INTRODUCTION

The Archaean rocks of Peninsular India, as else where, offer problems in their structural and petrological analyses that are difficult of solution. As is now generally understood, they are subjected to repeated periods of metamorphism as a consequence of which the nature of the original rock types is more easily imagined than proved, though, of course evidences are offered in support of one theory or the other. In spite of the divergence of views as to the nature and the origin of Archaean and the difficulty experienced in the interpretation of the complicated structural features presented by these rocks, there are zones in the Archaean terrain from where the field, petrographic and chemical data collected have provided unmistakable evidences as to the nature or origin of the rock types. Extrapolation of the results thus obtained has been one of the ways of solving the problem of origin of the rock types, occurring in zones of Archaean terrain, where evidences are scanty.

Having regard for such an approach to the problem, the author undertook the survey of a portion of the Archaean terrain to the south of Vajrakur (famous diamond-bearing horizon of South India) in the Anantapur District. The reconnaissance survey conducted in the area drew our attention to the existence of low grade schists amidst granites and gneisses. On examining the geological map of the adjoining state of Mysore, it is found that the schist patch occurring here is the northern continuation of the east-central band of the well-defined schist bands of the Dharwars in Mysore State consisting of the four series-Bandite Series, Kodamite Series, Bidaloti Series and Sakarsanite Series - as described by Rama Rao (Bull.17, Mysore.Geol.Dept. 1940).
The area surveyed and mapped is a square strip of country lying between Long. 77°20' and 77° 25'; Lat. 14°50' and 14°58' and forms part of the topographic sheet 57 F/5. The well-known Ramapuram temple, situated adjacent to the small rivulet that joins the Pennar river, is in the centre of the area under study, and forms an ideal camping place from where all the exposures can easily be approached. Fig. 2 is the topographic map of the area surveyed the location of which is shown in Fig. 1. Camps at Ramapuram temple and the project house near Konamanayanipalli were established for surveying and mapping of the area.

The schist patch of the area, under investigation, consisting of chlorite schists and phyllites, bordered by amphibolites and intruded by granites and gneisses, which forms the northern extension of the east-central band is petrographically different from the four prominent series of the Mysore State, referred above and may be designated as the "Mid Pennar Series" on account of the prominent development of the rocks with their characteristic and striking structural features.

**MID PENNAR RESERVOIR PROJECT**

The scanty rainfall, and frequent recurrence of droughts, often in consecutive years, make Rayakaseema (Anantapur, Cuddapah, Chittore and Kurnool districts of Andhra Pradesh and Bellary district of Mysore State) one of the worst famine affected regions of India, involving considerable expenditure by the Governments towards famine relief works. Realising the necessity for eradicating the famine in these areas, the Government of Andhra Pradesh has constructed a storage reservoir across the Tungabhadra river with a High Level Canal System, to afford irrigation facilities to as large an area as possible in the basins traversed by the
Fig. 1
rivers, Tungabhadra, Hegari, Pennar and Chitravathi, where most of the cultivation is dependent on local rainfall.

The Pennar river rises in Chintamani hills, northwest of Nundidurg, in Kolar District of Mysore State, and enters Ananthapur District in extreme south of Hindupur Taluk. The largest tributaries of the Pennar are the Numudvathi and Jayamangali. There is an existing project by name, "Upper Pennar" above the present site and another project is proposed at Gandikota lower down. Hence this project is called the "Mid Pennar Project" (Plate I, Fig.1.).

The Mid Pennar Project consists of a dam across the River Pennar and two canals taking off on either flanks. Actually the regulator was proposed to be constructed at a site ½ mile upstream of Konamanayanipalli village, but this site was condemned and the dam has been constructed one and a half mile upstream of the village. The details on this aspect have been dealt with in the appendix.

This Mid Pennar Regulator is for picking up the Tungabhadra Project High Level Canal water for irrigating about 84,115 acres. There are two main canals taking off from the dam through the sluices situated on either flank. The one that takes off from the left flank sluice on the northern side is the "North Canal", the other, a major canal, taking off from the right flank sluice on the southern side is the "South Main Canal". The terrain traversed by these canals is undulating, necessitating cuttings while negotiating ridges, and construction of aqueducts, syphons, under-tunnels etc., at points of crossing of natural Tanka courses. The High Level Canal will be a non-perennial canal supplying water to the tracts for a period of five months in a year. The irriga-
tion waters will protect the crops against drought and will serve to efface the famine conditions.

ANANTAPUR NORTH GOLD MINES:

This is an old abandoned gold mining area, where mining was actively pursued during the early part of the century producing 1.8 lakh ounces of gold. Mining was stopped by 1928 for reasons not well known and no serious attempts have been made to reopen the mines subsequently. These ancient workings for gold occur in the form of long narrow trenches scattered here and there throughout the schist belt. These workings are reported to belong to the period of Tippu Sultan.

Modern underground mining was carried out during the period 1906 to 1928 by Messrs. John Taylor & Sons., Thomas Richards of Nundidurg mine of Kolar Gold Field made a preliminary examination of the field in 1905. The Anantapur Gold Fields were formed with a capital of £30,000 and active prospecting and development commenced immediately. Most promising results were obtained in Buruju Block where two prospecting shafts, sunk midway between two ancient workings, resulted in the opening up of a 700 feet long payable shoot. The original Anantapur Gold Mines Ltd., formed in 1905, transferred a portion of its lease, the Buruju Block, to the Anantapur North Gold Mines Ltd., and continued prospecting and development at three other blocks in the field. Rich veins were located in one of these blocks which were subsequently transferred to the Nundidurg mines of Kolar Gold Field, operating under the name of Jibutil Gold Mines Ltd., with a capital of £2,20,000. These two companies carried out active mining and milling with a 20 stamp battery at Anantapur North
Gold Mines and 30 stamp battery at south Jibutil mines. The operations of Anantapur North Gold Mines, however, suddenly came to an end in 1922, followed by the Jibutil Gold Mines Ltd., in 1927. An average of about 10,000 ounces of gold were produced per annum for 18 years during the period of 1910-1927.

GEOMORPHOLOGY:

The area presents a series of ridges roughly extending North-west, south-east. The usual rock types are granites, gneisses, amphibolites, hornblende schists, granulites, Chlorite-schists, calc-chlorite schists, phyllite; quartzite; fault-zone breccia and dolerite dyke swarms.

The topography varies in height from about 1,716 ft. above M.S.L. near Udariyikonda to about 1,100 ft. at the pennar river bed near Appajipeta, the general elevation of the country being around 1,500 ft. at the west and southwest and 1,250 ft. in the mid east portion.

The country has a matured topography with gentle slopes and having no large plain surfaces. The cultivable strip of land is little, as the area is mostly rocky and is covered at lower levels, with rolled-down boulders, pebbles and such other rock fragments. The average level of cultivable strip of land is 1,250 ft. and the mounds in the region do not attain a height of more than 1,600 ft. Most of the hills are low mounds of average height of 1,350 ft. (Plate I, Fig.1) and hence present little difficulty in taking traverses. The vegetation is sparse, the rain fall being scanty, such that the barren grounds of this area have the finest exposures of rocks revealing their history in
almost every detail. Though the mounds, which are irregular in shape, have a haphazard distribution in the terrain, there are two well-defined ridges running predominantly in the northwestern direction and meeting at the southeastern end, near about the Mid Pennar dam. The oblong contours of the two ridges that coalesce at and south of the dam site testify to this. However, one, standing at the project house which is situated on the top of a mound, and taking a view of the region in the northwestern direction, could see the gap between these two ridges widening in the northwestern direction but becoming narrow in the southeastern direction and meeting and merging into a single, broad ridge with a south-southeast trend. The ridges thus present the shape of the letter Y, the tail of the Y having NNW-SSE trend. For the sake of convenience and also for the purpose of the description in the section on the field relations and structure, it was thought desirable to designate these two ridges, and accordingly the ridge with the maximum height of 1,605 ft. along its course and running near Ramapuram temple has been called the Ramapuram ridge, the other running north-northwest from the dam, but taking a northwesterly trend at its northern end, has been called the "Reef Ridge", in allusion to the gold mines situated on the ridge, two and a half miles north of the dam.

The major drainage is that of the penner, which flows from the southwest to mid-eastern portion of the area included in the Toposheet 57 E/5, across the trend of the rocks, making a right angle turn, two miles north of Udaripikonda. The Pennar river is a superposed river over the high erosion surface (3,000 ft - 2,800 ft.) and the interesting feature about the river is that it meanders with apparently a mature aspect (South of this area), while it has a greater gradient with a major change in the area,
under investigation. The change in the direction of flow has been attributed to possible river piracy (Vaidyanathan, 1962). The third order drainage is essentially made up of consequents and they present a trellis pattern in some parts of the area, and a dendritic pattern in other parts. The difference is primarily due to the attitude of the strata making up the terrain in the area. According to Vaidyanathan (1964) this area as a whole is a dissected part of the lower erosion surface (1750' - 1500') which has a gentle slope towards ENE and east.

In addition to the major river traversing through the heart of the area, numerous small water courses, hill streams, stream-lets, and tanks, constitute the drainage pattern. (Fig. 12.) Most of these are dry for a major part of the year. In some places, natural rock basins of varying sizes are also seen in which water is stored only in the rainy season. A majority of the water courses of the area are consequent upon the joints and other fracture patterns as well as the northwest foliation of the rocks of the area.

Drainage of the region faithfully reflects the topography. Parallel to the two main ridges and on either side of them, run stream courses which join the Pennar river as tributaries. The Pennar river runs, in general, from east to west and the tributaries that join them run from northwest to southeast. This indicates a gradual slope of the terrain from northwest with a mean level of 1,500 ft. to southeast, where it falls to a level of 1,100 ft. The hills to the east and southeast stand out boldly as the level there is 1,100 ft. whereas the hill ranges at the northwestern portion of the area merge with the plains of the regions, whose general level rises to 1,500 ft. in the thesis area.
The rocks here have a general northwesterly strike and so the tributary streams courses, that run from northwest to southeast, may be considered as "strike streams". The Penner river, that runs from west to east, cuts through the two ridges and the dam is constructed at the point of coalescence of these ridges.

In these regions, the ground-water table is deep and the excess of water permits removal of considerable materials in solution, so that the water tend to have large content, in parts per million, of soluble materials. During dry seasons, the ground water will have upward movement and there is much deposition of soluble and colloidal substances, in and on the surface materials. These materials are chiefly carbonates and sulphates of Ca, Mg, and Na. These soluble salts occur in the form of calcite, tepetate, kanker, hardpan and other concretionary structures and cement. They are deposited in the surface materials, mostly seen on amphibolites and dioritic masses (Plate I, Fig.2).

Climate:

The frequent famines and years of distress have debilitated the people considerably. Their vitality has been lowered to such an extent that they have not much power of resistance even to ordinary diseases.

The period, from December to March, is characterised by a cool and dry weather. The day temperature rises gradually after January, with fairly low night temperature. The second period, from April to May, is hot and dry, with day temperatures reaching 110°F in some parts, but during the nights the temperature is not much. Occasional thunder showers occur in this period but they are not, however, certain. Hot winds blow over the area from the north-
west and west. The area is visited by southwest monsoon from June to September. Rains may set in early or late or never in time for the Mungari Crops. October and November are the main northeast monsoon months, but the rains during these months are less dependable than the southwest monsoon rains. Average rain-fall worked out for the whole year, over a period of ten years, is 12.75" in northeast monsoon.

Soils and Vegetation:

The terrain, in general, is subjected to heavy erosion and run off losses. In most part of the area red skeletal soils are located. In the highland areas red loams and red clays are met with. In general, the soils include black clay, black loam, black sand, red clay, red loam and red sand. Of these, soils made up of black sand is the most fertile, while the soil made up of red sand is the least fertile.

No definite rotation of crops is practiced, but in years of good rainfall, these lands are sown with Korra, Cotton under dry conditions. In the central highland tracts, garden cultivation like betels, lemons is established under well-irrigation. Ragi, paddy, cholam, Sajja, Korra and Onion are the chief food crops, while groundnut, gingelly and tobacco are the commercial crops. Some of the hill slopes are covered with thorny shrubs and wild grasses (Plate II, Fig.3), with runs of dolerite dykes along the ridges.

GEOLOGIC SETTING:

The general succession given hereunder has been established by the author for the M.P.R. Project area, based on the field investigation.
Acid dykes
Trap rocks
Closepet or Arcot Granite
Peninsular gneiss
Dharwar Group

Pegmatite, aplite and quartz veins.
Dolerite dykes.
Granites and Pegmatites.
Granite gneiss and Migmatitic gneiss.
Amphibolite, quartzite, ferruginous quartzite, chlorite schist, phyllite, calc chlorite schist.

The hill ranges of the Marutla and Bhadrampalle Reserve Forests are made up of the rocks of the Dharwar suite, peninsular granite gneisses, dolerite dykes and intrusive acid veins.

The rocks of the Dharwar suite are represented by chlorite schist, phyllite, quartzite, amphibolite and calc chlorite schist.

To the east of the Dharwar belt the granites and gneisses form an undulatory plain with isolated hillocks. But to the west of it, they form high ridges. The granites and gneisses usually contain numerous, lenses of varying sizes of the Dharwar suite granitic rocks that occur close to the Dharwars are medium grained, while those lying farther away are coarse grained to porphyritic in texture. These granites consist of milky or blue quartz, pink or grey feldspar and dark biotite and/or hornblend and often include caught-up patches of varying sizes of Dharwar rocks. In the area, south of the pennar river, the dolerite dykes swarm in number and cut across the Dharwar suite of rocks and granites in northwest-southeast, east-west and north-south directions. They are fine to medium grained in texture and show chilled phases.

The acid dykes, forming the youngest members of the thesis area, comprise granite, monzonite and quartz veins and are of restricted occurrence.
PREVIOUS LITERATURE:

Wetherell (1903) of the Mysore Geological Department was the first to locate and map the Ramagiri schist belt, extending from the Pavada taluk of Mysore State into Penukonda and Dharma-varam taluks of Anantapur District, Andhra Pradesh. He did not, however, mention the gold lodes and ancient mines at Ramagiri. The earliest recorded description of these parts in connection with the Anantapur Gold Field is a short note published in the Mining magazine, London (1910) which dealt with the prospecting activity of the Anantapur Gold Mines Limited.

Bosworth Smith (1919) and Prvor (1921), consultants to North Anantapur Gold Mines Limited, described the nature and extent of gold mineralisation. To find out the possibilities for further development the systematic mapping of these parts of Anantapur district was carried out by Sastry (1954); but his work was mainly confined to regional mapping. Narasayanswami (1957) made a preliminary survey and sampling of the gold quartz vein of the field and considered that the economic potentialities of the field were encouraging to warrant detailed exploration.

Krishnamurthy (1963) carried out mapping and study of gold quartz vein, ancient workings, modern mines and structural features of gold quartz mineralisation and summarised the geology and stratigraphic controls for ore-mineralisation and economic potentialities of the field for future mining.

METHODS OF STUDY:

Field work was undertaken in and around Mid Pennar Reservoir Project area, covering about 80 square miles. In total about 8 months were spent in mapping the area, spread over a period of three and half years.
The regional distribution of the constituent rock units has been studied. Structural map of the area has been prepared. Petrographic study of about 530 thin sections, cut from about 300 representative rock specimens, has been made.

Modal composition of the rocks has been determined by estimating the volume percentage on Leitz Six spindled Integrating Stage. In the case of coarse grained rocks and in the rocks exhibiting erratic distribution of mineral assemblage, determinations have been made on three or four sections, cut from the same rock at different portions and the averages of the traverses measuring in total of 300-400 mm. have been taken to obtain close approximation to the actual volumetric composition. In the case of intergrowth textures like perthite and antiperthite, volumetric estimation has been carried out with camera lucida diagrams. Camera lucida diagrams of the intergrowth textures of the minerals have been drawn on a tracing paper, which is superposed on a graph sheet. The area occupied by each mineral is represented in percentages.

Optic axial angle, extinction angle, birefringence, pleochroic scheme, and crystallographic distribution of perthitic blebs in potash feldspars, have been determined on the Leitz 4-axes Universal Stage.

The anorthite content and the twin laws of plagioclase feldspars have been determined on the 4-axes Universal Stage by Reinhard (1931) and Rittman Zonal methods (Emmons, 1943; Kennedy, 1933). The complex laws have been checked by the methods of Nikitin (1936) and Berek (1924). In all these Universal Stage methods, hemispheres with R.I. 1.514, 1.554, 1.557 and 1.649
have been used and appropriate corrections have been applied.

The mean refractive index ($N_m$) has been determined on grains passed through 80 mesh and separated in bromoform and various dilutions of Clerici's solution, observing the conoscopic figures in sodium light. The refractive index has been read immediately on Abbe refractometer or Leitz Jelly refractometer.

Separation of minerals from rocks, for chemical analysis has been carried out by using horse-shoe magnet, heavy liquids and Frantz Isodynamic magnetic separator. Chemical analyses have been done by the standard chemical methods outlined by Groves (1951), Shapiro and Brannock (1956) and Riley (1958). S.P.600 Unicam spectrophotometer has been used for the determination of SiO$_2$, Al$_2$O$_3$, Ti O$_2$, Fe$_2$O$_3$, MnO and P$_2$O$_5$. Na$_2$O and K$_2$O have been determined by making use of the Kipp flame photometer. The standards have been repeatedly checked against the standard specimens of the granite (G.1) and the diabase (W.1) described by Fairbairn, et.al (1951).

NOMENCLATURE:

Many terms have been introduced by many petrologists for many rocks, many processes, and many ideas. Smithson (1963,P.12), points out that many useful and petrographic terms have genetic implications, even though they should be descriptive. In the present work some of the terms used have descriptive significance and some have genetic significance and are hence described below for clarity.

**Granite:** is a phaneritic rock composed essentially of quartz, potash feldspar and/or sodic plagioclase (Turner and Verhoogen, 1960, P.330; Smithson, 1963, P.13).

**Granitisation:** is any process or group of processes involving...
entry and exit of material and by which solid rock is converted (or transformed) to a gneissic rock without passing through a magmatic stage (Sorensen, 1961).

**Gneiss**: is used here in a lithologic sense and is not intended to mean that the rock is of igneous origin. It refers to a foliated metamorphic rock (commonly quartz- and feldspar-rich) the approximate composition of which is generally indicated by suitable petrographic, mineralogic or even petrogenic modifying terms.

**Migmatite**: is megascopically composite rock that once consisted of geochemically mobile and immobile (or less mobile) parts (i.e., it consists of igneous or igneous-appearing, and/or metamorphic materials), (Sorensen, 1961).

**Schlieren**: Irregular streaks or masses with blended outlines which occur in some migmatites and magmatic rocks (Sorensen, 1961).

**Granulite**: as used here follows the usage of Harker (1939, p.246-248) to designate a high-grade foliated metamorphic rock consisting mostly of quartz and feldspar. The term denotes a lithologic type and does not mean the granulite facies of metamorphism.

**Xenolith**: is a fragment of foreign rock (Compton, 1962, P.285).

**Sericite**: This term is used to designate very fine-grained micaeous minerals with positive elongation and rather high birefringence.

**Inclusion**: refers to any substance in any state which differs in chemical composition and which is noncommittal genetically.

**Porphyritic**: adjective applied to a rock containing megacrysts in igneous rocks (megacryst is a large crystal that occurs in a finer grained groundmass and it is used in place of phenocryst or porphyroblast when the origin is doubtful).
**Foliation:** Megascopically recognisable s-surfaces defined by lithologic layering, planar preferred orientation of grain boundaries, discrete fractures or combination of these. (Turner and Weiss, 1963, P.97).

**Schistosity:** Foliation defined by the preferred orientation of tabular minerals especially micas (Turner and Weiss, op.cit., P.100).