Sedimentary structures found in various members of the Tal Formation are described here. The Lower Tal, in general, do not show sedimentary structures, whereas Middle and Upper Tals enclose a rich collection of sedimentary structures. A detailed description of various sedimentary structures referred under lithologic description, is as follows:

1. Cross-bedding: Cross-bedding of various types and dimensions is preserved in the Middle and Upper Tals. The cross-bedding is simple, planar and trough type (classification after Mokee and Wier, 1953, fig. 2). The distribution of the cross-bedding in different members of the Tal is as under:

A. Middle Tal: It is present only in the Banded Siltstone Member.

(a) Banded Siltstone Member:

Small scale cross-stratification is seen in the siltstone (Plate 5, fig. 4) and graywacke beds. The thickness
of cross-stratification has not been found to exceed three centimeters. The lamination in cross-stratified sets is planar as well as tabular with dip in one direction; festoon type of sets having haphazard dips of lamination are also met with. Some of the truncated laminations show deformation. These deformed laminations are truncated by undeformed ones suggesting a penecontemporaneous deformation of the former. The cross-stratification is common in the upper part of the Banded Siltstone Member.

B. Upper Tal: The cross-bedding is abundantly present in the all the members of Upper Tal. Variations in cross-bedding are discussed in ensuing paragraphs.

(a) Lower Quartzite Member:

This is the most predominant primary structure developed throughout the Lower Quartzite Member (Plate 11, figs. 2-3). The average thickness of cross-bedded unit in the orthoquartzite is one meter. The thickness of cross-bedded unit in calcarenite bands varies from half a meter to one meter. The angle of cross-bed with the bedding plane is at an angle of 20°. It is rarely less or more. The strike width of cross-bed varies from one meter to four meters. In rare cases, it is more.
Simple, planar and trough types of cross-bedding are seen in the member.

(b) Shale Member:

It is commonly seen in the orthoquartzite interbeds of the Shale Member. The cross-bedding is of planar and trough types. The thickness of one cross-bedded unit varies between 30 cm and 45 cm. The angle of cross-bedding with normal bedding is between 16° and 20°.

(c) Arkosic Sandstone Member:

Large scale cross-bedding is universally present in the Arkosic Sandstone Member. The width of cross-bedded unit varies from one meter to two meters. The angle of cross-bedding with normal bedding varies from 5° to 18°. Due to obscure bedding, the cross-bedding is better visible from distance and is difficult to decipher from close quarters.

The cross-bedding is of simple to festoon types.

(d) Limestone Member:

Medium scale planar and trough types of cross-beddings are preserved in the calc-arenites as well as in the orthoquartzite bands. The width of the cross-bedded unit on an average is one meter.
(e) Upper Quartzite Member:

Medium scale current-bedding of planar type is present in the orthoquartzite beds. The thickness of cross-beded unit is between 30 cm and 60 cm. The inclination of cross-bedding with bedding is between 12° and 15°.

2. Ripple Marks: These are present in the members of Lower the Tal and Upper Tal. The description of ripple marks in different members is given below:

A. Lower Tal:

(a) Earthy Siltstone Member:

Oscillatory type of ripple marks are noticed on shale at Chatton. The ripples have an amplitude of two centimeters; the height of ridge is 0.5 centimeter. The crest and trough of the ripple marks are rounded.

B. Upper Tal:

(a) Lower Quartzite Member:

Both current and oscillation types of ripple marks are preserved in the orthoquartzite beds of this Member (Plate 11, fig. 4). The length (distance between two
consecutive crests) of the ripple marks is 2.5 to 3 centimeters and amplitude between 0.4 cm and 0.5 cm. The ripple marks are generally straight and parallel. However, in one case, curved and parallel ridges were also noticed. In curved ripples the amplitude was found to decrease till it became flat.

The ripple marks are present only in orthoquartzite beds, and were not observed in calcarenite or shale bands.

(b) Shale Member:

Current and oscillation types of ripple marks are present in the orthoquartzite interbeds. The maximum amplitude of ripple marks measured is four centimeters and amplitude two centimeters. The ridge of ripple marks observed is straight, except in one case, where before ripples flatten, the ridges show a tendency to swerve.

3. Graded bedding: This sedimentary structure is abundantly present in both the members of the Middle Tal. The coarser grain size in the siltstone/graywacke beds of the Middle Tal, gradually decreases upwards, in which finer are evenly mixed. The lower contact of graywacke/siltstone with shale
is sharp, while the upper is indefinite. The graded bedding is very clear on account of difference in (i) colour and (ii) texture: the finer bands are darker and smooth textured. Member-wise description of various types of graded bedding is given below:

A. Graywacke Member:

It shows following three types of graded bedding:

a) Massive graded bedding: This term is used for beds showing grading over thicknesses often exceeding two meters. In such cases grading is difficult to identify, unless chips of rocks broken from various levels are compared.

b) Graded bedding from graywacke to shale: In this, the upper contact of graywacke bed imperceptibly passes into shale layer.

c) Graded bedding in thin beds of repetitive type: This type of graded bedding is easiest to detect. Five to six graded units are repeated at close interval, till a thick bed interrupts the repetition (Plate 3, fig. 3).

B. Banded Siltstone Member:

The thickness of graded beds in banded siltstone varies from half to five centimeters. These graded beds are
rhythmically repeated. The grading is mainly of following two types:

1) Grading in which the grain size gradually reduces towards stratigraphic top (Plate 3, fig. 4).

ii) In the second type, the size of framework grains remains more or less constant but the percentage of matrix gradually increases from bottom to top. This gives relatively coarser and finer bands, which are seen as light (less matrix) and dark (more matrix) bands. The true character (i.e. constant size of framework grain) is revealed only under microscope. This type of grading in fact does not represent a true graded bedding. It, however, is described under graded bedding as, in field, there is no criteria to distinguish it from true graded bedding (Plate 6, fig. 3).

4. Massive bedding: It is present only in the Graywacke Member. In the middle part of this Member, a few thick graywacke and siltstone comprise structureless beds. For such structureless beds, the term 'Massive bedding' has been used. The graded bedding is confined to the upper part of these beds.
5. Horizontal lamination: It is prominently developed in the Banded Siltstone Member of the Middle Tal. Under this type alternate laminations of coarse and fine-material parallel to bedding plane have been included. It is the most common feature of the Banded Siltstone Member. The horizontal laminations are traceable for considerable distances, and their continuity could not be traced either due to lensing out of the bed, truncation by cross-lamination or a precipitous slope. The horizontal laminations are present in siltstone and rarely in graywacke bands. Each lamination has a sharp contact with overlying and underlying laminations. The thickness of one pair of lamination varies from a few millimeter to thirty millimeters (Plate 6, fig. 2). The finer laminations usually have larger thickness as compared to coarser bands.

6. Convoluted bedding: This was noticed only in the Graywackes Member of the Middle Tal. The convoluted lamination as defined by Haaf (1966, p. 188) is common in shale and in some graywacke beds of the Graywackes Member. In cross-sections the convoluted lamination shows a very complicated pattern (Plate 4, fig. 4). The convoluted laminations are also of minute and often microscopic dimensions. The folding is truncated by underlying and overlying beds and is
unrelated to regional fold pattern, hence positively represents syndepositional deformation.

There is no unanimity regarding the origin of convolute bedding. Kuenen (1953, p. 1057) suggested that intensification of ripple marks by hydrodynamic pressure combined with leading trough results in the formation of convolute bedding. Haff (1955) suggested that expulsion of incipient ripple marks due to accelerated rate of deposition produces convolute bedding. Both these authors emphasized the role of turbidity currents in the formation of the convolute bedding.

Since no ripple marks are found in the Graywacke Member, Haff's theory of formation of the convolute bedding does not seem to be applicable at least in the present case. The syndepositional deformation leading to convolute bedding obviously must have happened during plastic stage due to internal readjustment and consequent flowage. The author feels that besides the cause enumerated by Kuenen (1953) the deformation can take place if the basin of deposition had a sloping topography. The plastic sediments would have a tendency to glide down the slope especially under the weight of fresh influx of sediment. The weight of fresh influx of sediment would also exert hydrodynamic pressure as suggested by Kuenen (1953). Such a gliding will result in a chaotic
fold pattern as shown in Plate 4, fig. 4. This would also explain the presence of different directions of overturning of convolute folds in the Graywacke Member.

7. Flame Structures (Walton 1956, p. 267; Pettijohn and Potter, 1964, fig. 53 E): These structures are seen in siltstone interbeds (Plate 6, fig. 2) of the Banded Siltstone Member. In this structure the fine-grained lamination, which has a sharp contact with the overlying coarse-grained lamination, has forced itself later and acquired a shape resembling flame. The height of flame ranges from half a centimeter to one and a half centimeters wide. In a few cases the flame has been detached from the base. It occurs along with load casts.

Walton (1956) and Kelling and Walton (1957) suggested, with particular reference to flame structures above crests of ripple marks, that the flame structures have resulted due to adjustment of coarse and fine sediments in wet stage at irregular interfaces during compaction.

No ripple mark is present in the Banded Siltstone Member. The above explanation, therefore, regarding the origin of flame structure does not hold good in the present case. Since the flame structures, found in the Banded Siltstone...
Member, are found associated with load casts it could be possible that the flame structures described here are result of sagging of heavier layer in muddy layer. The mechanism, therefore, is akin to any load-pocket, in which as a reaction to sudden sagging of heavier layer, the fine-grained layer is splashed up.

8. Syndepositional deformation: Folds and trough which do not continue in overlying and underlying beds, and are unrelated to regional structure have been classified under syndepositional deformation. These folds in small area (Text Fig. 6-8) show plunge in various directions. Such structures are found on micro- (Plate 1, figs. 3-4) as well as on meso-scale in the Chert Member of the Lower Tal.

Text Fig. 6. Syndepositional folds in Chert Member (Loc Gubsar).
Text Fig. 7. Syndepositional fold in the Chert Member, Loc. Den.'

Text Fig. 8. Syndepositional fold in the Chert Member, Loc. Kandi.
9. Moulds of tadpole nests: These structures were found about 800 meters north of Kathwar village in a pale-white quartzite outcrop of the Lower Quartzite Member.

These structures occur as moulds on the underside of a right-side-up bed having a thin lining of shale and are confined to an area of two square meters. The moulds are raised mound-like circular structures with a restricted range of diameter within the limit of 0.7 cm to 1.1 cm. These structures are crowded with their centres located at 1.0 cm to 1.2 cm apart. Average height of these structures is 0.5 cm.

Fig. 1 (Plate 12) shows these moulds in top view. In side view (Plate 12, fig. 2) they show a semi-circular shape covered by thin layer of shale. An impression made of these moulds in wax (which in fact represents the cast of the original structure) shows bowl-shaped depressions of 0.5 cm average depth (Plate 12, fig. 3). The depressions in cast are separated by ridges which have a somewhat polygonal shape.

The cast amongst the structures described so far, resembles closely with the tadpole 'holes' described by Dionne (1969) and Ford and Breed (1970) and tadpole nests described by Cameron and Estes (1971).

Hitchcock (1868, p. 121-123) interpreted depressions of Lockport dolomite, New York, as structures produced by
tadpoles and named them as 'Tadpole nests'. These structures were also reported by Kindle (1914) from Lockport Dolomites. These structures are somewhat polygonal. Kindle (1914) thought that the tadpole nests are produced by interference ripples which are slightly modified by tadpoles. Later Kindle (1917) revised his interpretation and considered tadpole nests to be purely due to interference ripple marks.

In subsequent years the biogenic origin of tadpole nests was disputed and structures described earlier as tadpole nests were reinterpreted as interference ripple marks (Twenhofel, p. 575, fig. 69). Pettijohn (1957) and Pettijohn and Potter (1964) used tadpole holes synonymously with the interference ripple marks. Maher (1962) reported polygonal shaped depressions in ponds of a drainage ditch in a depth of 15 cm (0.5 foot). These structures, according to Maher, were produced by tadpoles. The thrashing action of tadpoles produced ripples in the ponds, which caused the formation of the depressions. Thus Maher (1962) reintroduced the role of tadpoles in the formation of these structures.

Beek@synthesize (1964) reported 'tadpole structures' in sandy clay occurring in less agitated water. The area occupied by these structures is about 0.05 square meter.
The structures are polygonal and bordered by ridges. Due to prevailing confusion between tadpole 'structures' and interference ripple marks, Boerschoten (1964) gave following characteristic features of these two structures (Table 8).

Table 8. Distinguishing features of tadpole 'structure' and interference ripple marks.

<table>
<thead>
<tr>
<th>Tadpole Structures</th>
<th>Interference ripple marks</th>
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<tr>
<td>2. Tadpole marks consist of irregular polygons, bordered by ridges with concave slope.</td>
<td>2. Polygons if present have a pattern directed along two axes with ridges which frequently possess convex slopes.</td>
</tr>
<tr>
<td>3. Smaller in size and have limited surface of development.</td>
<td>3. Of much larger size and cover extensive surfaces.</td>
</tr>
</tbody>
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It was, however, Dionne (1969), who claimed such structures to be truly biogenic in origin. Dionne argued that since tadpoles do not form nests, these structures should be called as tadpole holes. Dionne (1969) reported tadpole holes from pools occurring north of a river bed at Saint-Andre-de-Métabetchwanan, Quebec. Pool-bottom of soft silty
sand having an area of 25 square meter was pitted by little regularly spaced circular holes. The holes had diameter of 10 mm to 20 mm and depth of 10 mm with bowl-shaped bottoms. According to Dionne, tadpoles make circular movements by back legs and tail, thereby churn and displace the soft silty sand on the bottom. The tadpoles then rest in these holes.

Ford and Breed (1970) observed such structures from the middle part of Hancekawa Canyon in the northeastern part of the Grand Canyon, Arizona. The tadpole holes reported by these authors are circular in outline. According to these authors during hot weather, when the water in the pool is warm and evaporating rapidly, tadpoles congregate in the bottom of pools where it is cooler. There they scoop out small depressions with their tails. This activity deepens the water and gives the tadpole a slightly more favourable chance of survival for a series of small depressions, increase the depth of any basin.

Cameron and Estes (1971) have summarised the previous work on tadpole nest. Quoting dictionary meaning of nest (place for taking rest) these authors suggested that the term 'hole' is superfluous and revived the term 'tadpole nest'. The tadpole nests reported by these authors, were
found in two centimeter deep motionless water. The nests are surrounded by circular ridges which on close packing acquire sharp crest and polygonal outline.

There can hardly be any doubt regarding biogenic origin of recent tadpole nests as the actual process of their formation has been witnessed. The fossil tadpole nests, which on contrary, are mere interpretation can be mistaken for rain, hail and bubble impressions and interference ripple marks. However, the rain and hail prints have a rim around their depressions which is absent in the tadpole nests. Besides, the rain and hail impressions often overlap and coalesce which is not the case with the tadpole nests. The rain, hail and bubble impressions have a larger size range as compared to tadpole nests at a particular site.

Interference ripple marks do not have a circular outline, moreover, as suggested by Bockshoten (1964) the tadpole nests have an irregular pattern and ridges separating the tadpole 'polygon' have a concave slope, while the ridge of interference ripple marks often have convex slopes, also ripple marks are of much larger size and cover more extensive areas.
Tadpole nests as discussed above have variable shapes and sizes. Maher (1962) and Bockachoten (1964) have reported polygonal structure formed by tadpoles; while Dionne (1969) and Ford and Breed (1970) have reported circular tadpole nests. Cameron and Bates (1971) described tadpole nests as circular to nearly hexagonal interconnecting ridges with central depressions.

Cameron and Bates (1971) have suggested that the hexagonal honeycomb like arrangement of tadpole nests results from packing of circular ridges. This obviously implies that the tadpole nests which escape packing will retain circular outline. The possibility that some of the tadpoles have adopted readymade depressions caused by interference ripples and modified them in the course of their movement also cannot be ruled out as a possible origin of polygonal-shaped tadpole nest.

The variation in size of 10 mm to 20 mm reported by Dionne (1969) and 7 mm to 11 mm by the present author may be due to different numbers and energy of tadpoles inhabiting a particular depression.

10. Rain prints: The rain prints are seen on grey shale beds of the Shale Member. The maximum area of outcrop over
which rain prints are developed (1 km E15°W of Sakholi) measures four square meters. The rain prints in diameter vary from three millimeters to five millimeters. The rain prints show a rim around their periphery (Plate 13, fig. 4). The rain prints are sparsely distributed and are not seen to coalesce.

11. Ball and Pillow structures (Smith, 1916, p. 147): The ball and pillow structures are common in the Graywacke Member. These occur within and at the lower contact of graywacke and siltstone beds with shale. The ball and pillow structures have hemispherical, kidney, and pillow-shaped forms. The size of these structures varies from 15 cm to 45 cm. Smith (1916) thought that these structures result due to internal readjustment under the influence of gravity.

'Pillow and kidney shaped concretions', similar to ball and pillow structures were described by Auden (1934, p. 357) from the Simla 'slate'. He suggested that these structures originated as the 'Possible earthquake shocks jolted partly consolidated material amongst overlying softer muds that had been just previously deposited.'

The fact that majority of the ball and pillow structures in the present case occur at the lower contact of
the graywacke bed with shale, may in fact, represent a
variant of load cast (Kuenen, 1953, p. 1048 and 1058).

12. Flute casts: The name flute cast was suggested by
Crowell (1955, p. 1359) for oblong, roughly parallel bulges
on the undersurface of sedimentary rocks. The structures
were earlier referred to as lobate rill marks (Shrock, 1948)
and flow marks (Rich, 1950, p. 72).

The flute casts have been found in one of the members
of the Middle Tal and Shale Member of the Upper Tal.
Description of shape and size as seen in various members,
is as follows:

A. Middle Tal:

(a) Graywacke Member:

The flute casts in the Graywacke Member are present
on the underside of graywacke beds. The shape and size of
flute casts are variable. Most commonly the flute casts have
horse shoe shape (Plate 5, fig. 1); other types are conical
(Plate 5, fig. 2) and linguiform (Plate 5, fig. 3). The
linguiform flute casts are associated with squamiform load
casts. The size of flute casts varies from 6 cm to 30 cm.
The flute casts developed on same face, in the Graywacke
Member are roughly parallel; maximum angle of deviation between flute casts developed at same face was found in rare cases to be 20°. The flute casts on same face are of same shape and size.

The flute casts are believed to have been formed by turbulent scour by a current that had energy in excess of that required to carry its load. The scour once made is filled by the sand without destroying the flute. Crowell (1958, p. 334) believed that a later current fills the flute. Kuenen (1957), however, held a different view. Due to similar composition of filling and covering layer, Kuenen suggested that same current fills the scour immediately after they are excavated.

Since the composition of filling and covering layer is same in the flute casts of the Graywacke Member, the author prefers the origin suggested by Kuenen (1957).

B. Upper Tal:

In Upper Tal, the flute casts are seen in grey shale of the Shale Member near Koti Dhuman and Bhogar. The grey shale is interbedded with thin quartzite bands. The flute casts are linguiform in both the cases (Plate 14, fig. 2).
In either cases, the number of flute casts is limited. Near Koti Dhuman only two flute casts are seen. These two casts are at an angle of 10°. Near Bhogar there are only three flute casts, which are partially deformed; these flutes are subparallel.