CHAPTER 3

GEOLOGICAL ASPECTS

INTRODUCTION

In India, the Gondwana formations usually occur as isolated patches and strips (figure 1A). The Pranhita-Godavari valley of Deccan, India provides one of the most complete and well developed Gondwana sequences of fluvial and lacustrine strata along with a succession of Mesozoic vertebrate faunas (Kutty et al 1988). The present day Pranhita-Godavari valley partly coincides with an ancient basin in which Gondwana sediments accumulated over the Precambrian rocks. King (1881) worked out the geology of the Gondwanas of the Pranhita-Godavari valley for the first time and recognised six "Groups" (equivalent to Formations). He also divided the entire sequence into two divisions - the Upper and the Lower. Both the divisions had three formations. The Lower begins with Talchir which is followed by Barakar and Kamthi Formations and the Upper Gondwanas had Maleri, Kota and Chikiala in that order of succession. They were thought to be separated by unconformities. King (1881) also produced a geological map of the area (figure 2). From the Upper Gondwanas, two vertebrate faunas were recognised: the fauna of the Maleri and Kota Formations,
are respectively Late Triassic and Early Jurassic in age.

In the past twenty-five odd years considerable accumulation of new information has led to a thorough revision of the stratigraphy of the area (table 1). Among those new informations four points are particularly important. They are:

1) The Upper Gondwanas are now divided into more formations than the three recognised by King (1981). They are the Yerrapalli, Bhimaram, Maleri, Dharmaram, Kota and Chikiala in that order of succession. Another Formation - the Gangapur, mapped at the northwest of Pranhita-Godavari confluence may be equivalent to the Chikiala.

2) The entire sequence is a continuous one but for the Chikiala (=Gangapur) which lies unconformably over the Kota (Kutty 1969).

3) Instead of two, several vertebrate chronofaunas are identified which range from Middle Triassic to Early Jurassic. The Yerrapalli Formation is the oldest of the Upper Gondwanas. It has a definite Middle Triassic vertebrate fauna (Bandyopadhyay 1988). It is followed by the sandstones of the Bhimaram Formation (Sengupta 1970). The overlying Maleri Formation is rich in Carnian-Norian fossil vertebrates (Roychowdhury 1965) and the fauna from the Dharmaram Formation above is considered as Norian to Rhaetian (Kutty 1969).

4) Of the two Late Triassic Formations, the Maleri and Dharmaram, Maleri Formation is better known and richer in fossil vertebrates. Discovery of new fossil material from both the formations suggests that these formations have two faunal zones each (Kutty and Sengupta 1990).

The vertebrate bearing sediments crop out in a NW-SE trending
There are four dominant lithologies; red or purple clay, peloidal calcarenites, calcirudites (Sarkar 1988, this is equivalent to the "Lime Pellet" rock of Robinson 1970), sandstone and limestone. The differences in the type of sandstone as well as the sand-clay ratio are the basis of the formational divisions. The entire area is disturbed by numerous faults of different magnitudes.

GENERAL FEATURES

The sandstones, usually calcareous (often ferruginous), fine to coarse, contain very weathered feldspars with perthitic intergrowth and infrequent garnets. Clay galls of different size, shape and colour are common.

The quartz grains which floats on the calcareous cement are usually angular. Various aspects of diagenesis are also common in the calcareous cement. The sand bodies are usually cross bedded, ribbon or sheet like in geometry, multistoreyed with low interconnectedness. A fining upward trend is discernible within each storey. Each storey is separated from the other by erosional or scoured surfaces (Sarkar 1988). They are thought to be isolated channel fill deposits alternating with interchannel clay (Sengupta 1970, Sarkar 1988). The sandbodies form narrow elongate ridges (ranging from ten to hundred metre in width, from a metre to 150 metre thick; they have a considerable lateral persistence if not truncated by a fault (figure 4)). Between two sandstone ridges, clay valleys are present. These linear clay-sandstone alternations trend NW-SE. The sandbodies dip 12
to 18 degree towards NE. The paleocurrent direction is towards north. The dip however is difficult to measure due to the crossbedded nature of the sandstones.

The clay is dominantly red in colour. Brown, purple and green shades are also present. They are friable, may grade into silty clay or clayey silt. Occasionally they show red and white or green and white laminations. Otherwise, on the whole, the clay is structureless. When excavated they are found to be moist and plastic though on the surface they seem to be dry with cracks. Smectite is the major constituent of the clay (Sarkar 1988). Iron oxide is responsible for their colour. They are exceptionally rich in vertebrate fossils.

UPPER GONDWANA FORMATIONS

The Yerrapalli Formation has red clay and subordinate calcareous sandstone (Sengupta 1970, Bandyopadhyay 1988). Sengupta (1970) divided the formation into two parts; the lower part contains thin sheets of red and purple clay occasionally interbedded with small lenses or patches of pale green clay and the upper part is characterised by intimately interbedded clay and fine grained, poorly sorted calcareous sandstone with abundant clay matrix.

The Bhimaram Formation is a thick predominantly sandstone bearing formation with minor clay. Kutty and Sengupta (1990) recognised a lower part consisting of coarse and medium grained violet to brown ferruginous sandstones with feldspar, sometimes pebbly with local abundance of red clay - galls while the upper part essentially
contains three different types of sandstones with all possible intermediate stages. They are: 1, hard, compact ill sorted sandstone with grains of medium to coarse angular to subangular quartz, clasts of lime mud and peloids, 2, a pale quartzose sandstone with numerous green, yellow and ochre coloured clasts of lime mud of various sizes and shapes as well as fragments of penecontemporaneous sandstone, often taking the appearance of a conglomerate, 3, a fine to medium grained, white or dirty white quartzose sandstone often with shades of brown or pink. Impersistent thin clay bands often exist between the two.

The Maleri Formation is a clay dominant formation and is sandwiched between the sandstone dominated Bhimaram below and the basal thick sandstone of the Dharmaram above. It is the Maleri Formation which has yielded the two new temnospondyls studied in the present work. Different aspects of the Formation will be discussed later.

The Dharmaram Formation can also be considered broadly as an alternating series of sandstone and clay (Kutty 1969). Drastic lithological changes occur in the sandstone of the Formation both laterally and vertically (Kutty and Sengupta 1990). The sandstones of Dharmaram Formation are coarser, darker and tougher than those of the Maleri Formation. They do not contain large green lime mud/clay galls as found in the upper part of Bhimaram Formation. The ferruginous, violet, lower Bhimaram sandstone is also absent. The Dharmaram sandstones have infrequent small red clay galls and pink feldspars which often impart the sandstones a mottled pink colour. Peloids and fine grained sandstones are rarer than in the Maleri. At several
places a 1 to 4 m. thick dirty white marl appeared just at the junction of the sandstone and clay.

The Kota Formation has a prominent limestone associated with sandstone and clay.

The Gangapur Formation is composed of coarse gritty sandstone, grey white to pinkish mudstones with interbedded ferruginous sandstones and concretions (Kutty et al 1988).

Figure 3 shows regional geological map of the northern part of the Pranhita-Godavari valley. The rectangular enclosure in the map indicates the area chosen for detailed study.

**Maleri Formation**

**Background**

Maleri village, situated 30 km. off the right bank of the Pranhita river, has long been known for its vertebrate fossils. Oldham (1859) recognised several species of *Ceratodus*. Hislop (1864) noted some reptilian bones and Huxley (1869) identified the reptilian bones as belonging to *Hyperodapedon* a rhynchosaur. Lydekker (1885) later created a new species *Hyperodapedon buxleyi* and also described a phytosaur - *Parasuchus hislopi*. While the paleontologists were increasingly attracted by the fossils, the lithology and other geological factors of the Maleri Formation remained neglected. King (1881) mentioned an area around Nimbal and Dharmaram as "the only area where anything like a section ... is seen" (p.121). This gives a
picture of the inadequacy of the good outcrops present in this area. The overall similarity of the sandstone and clay alternations is another problematic factor. On the whole the absence of systematic mapping in a difficult terrain had led many workers to form the idea that whatever fossils were collected from the villages of Maleri, Achlapur, Nimbal, Rechni, Nalapur and Dharmaram would represent elements of a single chronofauna as if collected from one Formation. The first geological note around Maleri was communicated by Aiyenger (1937). He observed that, a good section is present near Rampur, a village about 1 km. south of Maleri.

During the last three decades, efforts to study the entire area in the light of the new information show that the 120 square km. area mapped between Dharmaram and Maleri really consists of several formations rather than one (figure 4). The formational name Maleri has been used in a somewhat modified sense and the upper and lower limits of it have been redefined. The Maleri Formation, as we consider it now, has distinctive lithology and fauna (Chatterjee 1967, Kutty 1969, Kutty and Sengupta 1990). The outcrops around Maleri is not the best. However, the formational name Maleri has been widely used in literature. To avoid confusion, it may be stated here that the formational name Maleri is used in the present work in the sense as given in table 1. The rectangular area in figure 3, chosen for detailed study was pointed out by King as the best area to study the Maleri Formation where the outcrop condition is the best. As stated previously, many important fossils were also collected from this area without realising the shift created by the faults at that place. The
vast clay grounds of Maleri has been found to be really parts of two Formations. Precise location of each fossil locality with respect to the sandbodies has enabled to produce a pictorial concept of how the two different chronofaunas occur in the Maleri Formation. Kutty and Sengupta (1990) noted that a large phytosaur probably belonging to *Micosaurus* (Kutty, personal communication), some scutes similar to *Paratypothorax* (Long and Bellew 1985) and *Ceratodus hunterianus* (Miall 1878) found around Maleri do not belong to the Maleri fauna. The detailed mapping ensured Kutty and Sengupta (1990) to comment- "It is clear that, among the fossil material collected from the "Maleri Group" (King's Maleri that is) what were described by Miall (1878), Lydekker (1885) and Huene (1940), at least three forms appear to be typical of Lower Dharmaram fauna." This is very consistent with the geology around Maleri given in figure 4. Thus, the geological mapping not only helps in describing the geological aspects of Maleri Formation in greater details, but also guides a fossil collector, helps him in finding fossils and moreover alerts him about the possible mixing up of different faunas in an area where a network of faults shifted the outcrops frequently.

**Extent**

In the present study, the major outcrops in the northwestern part of the Maleri Formation have been mapped. These outcrops are repeated by a network of faults. Three major repetitions are most conspicuous (figure 3). The longest outcrop is an approximately 80 km. long strip.
which has Gangapur at its northwest corner and the Pranhita-Godavari confluence at the southeast. Width of this strip reaches its maximum of 3 km. near Maleri. The second important outcrop, about 12 km. long and 2 km. wide, is present near Nanneal. The third is at the east of Bhimaram. This outcrop is approximately 15 km. long and 2.5 km. wide. The last two are truncated by faults at their upper parts. Apart from this, few outcrops of smaller length and width are also present. The important fossil localities, however, lie in the first three.

Contacts with underlying and overlying formations

The Maleri Formation lies between two thick sandbodies; the upper part of the Bhimaram sandstone below and the basal sandbody of Dharmaram above. It has a thick clay at the base. The lower boundary of this clay with the Bhimaram sandstone below is well defined. The upper boundary of the Maleri is not sharp at all. The sandstones present at the top of the Maleri Formation rather grades into the basal sandstones of the Dharmaram.

Fossil occurrence

The Fossils of the Maleri Formation occur usually in the red clays or within the lenses of peloids or sandstones. The ridge forming sandstones are usually barren. Articulated skeletons are usually restricted in the clays.
Geological age

The *Ceratodus, Hyperodapedon* and *Parasuchus*, found from the Maleri Formation, are comparable to genera found in European Trias (Oldham 1859). There is another village Kota, situated at the left bank of the Pranhita river which is also famous for its fossil vertebrates. Oldham (1859) mentioned Egerton's (1851) description of nine fossil fish species from the limestone of Kota Formation all of which show similarity with genera noted in European Lias. Hughes (1876) preferred to group Maleri and Kota into one group. He would like to designate them as the Kota-Maleri Group (see King 1881, p. 118). Blanford (1878) separated Early Jurassic vertebrate bearing Kota from Triassic fossil bearing Maleri basically on paleontological evidences. King (1881) supported this view on what he called "Lithological and stratigraphical evidences" as well as by their fossils. The collections which followed were described by Huene (1940) who assigned a Late Triassic age for the Maleri. Roychowdhury (1965) designated Carnian to Early Norian age for the formation.

In the present work, the Lower fauna of Maleri is considered as Carnian while the Upper fauna has been thought to indicate Norian affinities. The age of the Maleri fauna will be further discussed in a later chapter.
Type area

It is rather difficult to pin point a lithological type area, village or section for the Maleri Formation. The area between Maleri and Dharmaram has good outcrops of the sandstone clay alternations quite typical for the formation. The scarp slope side of the ridge forming sandstone usually gives a good picture of the lithology. Otherwise, the soft sediments of Maleri do not represent good outcrops (King 1881). River cut sections are also rare. Few sections are, however, studied in detail (figure 5). Vertical logging is also difficult due to the broken and covered nature of the outcrops. A few traverses have however been chosen (figure 6). The lithological logs depict a general pattern of the lithology. Exposure of the upper part of Maleri are poor near the Maleri village. The village itself is situated at the top of the basal clay. A section do exist near Rampur as mentioned by Aiyenger (1937) but this has been found to have Dharmaram lithology and mapped as Dharmaram Formation in the present work.

Lithological attributes

The Maleri Formation is a continental red bed sequence with a few elongate sandbodies and occasional peloidal clacirudite/calcarenites lenses. The mud :sand ratio is high (3.5:1 to 2:1, Sarkar 1988).

The Maleri Formation has: 1) a thick clay at its base with occasional mounds of peloids and 2) a series of sandstone and clay
alternations (figures 4, 6). The sandstones are narrow (5 to 100 m. wide), elongate, ridgeforming in nature. Their thicknesses usually do not exceed 15 m.

The sections and lithologs (figures 5, 6) together with the new geological map (figure 4) help to build up certain characteristic features of the Maleri Formation. These are given below:

1) The basal thick clay and upper clay sandstone alternations persists on a regional scale, a feature rather unusual for an ephemeral fluvial deposit.

2) The peloidal calcarenites/calcirudites occur either as solitary mounds and/or a string of such mounds within the red clay and also at the bottom of each single storey of the ridge forming sandstone (Sarkar 1988, p.267). They are crossbedded with overlapping troughs of various magnitudes (figure 5a). This particular rock type is basically calcite - cemented spherical or discoid peloids made up of micrite or microsparry calcite. It often has quartzose components. According to Sarkar (1988) the paucity of broken abraded peloids and other evidences indicate a local pedogenic, origin of the peloids.

3) The ridge-forming sandstone bodies usually have thin bands of green clay at their contact with the red clay (figures 5d, e, f, h). A bottom facies made up of peloids usually occur at the base. Next comes a thicker sheet-like quartzose sandstone. This sandstone is fine, at places silty with calcareous cement. It has a characteristic dazzling white colour and often shows parallel lamination and/or long low angle foresets. Clay lenses are generally present. Alternating laminations of fine white sand and red or green clay are also common.
A more calcareous hard silt with excellent ripple laminations, is also present. This calcareous silt also occurs as separate units within the clay. Another concretionary variety of the calcareous silt with planar cross stratification is also common (figures 5c, f, h). The entire suite may repeat with an erosional or scoured surface placed between each repetition.

An analytical method has been proposed by Allen (1983) and Miall (1985) for subdividing fluvial sediments into a hierarchy of local suites of one or more set(s) of three dimensional units. These units are termed as architectural elements. Detailed mapping and study of sections can reveal "an hierarchically ordered system of mainly erosional bedding contacts which divide the beds into hierarchically structured packets" (Allen 1983). Miall (1988, p. 69-75, figure 4.2) has discussed the various orders of bounding surfaces present in a fluvial deposit. In the present study this concept of architectural element becomes very useful to depict the general pattern of sedimentary packages and the occurrences of fossils within them (see Chapter "Microstratigraphy" in Badgley and Behrensmeyer 1980). The architectural elements recognised in the Maleri Formation are listed below. (The element with lowest rank in the hierarchy is written first)

**Element 1.** The individual beds of a crossbedded trough/package of planar crossbeds/parallel laminations etc. (figures 5a, b). The usual thickness is roughly 1 mm.

**Element 2.** A total individual trough/package of planar crossbeds or parallel laminations. Their thickness is widely variable (1 cm. to 1
m. roughly (figures 5a, b).

**Element 3.** A sequence of troughs + planar crossbeds + parallel laminations + crossbeds with long low angle foresets. The first one is common in the peloids while the others in the fine white sand and its variants. Thicknesses vary from 1 m. to 10 m. (figure 5c).

**Element 4.** A combination of several lithounits with elements 1, 2 and 3. Thickness vary from a metre to nearly 12 m. (figures 5d, f).

**Element 5i.** A repetitive sequence of element 4. with an erosional surface present in between each two. The upper bounding surface is almost always an erosional surface. The total thickness of this unit can reach up to 17 metre (figures 5e, g, h, i).

The clay is usually structureless but noting their outcrop width, thicknesses and alternating occurrences with element 5i, they are given the same rank (5ii). 5i constitute ridges while 5ii forms valleys in between (figure 4, plate 1).

5i & 5ii together constitute the total thickness of the Maleri Formation which is 250 metre at north of Achlapur and Nalapur and 330 metre at northeast of Jaklapalli (figure 6). Near Maleri the thickness is more or less the same with that of northeast of Jaklapalli.

The above discussion clearly brings out that the Maleri sandbodies are structurally compound. Such type of complexes may represent greater time interval than what is calculated from their thicknesses (Saddler 1981). Significance of the phenomenon will be taken up later in the chapter dealing with taphonomy.
Condition of deposition

The Gondwana deposits of the Pranhita-Godavari valley have been traditionally considered as sediments accumulated in a large river valley or a system of such valleys (Oldham 1859, King 1881). The terrestrial and/or fresh water fauna and the repetition of sand-clay alternations of the Gondwana sequence basically led to that idea. Later workers like Roychowdhury (1965), Robinson (1970) and Sengupta (1970) also opined in favour of this view. Sengupta (1970) noted that while the clay represents the interchannel facies, the sand bodies are deposited in the channels of a river system flowing from south to north in a large valley trending NW-SE. Maulik and Chaudhuri (1983) described the Upper Gondwana sandbodies as ephemeral channel fills. Recently Sarkar (1988) observed that the Maleri sandbodies with overlapping troughs of various magnitudes are multistoreyed in nature with a fining upwards sequence identifiable in each storey. The Maleri peloids, in particular, designate a periodic drying up of the channels as well as a periodicity in the stable level of the alluvial plain with a low to moderate rates of alluviation.

In the present study, the multistoreyed nature of the sandbodies with sharp bounding surfaces are confirmed from all the major ridge forming sandbodies of the Maleri Formation. Various sections and lithologs (figures 5, 6) show the presence of clay strata within the major sandbodies. Overlapping troughs of different magnitudes are found as a common feature of the sandbodies. Fining upward sequence is also noted at many places within a sandbody. All these provide strong
evidences in favour of the conclusion that the elongate, narrow clay–sand alternations are the result of superposition of channels coupled with lateral switching (see Sarkar 1988). The presence of peloidal calcirudites with bone fragments at the bottom of a sandbody in many places also supports the periodic drying up of the channels.