Chapter I

INTRODUCTION

LOCATION:

The Kadana Reservoir area extends from the southern part of the Rajasthan State to the northern part of Gujarat State of India. Geographically, it occupies the western part of the Indian Shield and lies within the administrative boundaries of Banswara, Dungarpur and Udaipur districts of Rajasthan and Panchmahals district of Gujarat. For the present study, a total area of about 500 km$^2$, between North latitudes 23°15' to 23°30' and East longitudes 73°45' to 74°15', falling within the Survey of India toposheet Nos. 46 E/15 and 46 I/3, was selected for detailed field investigations including survey and mapping (Fig. 1).

COMMUNICATION AND ACCESSIBILITY:

The area has a well-linked network of all-weather metalled roads connecting the main towns of Rajasthan and Gujarat. The area being situated about 800 km south-west of Delhi, is approachable from Delhi through the National Highway No. 8 via Kherwara. From Kherwara, the metalled road that connects the National Highway No. 8 with the Ajmer-Ratlam State Highway, passes through the towns of
FIG. 1

LOCATION MAP

K.M. 100 50 100 400K.M.
SCALE

Area of detail study

DELHI
JIPUR
Ahmedabad
MADRAS
BOMBAY
CALCUTTA
BHOPAL
CEYLON

FIG. 1
Dungarpur and Banswara which are the approach points to the right and left banks of the Kadana Reservoir in the area.

The nearest rail-head in the area is Lunavada, which is approachable from Delhi via Godhra by the Delhi-Ahmadabad Broad Guage Railway. From Godhra, Lunavada is connected by a Narrow Guage Railway. The area is also approachable from Jaipur by the Jaipur-Ahmadabad Meter Guage Railway via Dungarpur, which is the nearest rail-head for the northern part of the Kadana Reservoir area.

CLIMATE:

The region falls within the semi-arid zone of western India. It has the influence of three major climatic changes in a year viz., winter, summer and rainy seasons. The winter lasts from November to March, when the atmosphere remains clear and mostly dry. From April to June, till before the onset of the monsoon it remains hot and dry and is largely swept by the westerly winds. The summer months of April and May are extremely hot and inhospitable. The rainy season lasts from July to October. The annual rainfall varies from 90 cm to 100 cm and most of which is received between July and August through the south-west monsoon. Climatically, the area is included in the monsoon belt of India.
FAUNA AND FLORA:

Most of the varieties of wildlife of the area have vanished with urbanization accompanied by accelerated forest clearance. However, the carnivorous animals like panther, leopard, hyena, wolf and rarely, tiger could be found in the protected forests. Jackals and hares are the more common wildlife. Pigeon, peacock, crow, dove, crane and patridge are the more common aves to be found in the area. The patridges dwelling in the bushy hills of the Kadan Reservoir area are most delicious table birds. Domesticated animals like buffalowes, cows, bullocks, camels, horses, donkeys, sheep, goats and dogs are commonly seen within the villages. Local ponds and perennial nalas in the area have some varieties of fishes.

The vegetation in the area is rather poor and shrubby. At places patches of teak (Tectona grandis), mahua (Madhuca indica), salar forests with wild creeper and grassy undergrowths are present in the reserve forest areas. The trees like those of mango (Mangifera indica), mahua (M. indica), nim (Azadiracta indica), tamrind (Tamrindus indica), ber (Zizyphus jujuba), banyan (Ficus Bengalesis), Pipal (Ficus religiosa), semal (Salmolia malheria), dhak (Bhutea frondosa) and bamboo (Dendralamus strictus) are generally grown near the villages as a part of social forestry programme.
PHYSIOGRAPHY:

The study area (Fig. 2) within the Mahi River Basin may be classified into the following four major geomorphological units:

1. The table land of the Deccan Traps.
2. The rolling plains of the Aravalli rocks.
3. The structural hills of Aravalli quartzites.
4. The alluvial tract of the Mahi river.

The Table Land of the Deccan Traps:

In the south-eastern part of the area, south of the Aravalli hilly tract and rising above the Aravalli rolling plains to an elevation of 320 m, is the table land of the Deccan Traps, made up of basaltic lava flows. The morphotectonics of the table land are largely controlled by joint patterns of the bed rocks. The top of the table land is flat corresponding to a planation surface of 320 m. The unit is characterised by steep scarp faces with nick points around 280 m elevation, which represents the lithocontacts of the Deccan Trap basalts with the underlying Aravalli metasediments. The unconformity between them is represented by the 280 m contour. The unconformity possibly represents a palaeo-planation surface in the area.
GEOMORPHIC UNITS OF KADANA AREA

MILES 4 2 0 4 MILES

LEGEND

THE TABLE LAND OF THE DECCAN TRAPS

THE ROLLING PLAINS OF THE ARAValli ROCKS

THE STRUCTURAL HILLS OF ARAValli QUARTZITES

THE ALLUVIAL TRACt OF THE MAHI RIVER
The Rolling Plains of the Aravalli Rocks:

The Aravalli rocks, composed generally of subgraywackes, meta-protoquartzite, phyllites, slate, meta-siltstone and garnetiferous quartz-biotite schist form gently rolling to almost flat plain. The plain is usually covered by a thin veneer of soil. The solid geology occasionally crops out from beneath the alluvium as ruwares whose trend is generally determined by local penetrative planar tectonic anisotropy. The planar homogeneity of the erosional surface has been modified by the development of the sub-dendritic drainage network, whose morphotectonics is controlled by the locally prominent planar tectonic elements.

The Structural Hills of Aravalli Quartzites:

The drear monotony of the Aravalli rolling plains in the area is punctuated by some winding linear hogbacks formed of the Aravalli quartzites, which appear as subvertical monoliths overlooking the plains. These hillocks, which are the manifestations of the structural pattern of the rocks provide dependable markers for interpreting geomorphic signatures in terms of structure and stratigraphy of the formations composing them. They are composed of quartzites and form flat-topped structural hills which reflect planation surface corresponding to 280 m elevation.
The Alluvial Tract of the Mahi River:

To the west of Kadana and on either banks of the Mahi river, the thick pile of alluvium accumulated between Kadana and Lunavada, represents an older aggraded flood-plain of the Mahi river. The surface of the alluvial plain lies at a general elevation of 110 m above M.S.L. Subsequent rejuvenation of the Mahi has dissected parts of the older flood-plain. The alluvial sediments are composed of medium to fine grained sand and silt mixed with locally deposited coarser sand, gravel and pebbles, which are supposed to be the common flood plain deposits. The depositional characteristics of the sediments comprising this geomorphic unit are found within the fluvial regime (Iqbaluddin, 1977).

The clastogenes within the size range of medium to fine grained sand and silt are dominant, coarse sand, gravel and pebbles occur as subordinate clastogenic constituents in the flood plain deposits.

DRAINAGE:

The area is commanded by a part of the Mahi drainage basin, which is bounded by the Ganges Basin in the northeast, the Sabarmati Basin in the northwest, the Karjan Basin in the southwest and the Narmada Basin in the south (Fig. 3).
THE MAHI AND ADJACENT RIVER BASINS

SCALE
1:6000,000

0 100 200 300 400 500 600

SABARMATI BASIN

MAHI BASIN

NARMADA BASIN

KARJAN BASIN

Bombay

FIG. 3
The regional slope of the area controls the southwesterly drainage of the Mahi basin. The sub-basin drainage is controlled by the major structural trends and the formational contacts.

The Mahi and its tributaries, the Anas and the Chibota rivers, which are the main arteries of drainage in the area, generally follow the regional slope. These are fed by innumerable smaller tributary streams, whose drainage trends are determined by the local structural, topographical and lithological set-up. The first order channels are generally joint-controlled, whereas most of the channels of second and third orders are influenced by the local topography. The Anas and the Chibota rivers constitute the fourth order and the Mahi, fifth order drainage channels. Their tributaries are mostly ephemeral. The Mahi, the Anas and the Chibota rivers are perennial, but in unusually drier months they are reduced to mere puddles with little surface run-off.

PURPOSE OF STUDY:

The Governments of Rajasthan and Gujarat States with the assistance of the Government of India, have launched a project for the multipurpose development of the Mahi Basin. This involved construction of several dams for river control, development of irrigation and generation of power in the area (Fig. 4). With the completion of Kadana Dam the proposed
DEVELOPMENT PLAN OF MAHI BASIN

FIG. 4
Kadana Reservoir is expected to submerge under water, an area of about 500 km$^2$ upstreams of the dam. Recent excavations made at the Kadana Dam site have brought to light a number of features of geological interest. They drew attention of the author to have a closer look at the excavation sites for an immediate study and research, which involved a systematic geological survey and mapping of the area and investigations on sedimentation, lithology, stratigraphy, structure and metamorphism of the rocks exposed in the area. The ultimate objective of the investigation was to provide data relevant to the evaluation of the seismotectonic status of the reservoir area and tightness of the basin periphery, which however, does not come under the perview of this investigation.

SUBJECT AND SCOPE OF THE STUDY:

The stratigraphy, sedimentation and tectonic history of the rocks encountered in the Kadana Reservoir and adjacent areas and their temporal and geological relationship with the Aravalli sequence of Rajasthan and Gujarat form the main theme of the present study.

In pursuance to the purpose of the present study, scope of the work had to be extended beyond the limits of the reservoir area, as an understanding of the regional
Stratigraphy-cum-structural set-up was considered to be essential. The present investigation has brought to light many new and interesting data and informations relating to the stratigraphic and structural framework of Precambrian metasedimentary formations encountered in parts of Rajasthan and Gujarat.

**METHODOLOGY**:

The methodology and techniques adopted in course of the present study are mostly those which are usually applicable to geological survey of the area and pertinent laboratory investigations for probing the stratigraphy, structural and petrographic fabric of the different units of Kadana Reservoir area were followed for interpreting the geotectonic environment and temporal relationship of the sequence with the rest of Aravalli rocks of Rajasthan and Gujarat.

Field and laboratory methods adopted in the present study are enumerated as follows:

**Geological Survey and Field Observations**:

1. Reconnaisance traverses were taken for developing local and regional perspective in the Kadana Project area.
The general lithostratigraphic characters of the individual units, their structural fabric and distribution of lithounits in time and space were the targets of this investigation prior to mapping of the submergence and adjacent areas.

2. Lithological and structural maps of the area falling within parts of Survey of India toposheet Nos. 46 E/15 and 46 I/3 on a scale of 1:63,360 were prepared following the usual method adopted by the Geological Survey of India. The important features like the formational boundaries, attitudes and orientation of primary and secondary structural elements, sedimentary characteristics of the lithounits, nature and locations of the fault, shear zones, etc., were carefully recorded. Representative hand specimens of rocks encountered were systematically collected in addition to their chip samples from the different geological formations.

For plotting of field data, hachured Survey of India one-inch toposheets and photostat enlargement of \( \frac{1}{4} \) mile toposheet to 1:63,360 scale were used as base maps for the area lying in parts of toposheet Nos. 46 E/15 and 46 I/3 respectively.

Laboratory Investigations:

1. Thin section studies of the rocks were carried out for their petrographic identification including clastogenic
and tectonic microstructures and for establishing the relationship between deformation and metamorphism of the various rocks, under study.

2. Photomicrographs were taken of some of the thin sections of rocks showing important textures, fabrics and tectonic anisotropy.

3. Structural data collected during the field work were screened sub-area wise, tabulated and plotted on stereonets for the preparation of stereograms and synoptic diagrams.

4. In the final map, line symbols have been used for the presentation of different lithounit, bedding characteristics and some of their structural elements.

5. Stereomodel study of the area was carried out for air-photo mapping of major fracture systems in the area.

A REVIEW OF PREVIOUS WORK:

The area was first geologically surveyed by Daru, D.N. of the Geological Survey of India between 1907 and 1914. Death prevented the publication of Daru's work. The author had an access to his unpublished original maps, which formed a basis for the synthesis presented by Gupta and Mukerjee (1938). The metasedimentary sequence, exposed in the former princely states of Kadana, Santrampur, Lunavada, Banswara and Dungarpur, was included in the 'Aravalli System' by
Daru (1907-1914). He referred the rocks located in the area southeast of Kushalgarh as 'transitional stage between quartzite and phyllite'.

The low grade metamorphites exposed south of the Kadana Reservoir area, around Rajgad and separated from the main expanse of the Aravallis by the Godhra Pluton were designated as Rajgad shales by Rama Rao (1931).

The first detailed account of the geology of the area was given by Gupta and Mukerjee (1938) based partly on the synthesis of Daru's work and partly on geological surveys conducted by them between 1931 and 1935 in the then Bombay Presidency. They recognised three main divisions in the Precambrian sequence of south Rajasthan and north Gujarat, namely the Banded Gneissic Complex, Aravalli System and Delhi System and presented their stratigraphic sequence (Table 1) as follows:

Table 1: Lithostratigraphy of Southern Rajasthan and North Gujarat (Gupta and Mukerjee, 1938).

<table>
<thead>
<tr>
<th>System</th>
<th>Delhi System</th>
<th>Alwar quartzites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erosional Unconformity</td>
<td>(Composite gneisses, phyllites, slates and schists with quartzitic intercalations.</td>
</tr>
<tr>
<td>Archaean</td>
<td>Aravalli System</td>
<td>(Limestone, Basal quartzite, and conglomerate) Intrusive quartz veins, pegmatites, granite, epidiorites (amphibolites).</td>
</tr>
<tr>
<td></td>
<td>Erosional Unconformity</td>
<td>(Banded Gneissic Complex)</td>
</tr>
</tbody>
</table>
In their report (Gupta and Mukerjee, 1938) the gneisses and migmatites of Banswara were classified under the Pre-Arvalli rocks, and the metasediments exposed around Bhukia, Kadana, Santrampur, Lunavada and Devgad Baria, were mapped as phyllites and micaceous schist of Aravalli System. The quartzites forming the prominent ridges around Kadana, Santrampur, Lunavada and Devgad Baria were considered as intercalations in the Aravalli phyllites and schists. The low grade metamorphites of Kadana and Santrampur area were not separated from the more metamorphosed Aravalli rocks of adjacent areas of Banswara and Dungarpur though they remarked that 'in Southern Rajputana States instances have been noticed where the phyllitic or slaty formations have gradually passed through a kind of knotted schist into biotite-garnet-quartz schist'. The gneisses exposed south of Devgad Baria were equated with the Mixed Gneisses recorded from the southern part of Central Mewar (Gupta, 1934). The granite exposed around Godhra was considered to be post-Delhi intrusive. Gupta and Mukerjee (1938) further observed 'Its mode of occurrence and association with the Aravallis are clearly indicative of the fact that it has at no stage been involved in the tectonic movements responsible for the folding of the ancient sedimentaries'.

The earliest authors to refer about the deformation and isograd variations in the rocks of the area, under study, were also Gupta and Mukerjee (1938). The disposition of the
lenticular patches of 'conglomeratic quartzites' in the Aravalli rocks of Banswara and Jambughoda was explained by invoking the possibility that they might represent truncated anticlinal crests. The variations in the argillaceous rocks from 'soft siliceous shales' to micaceous schists through slates and phyllites with well pronounced foliation were recorded as isograd changes. The schists were often found to be studded with small garnet porphyroblasts. Though they have not delineated the isograd variations from shale to schist in a regular way, yet their account of the argillaceous rocks brought out clearly that the regional deformation was responsible for the metamorphism.

Krishnan (1953) while discussing the tectonic trend lines in the Archaean of India mentioned about the splaying of the northeast - southwest Aravalli strike in Gujarat and considered the rocks of the area to be laterally linked with the Dharwars underneath the intervening Deccan Trap terrain. On the basis of southeasterly and easterly trends in the Aravallis of Gujarat, he also suggested their possible continuation with the Satpura trends. In the absence of sufficient supporting data in this critical area regarding spatial continuity of the Aravallis with the Satpura trends in the Central India, Krishnan (1953), however, did not press his argument but suggested the possibility that the anomalous trends of the Aravallis in north Gujarat might be the result of superposition of ENE-WSW Satpura trends over
the northeast-southwest strike of the Aravallis in the area.

Rasul (1963) recorded some exposures of older metamorphic rocks from the Champaner Basin, Gujarat south of the Kadana Reservoir area and considered them to be the southern extension of the Aravallis supporting an earlier view of Fermor (1909) and West (1934).

Jamusaria and Merh (1967) studied the deformational history of the Jaban conglomerate belonging to the Champaner series of district Panch Mahals, Gujarat. They recorded selective elongation of the phenoclasts in the direction of fold axes, development of cleavage in the matrix and preferred orientation of flat phyllites and marble fragments parallel to the schistosity in the matrix. The deformation as conceived by these authors for the Jaban conglomerate involved shearing and slipping normal to fold axes in the direction of tectonic transport along the schistosity planes during the structural evolution of the Champaners. They also considered that as a result of metamorphism (related to the regional deformation) the 'heterogenous (graywacke) matrix of the original rock has been transformed into an assemblage of biotite-(chlorite)-muscovite-(sericite)-quartz-plagioclase, while the arkosic matrix of the original rock has been transformed into an assemblage containing quartz, muscovite, sericite and microcline in varying proportions'. Thus, according to them
the isograd had reached the green-schist facies during the regional metamorphism of the Champaners.

The Rajgad shales, occurring adjacent to the area of present study, have been studied in some detail by Sathe (1967) who recognised two phases of metamorphism in these rocks, viz., (1) low grade corresponding to quartz-albite-epidote-biotite and quartz-albite-epidote-almandine subfacies of the greenschist facies. This metamorphism is regional and related to the regional deformation of the argillites which resulted in the development of foliation in the metasediments, and (2) controlled by the intrusions of granite, pegmatites and quartz veins which were considered to be post-tectonic to the regional deformation in the Rajgad 'shales'. The intrusions produced small contact aureoles and local thermal effects at the contacts, resulting in the rise of isograd in the metasediments up to the hornblende-hornfels facies. Thus, Sathe (1967) assigned regional metamorphism to garnet grade and thermal to hornblende-hornfels facies with slight metasomatic effects in the Aravalli rocks of Rajgad.

Gopinath et al. (1977) have studied in greater detail the structural history of the Champaners and the Aravallis of Devgad Baria which form the southern extension of the area, under study. They recognised three deformative phases in the Champaners. The tight, sometimes overturned to isoclinal folding in the Champaner rocks along ENE-WSW to
ESE-WNW trending axial traces, southwest of Jambughoda, have been attributed to $F_1$ folding phase. They found that the $F_2$ folds are open, steeply inclined and moderately plunging to westnorthwest and that the trend of their axial trace is WNW-ESE to East-West. The $F_3$ folds were found to be open with steep northerly plunge and north-south trending axial traces, which were observed in the area around Pani Mines. Gopinath et al. (1977) have assigned the $F_1$ phase to pre-Champaner and $F_2$ to post-Champaner folding. They have also considered the $F_3$ folds as cross folds associated with post-Champaner deformation.

The intrusive granite around Godhra, which according to Gupta and Mukerjee (1938) has at no stage been involved in the tectonic movements responsible for the folding of the ancient sedimentaries was considered as syntectonic to the $F_2$ fold movement by Gopinath et al. (1977). It has been dated as 950 m.y. by Gopalan et al. (1979), corresponding to Erinpura phase of magmatic activity in western part of the Indian Shield.