² and forms nearly 10% of the total area of the state. The valley is encircled by hills on all sides although, narrow inlet and outlet of the Imphal river occur respectively on the northern and southern sides. It has a small fresh water lake called, the Loktak Lake, in the southern part of the valley. The lake has an average elevation of about 765m above the sea-level. A few small hillocks do occur within the lake in the form of isles - these are Thanga, Karang and Ithing hills. On the south-eastern side of this lake, Keibul Lamjao National Park and Wild Life Sanctuary, the only floating park of the country occurs. In this park a rare, rather endangered species of deer, the brow-antlered deer (Cervus eldi eldi) is found which is facing extinction. Brief physiographic descriptions of the valley have already been outlined in chapter 1.

Till date, no precise theory on the evolution of the valley has been provided although, various views and ideas on its origin exist. It is, therefore, attempted here to provide a concise account about the evolution of the valley in this chapter.

8.1 GEOLOGICAL SETTING

Imphal Valley is virtually a flat land filled with alluviums of fluvio-lacustrine origin. It occurs as an intramontane basin in the IMR of Northeast India. It has an elevation of about 780m above the sea-level although, there is a low gradient towards
Fig. 8.1. Geological and structural map of the Imphal Valley and its adjoining region. A-B, C-D-X-Y are profile lines of figures 8.2 and 8.5.
south. The alluviums are mainly composed of clay, silt and sand, and their basement is more or less exclusively made up of Disang shales. A number of isolated, small to considerably large, hillocks do occur within the valley protruding above the flat alluviums somewhat like monadnocks/inselbergs. Imphal river and its tributaries - Irl, Thoubal and Khuga rivers constitutes the main drainage system of the valley. But none of these rivers falls into the Loktak Lake which occurs on the south-eastern side forming the lower altitude of the valley. It possibly reflects some typical, possibly tectonic origin of the lake as well as that of the valley itself.

The valley is bounded by a prominent thrust fault, known as the Thoubal Thrust, on the eastern side and the western side is also marked by another important thrust known as the Churachandpur-Mao Thrust which partly serves as the tectonic contact between the Disangs and Barails (Figs. 8.1 and 8.2). All the lithounits and structural elements in the valley, conform to the regional NNE-SSW strike. Figures 8.1 and 8.2 provide geological and structural information about the valley and its adjoining region. The principal lithounits present in the valley, as mentioned earlier, are Disangs, Barails and Alluviums. Descriptions of Disangs and Barails have already been given in chapter 2. Description of Alluviums although, briefly provided in chapter 2, some of the important features are iterated here.

Alluviums, covering the widest areal extent of the valley, are mainly dark grey to black carbonaceous clay, silt and sand of fluvio-lacustrine origin. Of these, clay and mixture of clay and silt are the predominant sediments while silt and sand, forming lensoids and bands within the clay, are quite subordinate. These sediments also constitute the central as well as major portions of the valley. The alluviums have highly variable thickness from place to place. Drilling data indicate a thickness of more than 200m at places with a possible (or ? more) average thickness of 150-200m. Majority of the drillholes in the central part of the valley indicates clay and silt upto 150m from the ground surface (CGBW, 1977). Till date no drilling upto the bedrocks has been carried out and so, the actual depth is not known. But, near the foothills the thickness may be 50m or even less in the average. In the peripheral piedmont regions, sandy, pebbly and bouldery deposits are common and usually well developed along the western margin of the valley.
Fig. 8.2. Geological profiles across the Imphal Valley. A. Transverse profile, C-D across the valley (WNW-ESE) showing the subsurface structural configuration.
B. Longitudinal profile, X-Y along the valley (NNE-SSW) parallel to the tectonic trend showing the inferred faults that may characterised the rocks of the valley. The drop in elevation is employed to compute the extension or stretching and subsidence of the valley (inner X-Y).
Some of these deposits are reworked by the streams or rivers themselves which probably suggest an older age although, assignment of a definite figure is practically difficult. The thickness of these reworked alluviums is also highly variable having 30m or more at some places (Motbung) and very thin at others. Detailed stratigraphic and other geologic investigations of these alluviums are still yet to carry out to its fullest extent.

8.1.1 Some Salient Features of the Imphal Valley

There are some topographic as well as geologic features which are typical and characteristic in nature. All these features may have a direct or indirect relationship with the evolution of the valley and hence, they are outlined below.

1. It is an elongated irregular rectangular or rhomb (oval) shaped valley (see Fig. 1.3) nearly 60-65 Km (N-S) long and 30-35 Km (E-W) wide.

2. It is practically a flat valley having an average elevation of about 780m above the mean sea-level although, on the southern part, it is about 765m from the sea-level.

3. The valley is surrounded by hills on all sides. The average elevation of the valley (780m) is nearly 750-780m below the surrounding hills (see Figs. 8.2).

4. It has a small lake on the southern side (Loktak Lake) within which hillocks do occur in the form of isles.

5. Imphal river is the main draining channel of the valley. The river and almost all of its major tributaries - Iriel, Thoubal, Khuga have a nearly N-S trending courses. None of them falls into the lake but, artificially connected.

6. Streams and/or rivers sometimes pass through the small hillocks occurring within the valley in the N-S or E-W directions showing an intimate relationship and structural control of these streams.
7. The hillocks within the valley though, sometimes widely separated have some strike continuity and show structural control. Close to the foothills of these hillocks, specially on the northern and southern sides, marshy and swampy lands do occur frequently.

8. The hillocks within the valley show an average elevation of about 900m above the sea-level although, minor variation occurs. This suggests that they were once at a more or less equal elevation.

9. The valley is bounded by two large and prominent structural and tectonic lineaments. The one on the eastern side is the Thoubal Thrust while the other, on the western side, is known as the Churachandpur-Mao Thrust fault. This western tectonic lineament serves as a structural contact between the Disangs and Barails at places and runs nearly parallel to the western periphery of the valley.

10. Almost all the hillocks within the valley are chiefly composed of Disangs. They usually have thin to very thick bands/lensoids of silt and sand. Some outcrops of the Barails occur as capping in the form of outliers mainly on the eastern part of the valley having certain strike continuity.

8.2 PREVIOUS ACCOUNTS OF THE VALLEY

Probably Major Godwin-Austen was the first worker who ventured to give a brief idea about the origin of the valley. In his published (1874) account of official report on the Topographic Surveys for 1872-73 and “Evidence of Past Glacial Action in the Naga Hills” (1875), he opined that the valley was an old lake basin gradually filled up by silting. Oldham (1883) differed from that of Major Godwin-Austen where he preferred a fluvial (rivial) filling of the valley. Oldham remarked, “It is impossible that, during the ages necessary for the gradual filling up of so large a lake, no terraces should have been formed by the inevitable cutting down of the outlet; but as has been mentioned no such terraces are to be seen, and consequently I am obliged to reject a lacustrine origin, for at least the upper beds of the Manipur Alluvium”. Later Pascoe (1965) gave the idea
concurring in between the two workers that it could have been formed as a filled lake although, there were no reasons for supposing such an idea of the valley, being occupied by deep water. Godwin-Austen (1874), however, gave a very important information about the earthquake of January 10, 1869. He wrote that "But the extent of this lake (Loktak Lake) has been, I fancy, altered by earthquakes; even that of 1869 (January 10th) produced in a short time great changes, and fishermen say it has never recovered its former state. The water then retired off a large area, showing the fish at the bottom, and returning swept immense numbers up high and dry. Such earthquakes, and no doubt many worse, have occurred at longer or shorter periods of past time over this area, and would as often tend to increase a lake of this sort as to drain it. In fact, the original formation of this mountain valley, 2,500 feet above the sea, may be due to a present tendency to depression".

The above account although, a single case, is sufficient to indicate the stretching mechanism of the rocks of the valley as contended in this work. Because, the lake water rushed into the gaps or spaces created by extension thereby reducing the surface area of the lake, and as he (Godwin-Austen) had rightly pointed out such a phenomenon had been taking place steadily in the recent geological past.

Godwin-Austen (1875), however, again indicated possibility of glacial activity in the northern part of the valley (Motbung, Keithelmanbi areas) after seeing the angular and bouldery deposits mingled with considerable fine materials found in the area. So, none of the previous workers indicated a clear model on the evolution of the valley even if, they all implied erosion as the basis of its formation. Since then, the same idea continued to influence all the workers of the Geological Survey of India. So, no further work has been envisaged to account for its origin though, diverse opinions still exist without any written or published data. Chakraborty et al (1987), however, indicated a possible structural control of the Imphal valley.
8.3 TECTONIC EVOLUTION OF THE MANIPUR (IMPHAL) VALLEY

Evolution and development of the Indo-Myanmar Range in the form of an accretionary prism has already been discussed in the last chapter. Its evolution has, therefore, a close relationship with the formation and evolution of the valley also. It has been mentioned that towards the end of Oligocene and during Miocene times, convergence between the Indian and Myanmar plates took place. It gradually gave rise to the development of the hills of Manipur state and that of the IMR as an accretionary prism. It is even believed that the accretion is still going on although, not as strong as the Mio-Pliocene culmination.

During this process of accretion and particularly towards the later phase, as an epeirogenic phenomenon, the Imphal Valley was evolved in the form of a small pull-apart basin or transtensional basin. Such an evolutionary model is exemplified by figures 8.3 and 8.4. However, prior to the formation and subsidence of the valley as a transtensional basin, whether this was initiated as an accretionary basin (Fig. 8.5) or not, is not clearly known. Although, there are no conclusive evidences, the evolution was a gradual crustal stretching process and probably initially started towards the end of Pliocene or Early Pleistocene times. Because, it does not contain any sediments similar to that of the Tipam Group which indicates that during its evolution, this part of the IMR was more or less completely sub-aerial. Since then erosion and denudation are carrying on with landscaping of the valley.

8.3.1 Imphal Valley - A Transtensional Basin

In chapter 3 and 4, it was mentioned that the hills of Manipur state evolved as an accretionary prism as a function of NE-SW dextral shearing between the Indian and Myanmar plates. This shear coupling produces NNE-SSW extension and WNW-ESE compression in the region (see Fig. 3.9). The shearing process was further enhanced by the NNE motion of Indian plate relative to Eurasia plate. The process was also further assisted by the easterly motion of the Shillong-Mikir Massif (Shillong plate of Curray et al, 1978) producing a zone of transpression as well as transtension in this part of the IMR.
The rocks of Nagaland state, lying between the Shillong-Mikir Massif and the Naga Metamorphics, virtually suffered transpression giving rise to the *belt of schuppen* of Evans (1964). On the other hand, the region lying on the south-eastern side of the massif and the Dauki fault strike suffered transtension in the microtectonics of the region. As a result, the region lying on the south-eastern side of Dauki fault suffered some sort of extrusion tectonics. This extrusion process, helped by shear coupling discussed in chapter 3 and 4, evolved the Imphal Valley as *Transtensional Basin*. This is the reason why the northern side of the valley or basin roughly coincides with the strike of the Dauki fault. The extension of the region was mainly suffered by the Disang shales due to its low competency. This is also another reason why the western periphery of the valley runs nearly parallel to the lithoboundary between the Disangs and Barails. A detailed discussion on basin formation in strike-slip fault zones of similar types can also be referred to Allen and Allen (1990). A strikingly similar example of detached pull-apart or transtensional basin in regions of lithospheric compression has been studied by Royden (1985) taking the Vienna Basin as the case study example.

Let us now work out the transtensional model applicable to the Imphal Valley briefly. In order to do so, a number of assumptions are to be made based on the theoretical background of these types of basin models as well as based on the field observations. These are given as follows.

1. The working principle of the model is based on the principle of balanced cross-section under plane strain condition as discussed by Dahlstrom (1969) and Hossack (1979). Its application employs the above principle as worked out and applied in extension tectonics by Gibbs (1983). Such a model, simplified and applicable in the case of the Imphal Valley is shown in figure 8.3A and B.
2. The model is a thin-skinned basin confining well within the sedimentary cover of the IMR only. The maximum possible depth at which the extension can detach is the top surface of the Indian plate. So, practically it is a cold basin without any thermal anomaly beneath the basin.
3. Since the model is a thin-skinned cold basin, heat flow through the basin should be equivalent roughly to that of the Disang-Barail Flysch Belt.
Fig. 8.3. Diagrams showing area balancing for extension tectonics in concurrence with the principle of balanced section under plane strain. A. ABCD is an initially uplifted block which is stretched and subsided to DEFG (see also Fig. 7.8B). B. Application of the principle of area balancing in extension or stretching of the Imphal Valley causing the subsidence. C. Graphic plots showing the relationship between relative thinning (1-1/β) and subsidence of the Imphal Valley (see text for details).
4. Since the stretching model does not affect the crustal layer(s), there should be no post stretching or extension thermal subsidence. And the subsidence is permanent that is, it will not be able to regain its original elevation.

5. Shearing and slipping take place along the pre-existing structural and tectonic weak planes/zones. The one on the eastern side is the Thoubal Thrust while the other on the western side is the Churachandpur-Mao Thrust. So, excessive crustal stretching of the rocks should practically be confined within the two structural limits. That is, the rocks outside the valley should suffer only the normal tectonic elongation.

Figure 8.3A is a simple example of balanced section where opposite concept to figure 7.8B is considered. That is, ABCD is initially an uplifted block corresponding to the original elevation of the Imphal Valley. Now the block is stretched and in the process the area is subsided by $AE = BH = S_i$. Then it has given rise to the position of DEFG so that $ABCD = DEFG$. From the figure it is further evident that

area of $ABHE = \text{area of} \ HFGC = X$.

Now recalling equations (7.4) and (7.5) and rewriting them in order to apply in extension or stretching phenomenon as well as from the figure it is evidently observed that

$$L_o = L_f - \frac{X}{d} \quad (8.1)$$

$$L_o = \frac{L_f d}{d_i} \quad (8.2)$$

$$\beta = \frac{L_f}{L_o} \quad (8.3)$$

From the above three equations, it is clearly observed that if we have the area $(X)$, then by knowing either the stretching factor $(\beta)$ or the depth to detachment surface $(d_i)$ the value of extension $(\epsilon)$ can be easily evaluated. Now, this simple principle shall be applied to the study of evolution of the valley.

Figure 8.3B is a simplified diagram depicting the longitudinal profile of the Imphal Valley compatible with figure 8.3A. $A$ is the area loss due to subsidence $(S_i)$ resulted from the NNE-SSW extension. If $L_f$ is the final length, $L_o$, the original length, $\epsilon$, 

245
Fig. 8.4. Evolutionary model of the Imphal Valley resulted from the dextral simple shear couple and slipping along the pre-existing thrust planes. The subsided part is characterised by a number of extensional faults. The flat-lying nature is due to in-filled alluviums (also compare with Fig. 3.9A).
the extension and $d$, the depth to detachment surface (or decollement), then by the principle of area balancing mentioned above (see also Barr, 1987), we get

$$e \times d = L_f \times S_i = A$$  \hspace{1cm} (8.4)$$

Now putting $\beta \times L_o$ for $L_f$ (see equation 8.3 above) and $L_o(\beta-1)$ for $e$ and rearranging the equation, we obtain

$$S_i = d \left(1 - \frac{1}{\beta} \right)$$  \hspace{1cm} (8.5)$$

Equation (8.5) is very important having analogous expression to initial subsidence (equation, 8.6) of crustal stretching given by McKenzie (1978). Now employing this principle and using the stretching factor ($\beta=1.25$, the minimum value) calculated in the last chapter we can find out the subsidence and other evolutionary stages of the Imphal Valley. In order to do so, the following procedures are followed.

A topographic profile of the valley is drawn along the tectonic strike i.e. NNE-SSW direction (see Fig. 8.1) and presented in figure 8.2B. Survey of India toposheet on 1:250,000 scale is used for accuracy as in the case of shortening estimation. Then, in order to find out the area ($A$), the initial elevation of the valley is assumed to be 1550m above the sea-level. The logic of assuming 1550m as the initial elevation of the valley is that the Koupnu-Laimaton-Thangjing Range immediately on the western side of the valley is the highest range of the state consisting of a number of peaks 2000m and above. This range, therefore, has an average elevation of 1700m above the sea-level approximately. On the other hand, the range on the eastern side of the valley has an average elevation of about 1400m above the sea-level. Since all the hill ranges of Manipur gradually decrease towards east and west of this Koupnu-Laimaton-Thangjing Range (see Fig. 7.9), the average of this one (1700m) and that of the eastern range (1400m) has been taken as the possible initial elevation of the valley. The assumption of this elevation figure, 1550m, is further strengthened by the altitude of the Nongmaiching peak (1583m, Fig. 8.1) that lies in the central eastern part of the valley - which seems to be little subsided by the extension or stretching. The present elevation of the Imphal Valley, 780m above the sea-level is taken as subsidence as a first instant. Now, the area between this initial elevation of the valley and the topographic curve (Fig. 8.2B) is graphically estimated. From the above the following data have been evaluated.
Area ($A$) between the topographic curve and the datum, $XY = 53.81Km^2$.

Subsidence ($S_i$) assumed initially = (1550-780) m = 770 m.

Final length ($L_f$) = 77.5 Km.

Initial subsidence ($S_i$) due to crustal stretching is given by McKenzie (op.cit.). The same equation has been slightly modified by Pichon and Sibuet (1981) (see also Allen and Allen, 1990) and represented as follows

$$S_i = \frac{T_L \left[ \left( \rho_m - \rho_c \right) \frac{T_C}{T_L} \left( 1 - \alpha \frac{t_m}{2} \frac{T_C}{T_L} \right) - \frac{\alpha}{2} \frac{t_m}{2} \rho_m \right]}{\rho_m (1 - \alpha t_m) - \rho_s} \left( 1 - \frac{1}{\beta} \right)$$

(8.6)

where $T_L$ is the thickness of the lithosphere

$T_C$ is the thickness of the crust

$\rho_m = \rho_c$ is the density of the mantle (lithosphere)

$\rho_c$ is the density of the crust

$\rho_s$ is the bulk density of the sediment or water filling the basin

$\alpha$ is the thermal expansion coefficient of both crust and mantle

$t_m$ is the temperature of the asthenosphere

The above equation can be simply written as

$$S_i = c \left( 1 - \frac{1}{\beta} \right) \text{ where } c = \frac{T_L \left[ \left( \rho_m - \rho_c \right) \frac{T_C}{T_L} \left( 1 - \alpha \frac{t_m}{2} \frac{T_C}{T_L} \right) - \frac{\alpha}{2} \frac{t_m}{2} \rho_m \right]}{\rho_m (1 - \alpha t_m) - \rho_s}$$

is a constant. This equation is exactly comparable to equation (8.5) above where $c = d$. The factor, $c$ which is a constant has values ranging from 3.1 to 3.6 for a water-filled basin with an average value of 3.3 (see Barr, op.cit.). It is true because, the parameters involved in the above equation (8.6) may not have wide variation from one part of the earth to the other although, minor differences may occur. In order to compute the subsidence ($S_i$) of the Imphal Valley, the above equation (8.6) may not be exactly applicable since it was already assumed to be a thin-skinned crustal stretching model of deformation where the crust and lithosphere are not involved. However, to have an approximate estimate for the IMR of Northeast India, as well as to check the applicability, we can make the following calculations.
For Northeast India, there is no precisely evaluated values of the parameters or factors involved in the equation (8.6). But using some of the values as mentioned by Mukhopadhyay and Dasgupta (1988) and some from Parsons and Sclater (1977), that is, 
\[ T_L = 80\text{Km}, \quad T_C = 20\text{Km}, \quad \rho_m = 3400\text{Kgm}^{-3}, \quad \rho_c = 2900\text{Kgm}^{-3}, \quad \rho_s = 1000\text{Kgm}^{-3}, \quad \alpha = 3.28 \times 10^{-5}\text{K}^{-1}\text{C}, \quad t_m = 1333\ \text{°C}, \]  
we get
\[ S_i = 1.97 \left(1 - \frac{1}{\beta}\right), \]  
which is relatively smaller than the average value of\( c = 3.3 \).

When we consider the average of crust density, \( \rho_c = 2900\text{Kgm}^{-3} \) and that of the sediments lying above the crust, \( \rho_s = 2400\text{Kgm}^{-3} \), i.e. \( \rho_c = 2650\text{Kgm}^{-3} \), we have
\[ S_i = 3.97 \left(1 - \frac{1}{\beta}\right). \]

The two values of \( c \), 1.97 and 3.97 are highly variable and so, in absence of precisely evaluated values of the parameters of equation (8.6), it will be better not to employ them in computing the initial subsidence of the Imphal Valley. Moreover, as pointed out above, applicability of (8.6) may be questionable since crustal stretching of the valley doesn’t involve the lithosphere. So, initial subsidence may be computed from equation (8.5).

Precise depth to detachment plane or surface, \( d \) is practically ascertained from seismic profiles or from accurately determined stretching factor, \( \beta \) (see Barr, op.cit.). For the present study area, there is no seismic profile(s), nor exact depth to the valley basement below the sediments. As well the stretching factor, \( \beta \) determined earlier (chapter 7) is also in the form of a range reflecting discontinuous and pulsatic stretching. So, we shall try to evaluate the value of \( d \), so as to make comparable to the average value of \( c = 3.3 \) (or within the range of 3.1-3.6) on a trial and error basis as a first approximation. Now considering the value of \( \beta = 1.25 \), the minimum possible initial stretching factor of the valley, we can calculate from equation (8.3) that
\[ L_o = \frac{L_f}{\beta} = \frac{77.5}{1.25} = 62.00\text{Km}, \]
\[ \therefore e = L_f - L_o = 77.5 - 62.00 = 15.5\text{Km}. \]

That is, assuming the area between \((X\text{-}Y)\) in figure 8.2B has suffered a minimum extension \((e)\) of 15.5Km, we get from equation (8.4)
\[ e \times d = A \]
i.e. \( d = \frac{53.81}{15.5} = 3.47 \pm 0.076 \text{Km} \).

Substituting this value in equation (8.5), we have

\[
S_i = 3.47 \left(1 - \frac{1}{\beta}\right)
\]  

(8.7)

The value of \( d = 3.47 \), is close to the average value 3.3 and well within the range 3.1 to 3.6. Thus, as a first approximation, it can be used for further computations. By calculation, however, there could be an error of about 0.076 Km i.e. 76m. Because, when the area, \( A = 53.81 \text{Km}^2 \) is divided by the final length, \( L_f = 77.5 \text{Km} \), an initial subsidence of 694m is obtained from the original assumed elevation of 1550m above sea-level (see Figs. 8.3B, C). But the present elevation of the Valley is 770m below the original elevation (1550m) and 780m above the present sea-level. Hence, there is a difference of (770-694)m = 76m, which is the possible error mentioned above.

Depth to detachment surface \( (d) \), can be accurately determined from seismic profiles or drilling data (Barr, op.cit.). Similarly precise value of \( \beta \) can also be evaluated from seismic profiles by comparing the original thickness with the stretched or extended thickness of the crust. Determination of \( \beta \) may be erroneous because, faults often tend to be listric at depth or otherwise quite often, high angle normal faults tend to become gentle dip at deeper parts of the crust (McKenzie, op.cit.). So, in the absence of any reliably estimated value of \( \beta \) of the valley, the figure (3.47) of \( d \) obtained above can be employed for further analysis.

Equation (8.7) given above is analogous with equation (8.6) and the expression for \( S_i \) is linear in \( (1-1/\beta) \) similar to the equation of a straight line, \( y = mx \). Therefore, a graph can be plotted as shown in figure 8.3C. From the solid straight line, generated by \( S_i = 3.47(1-1/\beta) \), it is observed that for initial stretching factor, \( \beta = 1.25 \), a subsidence \( (S_i) \approx 700 \text{m} \) is obtained. This figure gives a difference of about 70m (or 76m as given by mathematical calculation) with respect to the present elevation of the Imphal Valley which is taken as 780m above the sea-level. That is, a thinning factor \( (1-1/\beta) \) of about 0.225 which gives rise to a stretching factor, \( \beta \) of 1.29 is required in order to get the present elevation of the valley. Now considering the stretching factor, \( \beta = 1.77 \) which is thought to be the possible maximum value based on the estimation from field
observations, we can have a subsidence of 1500m from the original elevation of 1550m above the sea-level (Fig. 8.3C). It further implies that the basin (Imphal Valley) may contain a column of sediments of about 730m provided the stretching factor (i.e. $\beta = 1.77$) is correct. That means considering the average thickness of the Imphal Valley as 150-200m (as per the drilling data mentioned in section 8.1 above), the valley may contain an alluvium column between 150-730m. The maximum thickness of sediments that the valley can contain is $(3470-770)m = 2700m$ with a possible error of $\pm 76m$ when the stretching factor, $\beta \to \infty$ (i.e. stretching is infinitely large) provided the basin didn’t suffer any post-stretching sediment-load induced subsidence nor it was a pre-existing accretionary basin (Fig. 8.5). On the other hand, if we assume $\beta = 1.77$ as the initial stretching factor, then another straight line (dashed line, Fig. 8.3C) can also be drawn for $S_i = 1.6(1-1/\beta)$. The present elevation of the valley can be deduced for a stretching factor, $\beta = 1.90$ with a corresponding thinning factor $(1-1/\beta) = 0.475$. And the maximum thickness of sediments that the basin can contain for $\beta \to \infty$ is 830m which seems to be quite impractical. Because, the above assumption implies that the possible depth to detachment surface of stretching lies somewhere around the present sea-level which is quite contradictory to the depth to detachment or decollement roughly estimated from the crustal shortening discussed above which works out to be around 1.5 to 2.0Km below the present sea-level (see also Chapter 9).

8.4 THE TRANSTENSIONAL MODEL AND ITS IMPLICATIONS

The transtensional model discussed above and to be the evolutionary model of the Imphal Valley represented by figure 8.4 may be tested and confirmed only when precise subsurface data such as seismic profiles, drilling log, stretching factor and/or depth to detachment surface are known. Otherwise, the inferences made above i.e. possible thickness of sediments may be treated simply as a tentative value. Moreover, there is also possibility of larger thickness of sediments in the valley as a function of sediment-load induced subsidence. Such subsidence is sometimes quite substantial specially when the sediment is deposited over a thin crust resting upon the weak mantle. A detailed account about the sediment-load induced subsidence of basin has been discussed by Watts and
Fig. 8.5. A. Diagrams showing the probable compatibility between the Imphal Valley (IV) and accretionary basin of the IMR accretion prism. B. Geological profile (A-B) across the valley displaying similar condition of an accretionary basin.
Ryan (1976), Steckler and Watts (1978), etc. Watts and Ryan (op.cit.) provide the subsidence (S) caused by sediment-load as follows:

\[ S = h \left[ \frac{\rho_s - \rho_w}{\rho_m - \rho_s} \right] \]  

(8.8)

where \( h \) is the depth of water column available for sedimentation, \( \rho_s, \rho_w \), and \( \rho_m \) are mean relative densities of sediment, water and mantle respectively. In the same manner Steckler and Watts (op.cit.) give an equation expressing the relationship between the depth to basin basement corrected for sediment-load (Y) and thickness of backstripped or decompacted sediments (L). It is represented as follows (see also Allen and Allen, 1990),

\[ Y = L \left[ \frac{\rho_m - \rho_s}{\rho_m - \rho_w} \right] + W_d - \delta_{SL} \left[ \frac{\rho_m}{\rho_m - \rho_w} \right] \]  

(8.9)

where \( W_d \) is the depth of water column overlying the sediments, \( \delta_{SL} \) is the quantity of sea-level changes and other parameters are the same as in equation (8.8). The above equation can be reduced to

\[ Y = L \left[ \frac{\rho_m - \rho_s}{\rho_m - \rho_w} \right] \]  

(8.10)

since \( W_d = 0 \) and also \( \delta_{SL} = 0 \) if applicable in case of the Imphal Valley. And in both the equations (8.8) and (8.10) \( \rho_m \), the mean relative density of the mantle can be replaced by \( \rho_c \), the mean relative density of the crust. Because, we assumed that the model adopted here is a thin-skinned one and so, the sediments of the valley practically will rest upon a thick crustal layer. From this it appears that the sediment-load induced subsidence may be relatively small since the numerator is smaller than the denominator. Even then it may be necessary to know the accurate thickness of the sediments of the valley in order to compute the sediment-load induced subsidence. At present we do not have any precisely determined thickness value of the sediments of the valley nor drilling data. So, whether there could be an element of sediment-load induced subsidence, in addition to the initial subsidence associated with tectonic stretching, cannot be confirmed.

Another important aspect that can be pointed out in this context, whether the valley initiated as an accretionary basin in the earlier evolutionary stage of the IMR, is a matter still required to be examined. Such a conceptual model is exemplified by figure 8.5. Association of accretionary basin in the evolution of accretionary prism of
subducting plate margins is a common feature (see Allen and Allen, op.cit.; Green, 1977; Toksoz and Bird, 1977; Dickinson and Seely, 1979). The physical environment of the Imphal Valley is also quite comparable to that of an accretionary basin. But its investigation and evidences can be ascertained only after separation and isolation of the two subsidence mentioned above. That is to say that, the depth to basement of the basin, if greater than the depth produced by both tectonic and sediment-load induced subsidence together, then the excess depth may account for accretionary basin or any other mechanism that preceded the tectonic stretching and subsidence. From all the discussions made above, it can be clearly inferred that testing and confirmation of the model proposed and adopted here, and the subsidence history of the Imphal Basin may be correctly deciphered only when there is adequate subsurface data.

Whatever may be the mechanism or combination of mechanisms of the formation and evolution of the Imphal Basin (Valley), the topographic features of the valley and its surroundings, the deformation and evolutionary mechanism of this sector of the IMR, the stretching or extension suffered by the rocks of the valley, all directly or indirectly indicate that the valley evolved through a tectonic process not far in the geological past. Such a simplified transtensional model produced as a result of the dextral simple shearing is shown by figure 8.4. The valley itself appears as a flat alluvium plain due to gradual filling of the basin. It may be quite uneven at depth since the valley is composed of a number of tilted fault blocks (Fig. 8.2B). Even the thickness of the sediments (alluviums) may be highly uneven, if there are grabens and half-grabens resulted from the tilted blocks. So, at some places e.g. the half-grabens, the sediments may be quite thick due to tilting and subsidence of the hanging wall blocks, while on the foot wall sides, the sediments may be relatively thin. Occurrence of lakes, swamps and marshy lands, very close vicinity to the foots of the small hillocks within the valley, is basically due to such a phenomenon. Because, maximum depth of water occurs just adjacent to the uplifted foot wall blocks (hillocks) and due to the deeper nature, they cannot be easily and quickly filled up by sediments. Even, the Loktak Lake is also a similar example developed in the grabens and half-grabens, that’s why the Thanga, Ithing, Karang hills remain as isles surrounded by the lake water.
Another exciting feature of the Imphal Valley is its environs that the valley is nearly 780m above the sea-level and 770m below the surrounding hill ranges giving rise to a typical nature of depression. The volume of rock materials that has been lost due to such a depression is found to be $1386 \times 10^9 \text{m}^3$ taking average width and length of the valley as 30Km and 60Km respectively and 770m as its depth. Such a huge volume of earth material cannot be selectively removed by any erosional process of nature e.g. fluvial action, glacial action or any other without much disturbing the surrounding hill ranges. So, the earlier views, on the origin of the valley, as erosional one is likely improbable. Loss of such a huge volume of earth material or landmass can be satisfactorily explained by tectonic process rather than any other mechanism. Some of the structural complicacy were, however, noticed to Oldham (1883) that streams sometimes pass through the hillocks occurring within the valley. He explained that these were the result of rising level of the river or stream bed due to gradual filling of the valley. But, he did not examine, why the streams passing through the hillocks do exist. That is probably the reason, why they didn’t attempt to correlate the origin of the valley with any structural and/or tectonic phenomenon. Or otherwise, the knowledge of structural and topographic relationship was very incomplete in those days.

One of the most thought-provoking concept, on the origin and evolution of the Imphal Valley, is the old and mythological belief which is still persisting in the society. *That the valley was a lake filled with water, drained by the Lord Shiva using his trishul (trispear) who wanted to play Ras Lila with his beloved wife, Parvati in this remote and secluded part of the world.* Even the idea of Godwin-Austen (1874) that the valley was an old lake basin gradually filled and dried up by silting, might have been influenced by this mythological belief. Whatever, may be the implications of the past thoughts, one common thing is that an old basin was existing since time immemorial although, its formation and evolution mechanism was not clearly known.

The present study, the topographic features of the valley and its surroundings, the tectonic setup and emerging knowledge in the field of basin formation, all indicate a tectonic evolution of this valley as a small pull-apart or transtensional basin in conjunction with the shear couple deformation mechanism of the region. Such a
deformation mechanism as outlined in chapter 3 and 4 produced a NNE-SSW extension and WNW-ESE compression. This NNE-SSW extension was enhanced by the NNE plate motion of India with respect to the Eurasian plate in causing the slipping along the pre-existing weak thrust planes. As already pointed out earlier, this part of the IMR of Northeast India where the valley presently occurs might have suffered transtensional pull due to the high transpression of the IMR in the Nagaland sector lying between the Shillong-Mikir Massif and the Naga Metamorphic Complex. So, the region lying on the southern side of the Dauki fault strike, which is also the southern limit of the massif occurring around 25°N latitude undergoes extrusion tectonics. This extrusion phenomenon in association with the simple shear deformation mechanism discussed in chapter 3 evolved the Imphal Valley as a dextral i.e. right lateral strike-slip basin along the pre-existing weak thrust zones as an epeirogenic phenomenon towards the later phase of the IMR tectogenesis. Shearing and extension readily occurred in the shales due to their incompetency thereby forming the valley well within the Disangs. These are the reasons why the valley develops immediately on the southern side of the Dauki fault strike and the western periphery of the valley nearly coincides with the Disang-Barail lithoboundary. Farther south, beyond the valley, the usual tectonic elongation is accommodated by extension fractures only and so, no other valley or basin, like the Imphal Valley, develops along the strike of the IMR. Thus, the evolution of the valley is controlled by the microtectonics of the region.

Although, tectonic evolution of the Imphal Valley is evidently certain, still it is not reliably known when the stretching and evolution of the valley began. Because, as we do not have any adequate subsurface data regarding the depth or thickness of the alluviums of the valley, no calculation of age base on the general rate of sedimentation in strike-slip basins can be made, nor attempt of dating of the sediments of the valley using any method has been carried out by any worker. Hence, nothing can be precisely said about the beginning of subsidence of the valley. However, a possible beginning of the evolution can be inferred based on the principle of structural criteria of dating. This principle cannot provide any absolute figure but the relative age can be estimated based on the chronology of the structural and tectonic events.
As it is believed, the Disang-Barail Flysch Basin of the IMR might have been completely uplifted by Miocene or latest by Early Pliocene. Because, the small hillocks within the valley are all found to align parallel to the regional strike conforming to some synformal axes. That is, the synforms were already been inverted to ridges while antiforms have been well eroded and occupied by streams/rivers. One of the best example is the Nambul anticline occupied by the Nambul river itself (NNE-SSW course) in the central part of the valley. It indirectly indicates that there could be sufficient time gap before the beginning of subsidence and upliftment of the IMR thereby making the topographic inversion nearly complete. Otherwise, had the upliftment was immediately followed by stretching and subsidence of the valley, the topographic inversion should have not been so complete. Thus, the earliest possible beginning of the evolution and subsidence of the valley could be Late Pliocene or Early Pleistocene but may be as late as Holocene, say just about 10,000 years.