Nature of Metamorphic Basement of Cauvery Basin, India; Structure, Texture, Mineralogy and Electro log characteristics

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Abstract

This paper aims at establishing type and nature of basement in Cauvery basin. The Basement rocks of Cauvery Basin are high grade regional metamorphic rocks of granulitic facies namely banded quartzo feldspathic micaceous garnetiferous gneisses and migmatitic gneisses. Structurally they are alternating bands of coarse grained Felsic (Quartz+feldspar) and medium grained mafic (mica + pyroxenes) minerals. Differential grain interactions, differential secondary alterations are exhibited by these compositional variations, Felsic portions are more compact, less dense and offers higher gamma, lower PE and lower bulk density. Mafic portions are less compact, highly dense and offers lower gamma, higher density, and higher PE values. Resistivity is dependent of alteration coefficient. Contrary to the popular belief that metamorphic basement rocks exhibits less possibility of permeability, it is observed that mafic bands in banded gneissic rocks are permeable. Due to the platy mica dominance, and poor grain bonding in the mafic zones, a planar weak plane is naturally present and facilitates fluid movements when altered. Presence of Cordierite indicates that these are metasedimentary rocks formed by the metamorphism of existing sediments and are part of Eastern Ghat mobile belt or Southern Granulite terrain.

Keywords: Basement, Metamorphic, Gneiss, alteration, permeability

Introduction

Basement rocks can be described as any metamorphic or igneous rocks which are uncomformably overlained by sedimentary sequence in a sedimentary basin (Landes et.al, 1960). The Cauvery basin is one of the major pericratonic rift basins along the east coast of India that have developed during the rift-drift events associated with the breakup of India from the east Antarctica. It is divided into a number of sub-parallel horsts and grabens, trending in a general NE-SW direction and further sub-divided into four sub-basins namely Ariyalur-Pondicherry in the north, Tranquebar Depression, Nagapattinam Depression, Thanjavur Depression in middle part and Ramanad and Mannar Depression in the southern part (Ramraju et.al). The Precambrian rocks belonging to the Eastern Ghat Mobile Belt (EGMB) and Southern Granulitic terrain limit the basin in the west (M. Santosh, 2019).

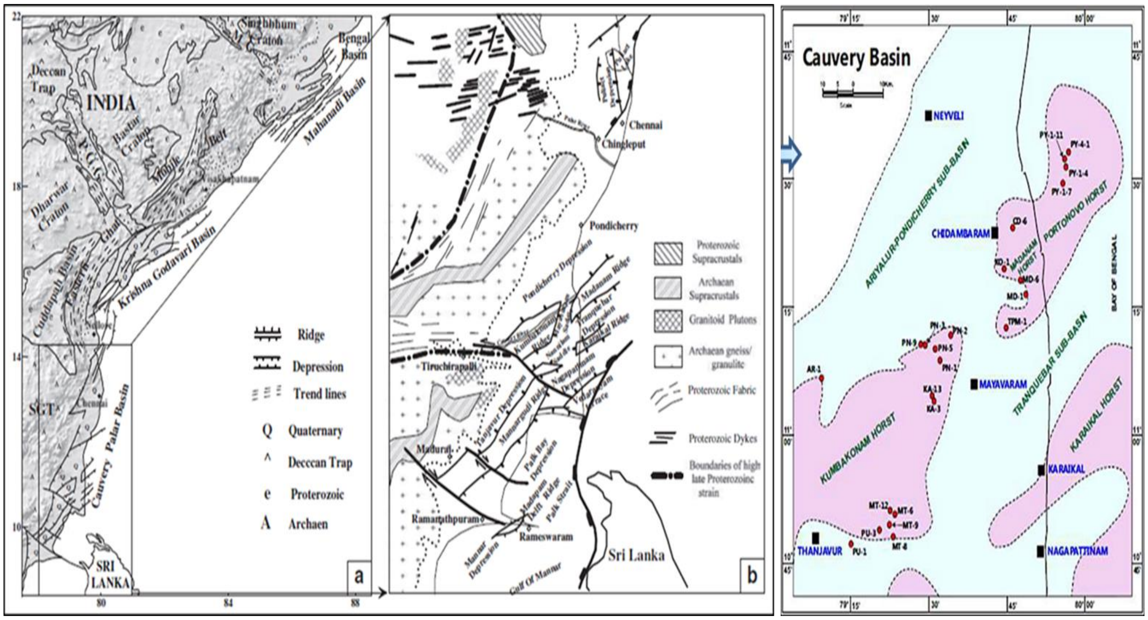

Fig 1. a) Morphotectonic map of East coast of India showing location of Cauvery basin. b) Geological, tectonic and structural features of the Cauvery basin (after D Twinkle et al, 2016). Cauvery basin with studied areas is displayed here.

Tens of wells were drilled into to basement mostly if not exclusively in Kumbakonam-Madanam ridge and its off-shore extension. Out of which around 15 wells are hydrocarbon producers and in many wells indications of hydrocarbons were present. Even though basement was encountered in many wells in all sub basins, hydrocarbon indications from basement were present only in the wells located at highs of Kumbakonam-Madanam-Portonova horst at relatively shallower depths. Basement reservoirs of Madanam, Mattur and Pundi areas are prolific. Basement is varying laterally and vertically at across the wells as well as fields because of the processes. Primary lithological variations and secondary chemical alterations causing electrolog parameters to vary (10-10000 Ohm-m resistivity and 20-150API gamma) vertically across a well and laterally across a field.

Objective

The objective of the study is to identify the basement type and its associated mineralogical suites, integrate mineralogical and micro structural data with electrologs to better understand the compositional and basic electrologs variation over the fields. Cutting samples as well as conventional cores were used for megascopic, petrographic studies. Major mineralogical constituents along with minor minerals were identified and accordingly metamorphic rock suites and zones were interpreted. The effect of mineralogical constituents on the electrolog are inferred.

Megascopic and petrographic studies

Megascopic and petrographic evaluation of conventional cores and cutting samples representing basement from different parts of the Kumbakonam-Madanam ridge are presented below

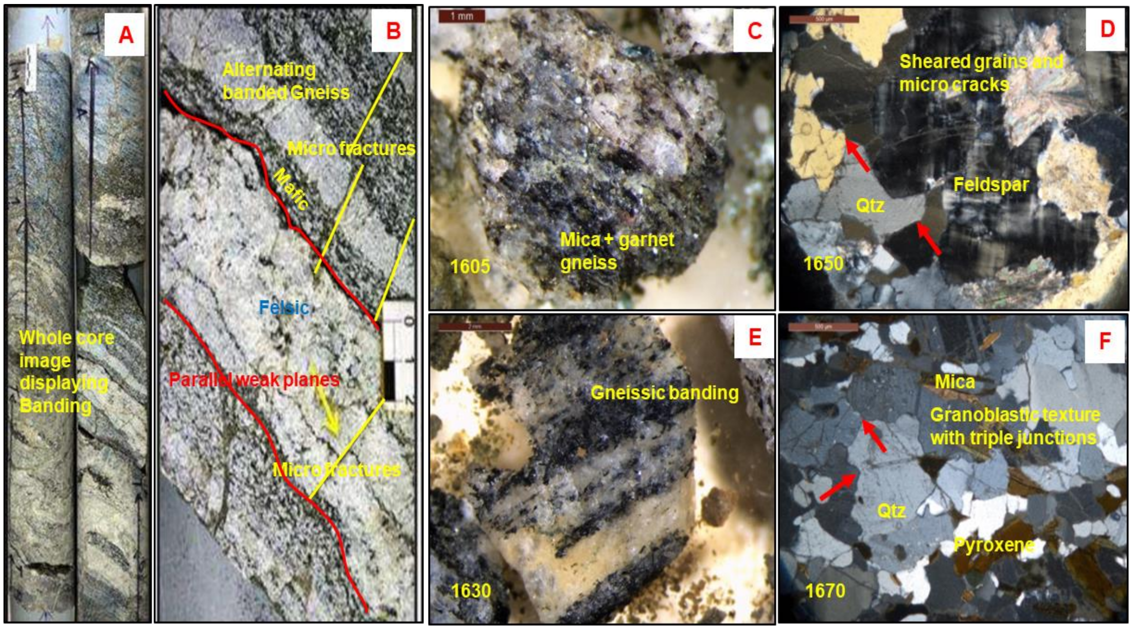

Fig 2. Megascopic and petrographic studies of conventional core CC-D and cuttings of the well Pundi-C. Image A displays whole core photograph displaying gneissic banding. Image B is a slabbed portion of the core. Alternate bands of felsic (whitish grey) and mafic (greenish grey) compositions can be seen. Parallel micro fractures perpendicular to primary banding can be seen. Images C&D are megascopic images of Basement cuttings those are displaying gneissic banding and Schlieren structures. Images D&F displays petrography of the basement. Granoblastic texture with multiple triple junctions along with sheared grains can be seen. Quartz, feldspar, pyroxene, mica and garnet are identified.

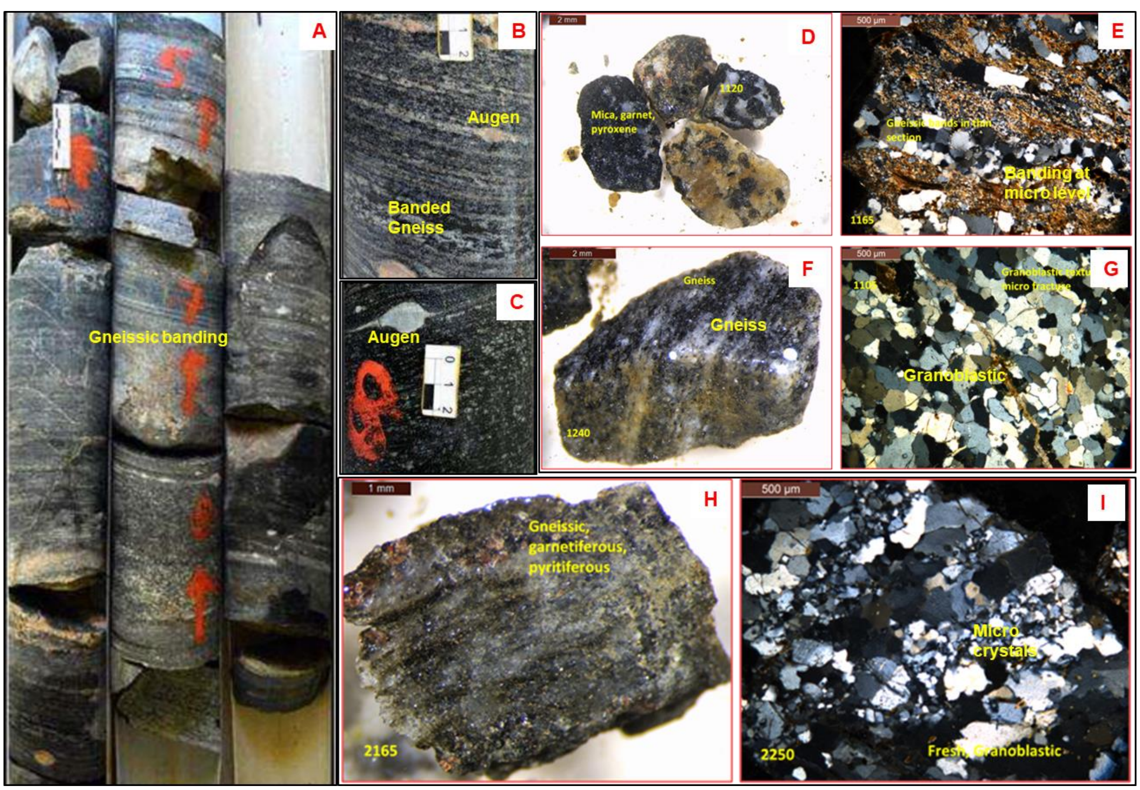

Fig 3. Megascopic and petrographic studies of conventional core CC-C of well Mattur-H and cuttings of the well Mattur-K and Mattur-L wells. Image A displays whole core photograph of CC-C of well Mattur-H displaying gneissic banding. In images B&C, augens can be seen along with gneissic banding. Images D, F displays megascopy of cuttings of the well Mattur-K. In petrographic images E and G, granoblastic texture and micro mineralogical adjustments can be seen. Images H and I displays Megascopy and petrography of cuttings of the well Mattur-L where garnetiferous gneiss can be seen along with clusters of micro-crystals those are remnant of former melts.

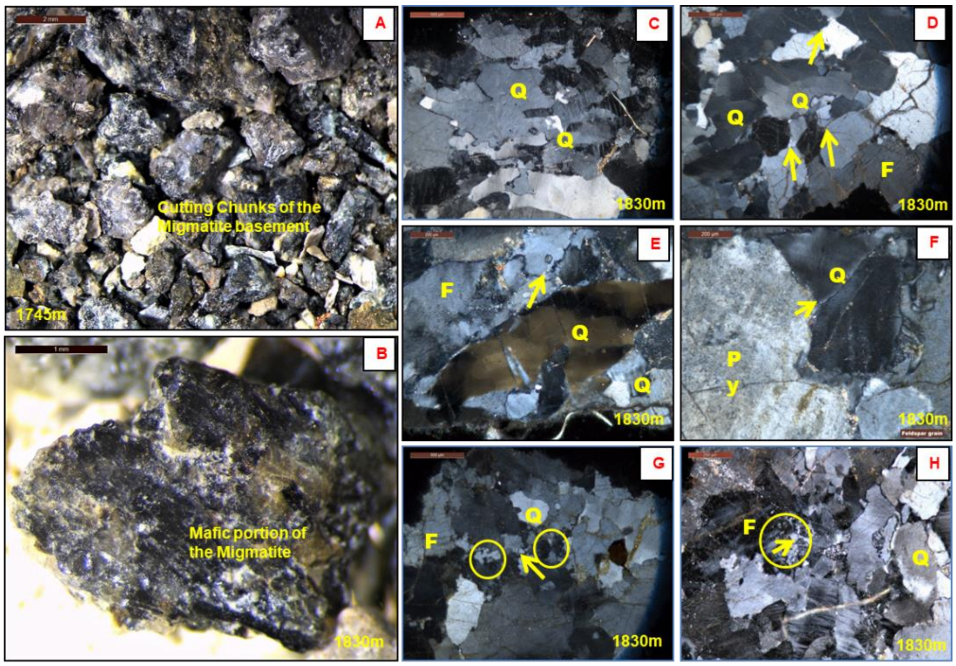

Fig 4. Megascopic and petrographic studies of basement, well Madanam-K. Megascopy of migmatite cuttings are displayed in the images A and B. No banding. This portion of the basement is mafic dominant. Microphotographs of cuttings are displayed in images C, D, E, F, G and H. Minerals quartz, feldspar, pyroxene are shown as Q, F and Py respectively. Granoblastic texture and micro-crystal clusters can be seen.

Mineralogy, structure and texture

As evident from megascopic and petrographic studies, basement encountered in the study area is exclusively metamorphic in nature. Major minerals identified were quartz, k-feldspars, plagioclase, biotite mica, ortho pyroxene and garnet along with cordierite. It can be termed as Quartzo feldspathic mica garnetiferous gneiss, migmatitic gneiss Presence of cordierite indicates that these are metasedimentary rocks formed by the metamorphism of existing sediments. Basement consists of zones of coarse grained felsic rich portions (quartz+feldspars) and medium to fine grained mafic rich portions (mica+pyroxenes) which are very different at grain interaction level.

Euhedral to sub hedral crystals of quartz and feldspar intergrow each other tightly with compact grain boundary because both are tecto-silicates and create compact bonding until disturbed by secondary fluids. Mafic zones those are rich with mica which is in platy crystal shape offers relatively weak bonding with surrounding mineral grains of different size and shape thus creating weak planes. These mica sheets are aligned parallel if not highly migmatized or folded. These two zones undergo differential alteration and produce different secondary minerals. Felsic rich portions are dominantly more compact and less dense when compared to its mafic zones. Weak minerals like feldspar, pyroxenes and micas undergo chemical alteration on interaction with hydroxyl ion and create hydroxyl alumina-silicates i.e. clay minerals. Granulitic gneissic structure and granoblastic texture is identified.

Basement rock is exhibiting granoblastic interlobate to granoblastic polygonal texture at places. Most of the grains are sub hedral to euhedral. Recrystallization, micro-fractures and cracks are seen. Large elongated polygonal quartz crystals with elongated grains contacts, parallel arrangement, presence of broad rounded suturing around the grains due to coalescence (indicative of high pressure gneissic domain), numerous triple point aggregates (indicative of high grade granoblastic granulitic facies) and small clusters of fine grained quartz and feldspar (remnants of former melts) are seen. Along with the numerous magmatic textures also identified. Schlieren structures, migmatitic foliations, augens, ptygmatic folds are some of them.

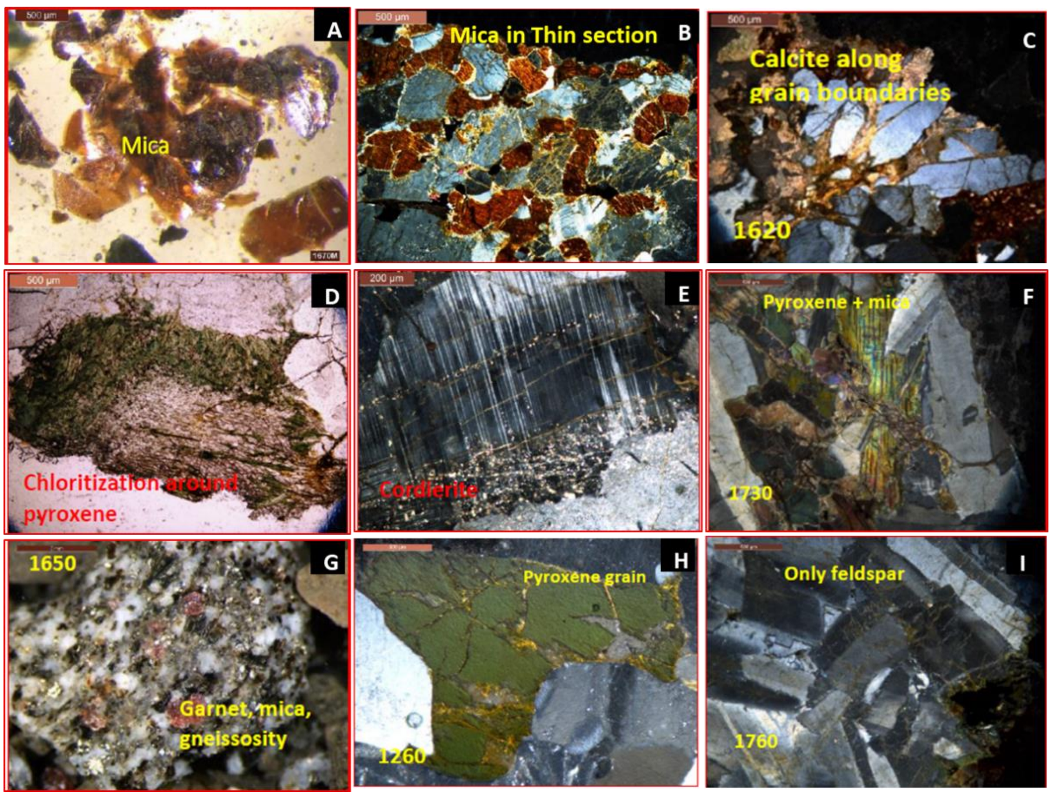

Fig 5. Primary and secondary minerals identified in studied area.

Electrolog Variations and relation with mineralogy

Log digital data is collected from LAS files and analysed to see patterns in resistivity, gamma, and density logs and to correlate them with mineralogical observations. A glimpse of all resistivity, gamma, and density of wells from the Kumbakonam-Madanam Ridge is presented below in charts. These variations are due to the primary mineralogical variations, felsic dominance on mafic portions and vice versa, secondary alterations, strength of migmatizations, structural variations, grain boundary interactions etc.

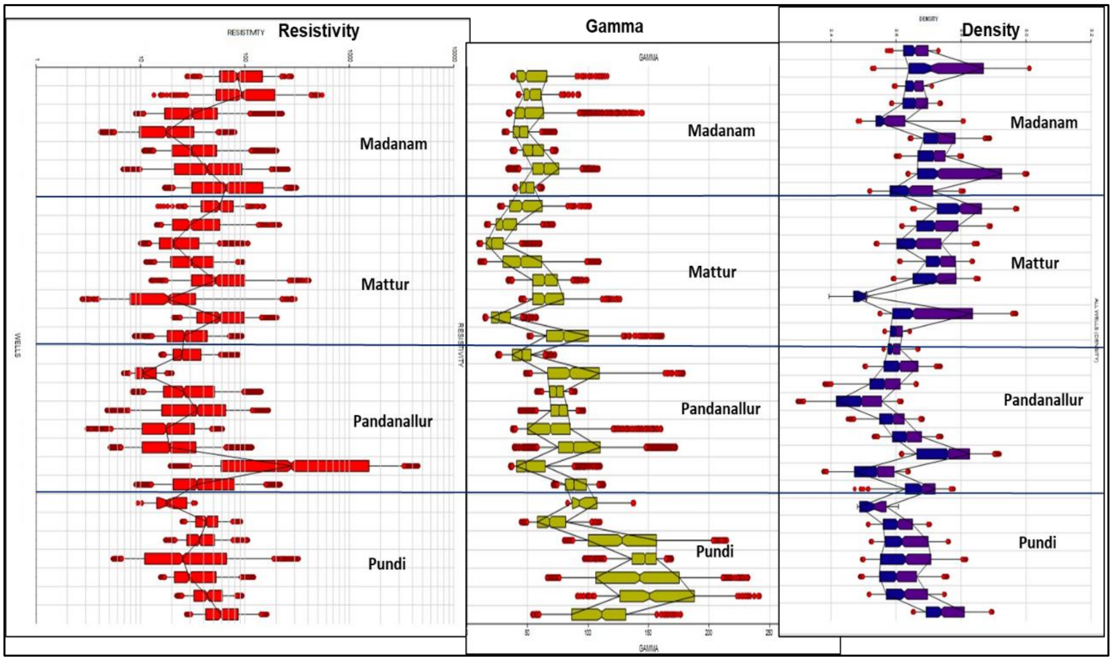

Fig 6. Resistivity, natural gamma data and bulk density (electrolog data) of the basement encountered in multiple wells of Madanam, Mattur, Pandanallur and Pundi fields are plotted in box plot.

Resistivity of Madanam and Mattur basement is higher compared to Pandanallur and Pundi area where as Gamma of Pundi and Pandanallur wells is higher compared to Madanam and Mattur wells indicating that Pandanallur and Pundi areas are rich in felsic compositions and altered. Density variation among the wells also conform that Madanam and Mattur areas are rich in mafic compositions.

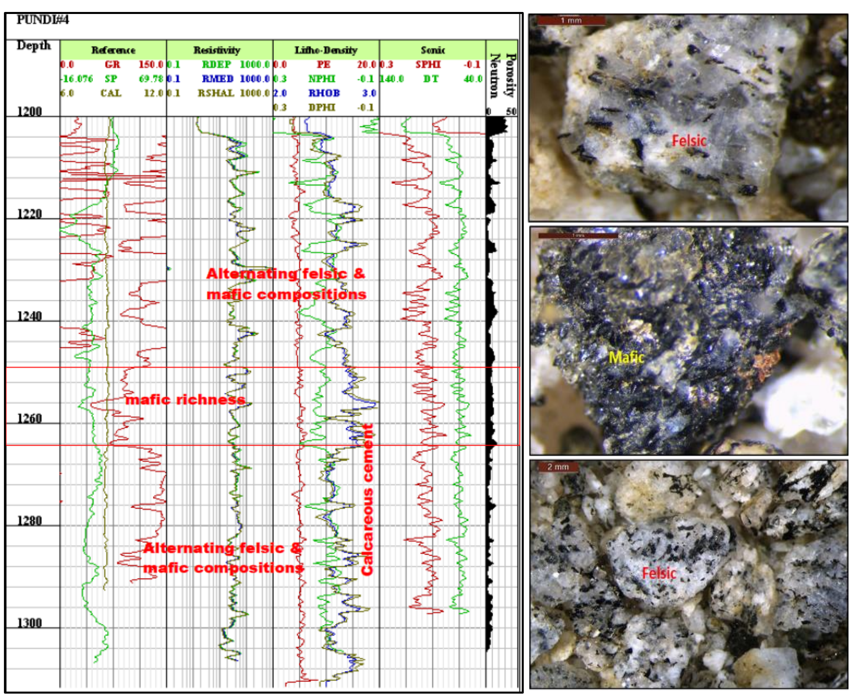

Fig 7. Felsic and mafic compositions on electrolog and corresponding mineral suites. Alternating felsic and mafic bands can be seen. Gamma of felsic portions is high and density of mafic portion is high.

Conclusions

The Basement rocks of Cauvery Basin are high grade regional metamorphic rocks of granulitic facies namely banded quartzo feldspathic micaceous garnetiferous gneisses and migmatitic gneisses. Structurally they are alternating bands of coarse grained Felsic (Quartz+feldspar) and medium grained mafic (mica + pyroxenes) minerals. Felsic portions are more compact and less dense and offers higher gamma, lower PE and lower bulk density due to strong grain interactions primarily and presence of K-rich feldspars. Mafic portions are less compact and highly dense and offers lower gamma, higher density, and higher PE values due to the presence of iron rich minerals. Resistivity is dependent of alteration coefficient. Presence of cordierite indicates that these are metasedimentary rocks formed by the metamorphism of existing sediments and are part of Eastern Ghat Mobile Belt or Southern Granulite Terrain.

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