Petrological and Mineralogical Characteristics of different rocks exposed in the Northern part of the Southern Granulite Terrain, Tamil Nadu, India

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Abstract

The Mafic–Ultramafic Complex (SMUC) in Salem District is significant in the Southern Granulite Terrane (SGT), India. It is located in the northern part of the Cauvery Suture Zone (CSZ), is also known as the Chalk Hills of Salem. This study is an attempt to review the petrographic characteristics of the mafic- ultramafic rocks which covers the SGT, especially northern side of the of peninsular India. The study of the petrographic characterization of present rock types aims to understand the textural and mineralogical variations present through the traverse covering the Madurai block, Palghat-Cauvery shear zone and Madras block. Various mafic-ultramafic complexes are located in Peninsular India's SGT. Among these, three essential complexes are Salem Mafic-Ultramafic Complex (SMUC), Sitampundi Anorthosite Complex (STAC) and Bhavani Mettupalayam Ultramafic Complex (BMUC). The different rock types like Anorthosite, Dolerite, Magnesite, Banded Magnetite Quartzite (BMQ), Laterite were concentrated from these complexes.

Keywords: Anorthosite, Dolerites, Banded Magnetite Quartzite (BMQ), Salem, Southern Granulite Terrane.

1. Introduction

The Southern Granulite Terrain (SGT) plays a significant role in the numerous Gondwana reconstruction models of South India. The important crustal blocks that occupies in the SGT are Madras, Salem, Madurai, Coorg, Nilgiri and Trivandrum. Among these, the Salem arc, Madras arc, Nilgiri arc and Coorg arc are the major tectono-magmatic arcs which are to be expected in the SGT (Sam et al., 2017; Mohan and Meyyappan, 2022). The shear zones are

occupied by ultramafic-mafic suites in the SGT. These rock minerals are able to preserve the chemical evidence of igneous processes and metamorphism (Sam et al., 2017; Mohan and Meyyappan, 2022). Magnesite deposits is significant and designated as Salem Mafic-Ultramafic Complex (SMUC) chalk hills, which are also located in the north-central portion of the Cauvery Shear Zone (CSZ) (Kutty et al., 1986; Yellappa et al., 2014). Many authors have concentrated on the petrography primarily focusing on the SGT. Earlier workers (Howie, 1955; Rama Rao, 1945) reported various petrographic descriptions of different rocks present in the SGT. Thus, the present study is carried out to highlight the importance of petrographic characteristics of the rock types in and around Salem district, Tamil Nadu.

Salem is located between 11° 14' and 2° 53' N Lat. and between 77° 44' and 78° 50' E Long. It covers the geographical area of 5205 km^2 with an average elevation of 278 m. The town is covered by hills: Nagaramalai in the north, Jarugumalai in the south, Kanjamalai in the west, and Godumalai in the east which is divided by the Thirumanimuthar river. Yercaud is located in the northern part of the Salem district i.e., in the Shevaroy hill range of the Eastern Ghats, at an altitude of 1515 m (4969 ft.) above the mean sea level which is located between 11°46' -11°77' N Lat. and 78°12'- 78°20' E Long. (Pandian et al., 2014). Bauxite mines found in Yercaud which shows the presence of Lateritic Bauxite and Weathered Charnockites. It occurred as irregular masses of lenses and bauxite pockets / bauxitic laterite occur in the high-level laterite cappings over charnockite in the Shervaroy hills (1535-1649m) (Krishnaswamy, 1958) at Salem District. The present study focuses on the petrography of different rock types namely Banded Magnetite Quartzite (BMQ) and Magnesite from Kanchamalai, Dolerite dykes and Laterite from Yercaud and Anorthosites from Pamagoundapalayam in and around Salem area (Fig. 1).

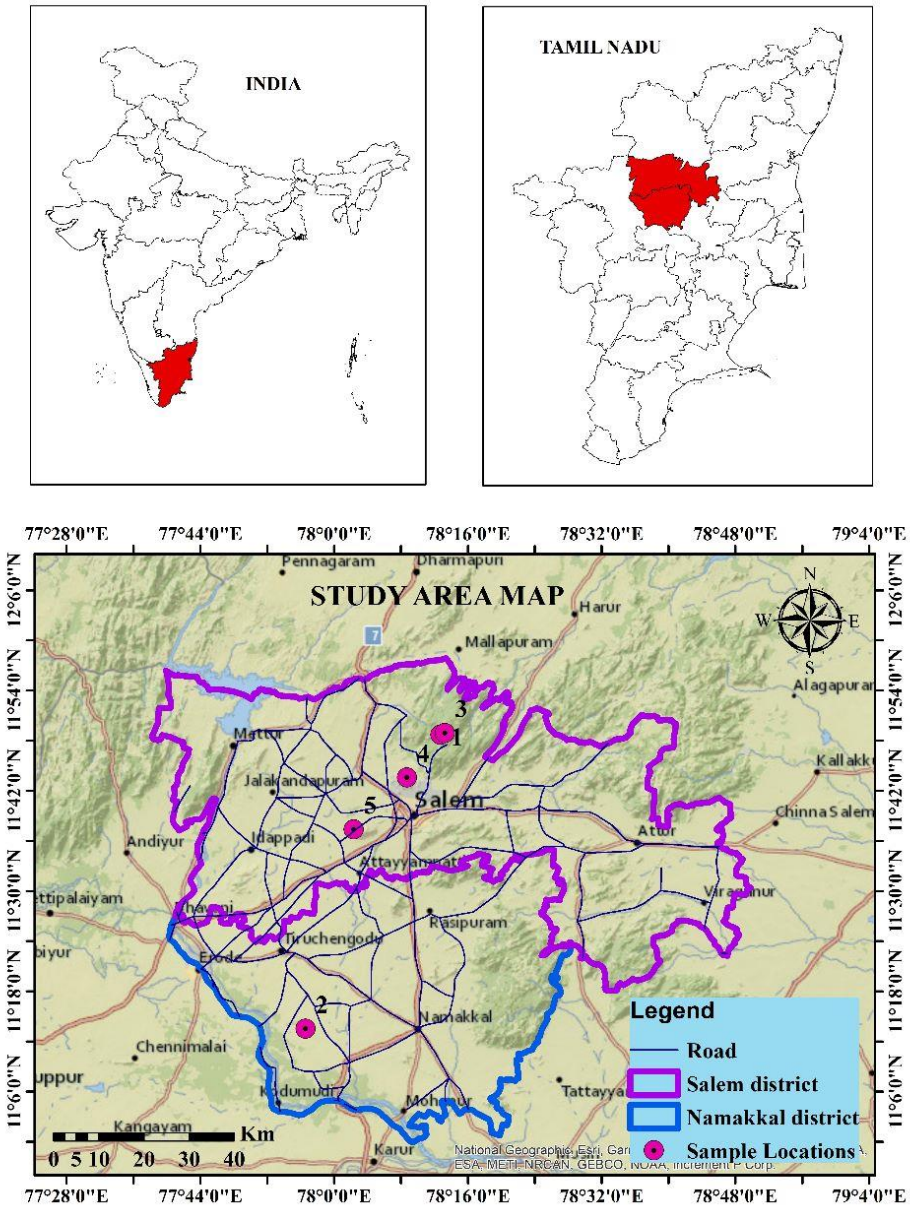


Fig. 1 Geological Map showing the locations of the samples collected from Kanchamalai, Yercaud and Pamagoundapalayam areas in Salem District, Tamil Nadu, India.

1.1 Kanchamalai

The Dharwar rocks in Kanjamalai are represented by the Ferruginous quartzites also known as Banded Magnetite Quartzite (BIF) are the oldest and the only sedimentary members in

this region. These rocks are overlained by the pyroxenites, amphibolites, gabbroic rocks and finally Dharwar rocks ended with dunite. Dharwarian rocks succeeded by peninsular gneisses and intrusion of granites, pegmatites, aplites are marked over the peninsular gneisses as closepet Arcot granites. Above all, dolerite dykes have been found as post-Archean which is youngest in the order of sequence of the Kanjamalai (Pandian et al., 2014). The earlier study of petrological, geochemical, petrogenesis and origin of iron formations reveals that the Kanchamalai at Salem area is the oldest formation having sharp contact with younger pyroxene granulite and granite gneissic rocks. The mineralogical composition is same among the bands (Lower, Middle and Upper) and it is quartz+ magnetite+ grunerite+ hematite+ hypersthene. The geochemical study reveals the contribution of clastic contamination. Moreover, the nature of deposition and lack of volcanic activity were observed and indicated that the Kanchamalai iron formation is Precambrian BIF and of meta-sedimentary origin (Rajendran and Chandrasekaran, 2000). Thick mafic bands of Kanjamalai complex consisting of interlayered BMQ which records a supracrustal shallow basinal sedimentation accompanying tholeiitic magmatism followed by repeated deformation (Bose et al., 2001).

1.2 Yercaud:

Charnockite suite of rocks are occupied by the Bauxites of yercaud area. They occupy the peaks of the hillocks which have characteristic flat-topped surfaces. Generally, bauxite occurs as small lenses, lenticular masses and patches of bauxites and aluminous laterites occur in laterite with gradational borders. The colour of the bauxite varies from yellowish brown to reddish brown and it is of the lateritic type (Pattan and Appangoudar, 1985). Dolerite dykes intruded (the lineament controlled alkaline complexes) in the older basement of gneisses and banded iron formations of Salem district which is exposed along the hill slope of Yercaud. The detailed geochemical studies have been carried out by Jayabalan et al. (2012). The report of these dykes of dolerite composition are intruded in the Southern Granulite Terrain (SGT) (Devaraju, 1995; Srivastava et al., 2008; Srivastava and Ahmed, 2008, 2009; Srivastava, 2011).

1.3 Pamagoundapalayam:

The ancient Earth crust consists of mainly anorthosites and play a significant role on petrogenesis and geodynamic processes especially related to convergent margins (Polat et al.,

2011; Hoffmann et al., 2012). In Southern India, Sittampundi Anorthosite Complex (SAC) is associated with Archean layered anorthosite-gabbro-ultramafic rock (Subramaniam, 1956; Bhaskar Rao et al., 1996). The layered sequence of meta-anorthositic gneisses containing chromitite bands and eclogite-gabbros are exposed in an arcuate belt (Subramaniam, 1956). Earlier studies of this highly metamorphosed anorthositic rocks are dominated by 90% calcic plagioclases with 10% mafic minerals (Subramaniam, 1956; Ashwal, 2000). The SIMS U-Pb age dating of zircon of these anorthosite reveals 2522±12 Ma. These ages revealed that the it was formed during the Dharwar cratonization and has been derived from mantle magma underplated to extensive lower crustal melting in Dharwar Craton (He et al., 2021). Similarly, Sm–Nd isotopic studies of SAC of age 2935 ± 60 Ma indicating Archean period (Bhaskar Rao et al., 1996). Zircon U-Pb geochronology for the anorthosite rock gives 2541 ± 13 Ma considered as magmatic crystallization age for Sittampundi anorthosites (Ram Mohan et al., 2013).

2. Geological setting

The present study area is located at the SGT i.e., at the northern part of the SGT in Tamil Nadu. The Salem area is considered as a part of high grade metamorphic rocks – mainly hypersthene bearing gneiss/granulite and hornblende biotite bearing banded dioritic gneiss (Yellappa et al., 2016). Basic/ultrabasic rocks like metapyroxenite and actinolite-talc schist occur as xenoliths of various shapes and sizes in the banded gneiss. Pink syenite, basic dykes, quartz reefs/veins and pegmatite veins are the younger intrusions (Yellappa et al., 2016). It is a part of north-central Tamil Nadu which lies between the two E–W trending lineaments i.e., Palar Lineament (PL) in the north and Moyar-Bhavani-Attur Lineament (MBAL) in the south. It is transected by two NNE-SSW trending lineaments, namely Jawadi Hill West Lineament (JHWL) in the east and Mettur-Palaghat Lineament (MPL) in the west. This zone extends from Gudiyattam in the north and Bhavani in the south known as central zone or Dharmapuri Suture Rift Zone (Gopalakrishnan, 1993). It shows a number of prominent alkali syenite carbonatite complexes (e.g. Elagiri, Koratti and Samalpatti) and quartz and quartz-ankerite veins/reefs intruded along shear zones carrying Mo, Pb, Cu mineralisation (e.g. Harur, Alangayam). The Omalur area forms the southern extremity of this zone which lies to the immediate west and NW of Salem.

2.1 Kanchamalai:

In Kanchamalai, we collected Banded Magnetite Quartzite (BMQ) and Magnesite. Banded iron formation was found on top of the hill (Fig. 2a & b). The Magnesite veins could be seen prominently in the hill. The kanchamalai was a hard rock and highly metamorphic terrain. It is important for banded iron ore formation. This banded iron ore also found in south Africa and Bihar. This hill is in the form of antiformal syncline because rock of hill is dipping toward center. The millions of years ago it was a geosyncline then the sandy particles are get trapped and deposits and form a sedimentary region then latterly due to magmatic process hematite were formed again by action of wind the sand was deposited and process of compaction and cementation the sandy matter which form a sandstone. Due to the metamorphism the sandstone and magnetite were change into the form of quartzite and hematite (cherry red in color). The west direction of that mountain from the downward to upward the major dunite intrusion would colloid the mountain, because of magmatic intrusion the horizontally banded magnetite quartzite would altered and form as a disharmonic fold. Three layers of BMQ around this hill: 1st layer is discontinuous band, from the western side it is in 150-200ft and from the eastern side it is 600ft in height. The 2nd layer which in 1369ft in height this layer also discontinuous band and the 3rd layer is continuous band. This hill is which look like inverted boat that's mean canoe in shaped. The trend follows SSE dip direction and NNW regional strike direction. Basement is the Archean rock. Age of the mountain is 2600 million years, dunite intrusion was 2100 million years. The estimated resource of three band is about 55.52 million tones where upper and middle band about 7.6m thickness and 9.6 km where1st and 2nd of iron ore whose grade is about 70% yield. Where Banded Magnetite Quartzite (BMQ) band shows many intricating fold due to shearing activity in cauvery-attur shear zone (Fig. 2c). This hill is surrounded by tonalite gneiss some schorl rock are seen where it is of quartz and tourmaline which is a metamorphosed by charnockite where the feldspar is replace by tourmaline.

An open cast mining located at Chettichavadi, Salem district, it is owned by Dalmiabharat sugar and industries Ltd (Fig. 2d). The basic Charnockite has been intruded by an ultra-basic magma. About 2100 million years ago, due to the hydrothermal hydration Dunite altered into magnesite ($MgCO_3$). This magnesite is a high grade one, containing 99% of MgO, 16% of Silica associated with Opal, Asbestos, Serpentine, Magnesium, Chromite was formed as

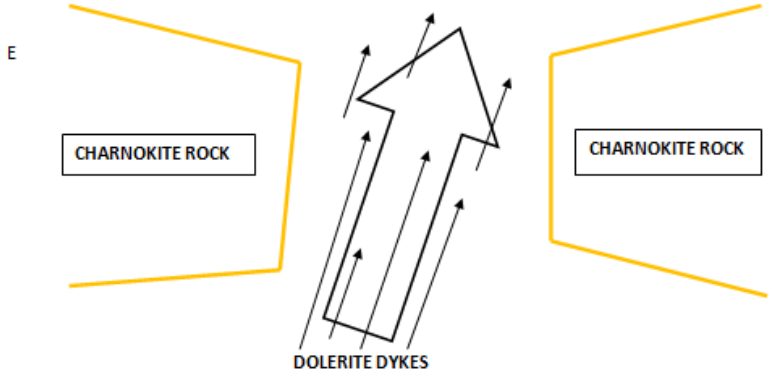
latter vein. Dunite is mono mineral rock of olivine, having sugary texture, Olive green in color which is used for ceramic bricks, refractories, etc. At present, mine is not operational but the number of pits proposed for production was 3 pits .

Fig. 2. Field photographs showing (a) Small hillock of Kanchamalai, (b) Banded Magnetite Quartzite (BMQ) bands present in this hill which is also surrounded by Tonalite gneiss, (c) Impure Bauxite (d) Magnesite mines at Chettichavadi area.

2.2 Yercaud:

The dolerite mine is exposed on the slope of the hill of Yercaud (Fig. 3a & b). The mine consists of olivine mixed dolerite, composed of labradorite, silica 5%, pyroxene, plagioclase feldspar and magnesium. The dolerite dykes are formed toward the East-West direction. During the Archaen age, due to some shearing activity at NNW to SSE, a major fracture was formed resulting to the exposure of secondary dolerite magma and crystallizing to form the dolerite. This dolerite is commercially called as “black granite”. The dolerite grains are fine grained and the texture is Aphanitic. The maximum width of a dyke ranges from 30-60 meters. The dolerite dykes are found intruded in between charnockite rocks and this is known as “Litho contact”.

The shervaroy hills known as Yercaud located in the (~ 10 Km) north of Salem town, which is elevated ~ 5000 feet above MSL. The laterites of Yercaud contains about 60-65% of iron and alumina (Fig. 3c). The geological succession of Shervaroy hill comprises a laterite and bauxite zone covered below black humus soil and underlain by rocks of Precambrian age comprising dolerite, charnockite and garnetiferous gneiss. The primary deposits are usually surrounded by detrital laterite zone, derived by the erosion. At few places, this detrital material is found to be recemented. The Shervaroyan temple located there inside a cave-which is made up of bauxite. The rock found at Salem is basic charnockite, which is metamorphosed into kondalite, due to chemical weathering this kondalite get altered into laterite which is red in color. The leached reduced iron ore mineral, limonite is found yellow in color in between the laterite. The continuous rainfall, high altitude and chemical weathering of laterite. Due to the above condition and porous laterite rocks are formed and due to continuous rainfall, the rainwater react with porous laterite the magnesium and iron content are washed out and remaining alumino silicates compact to form “Bauxite” (Fig. 3c). Since iron and magnesium remain with alumino silicate the bauxite is 90% impure.



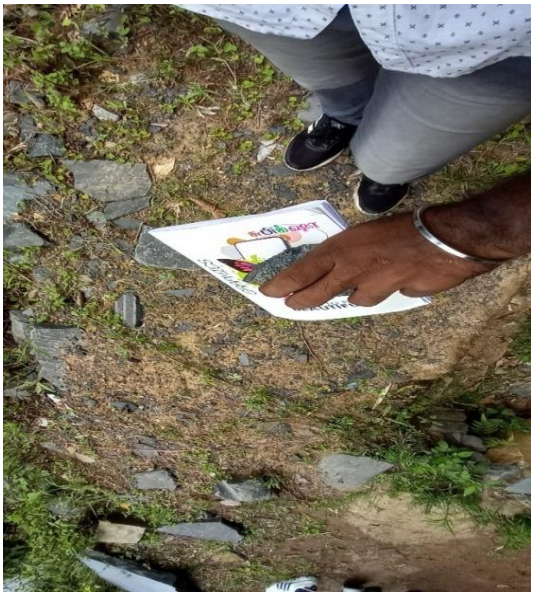


Fig. 3. Field photographs showing (a), (b) Dolerite dykes exposure at Yercaud, (c) Bauxite mines (where laterite was collected) at Yercaud

2.3 Pamagoundapalayam:

The anorthosite is closely layered with chromitite (Mono-minerallic rock of chromite) (Fig. 4). The age of the rock is around 2200 Ma. Origin of this rock is acid igneous. The anorthosite emplaced here is due to major shearing activity, along N-E, S-W direction. At the junction between chromitite and anorthosite, gemstones occur. Significantly, Ruby (Corundum) is observed. Chromitite is a deep-seated rock which usually does not occur in crustal surface. But

here it occurs in the crust, because of the tectonic shearing activity. This area belongs to Sittampundi complex.

Fig. 4. Field photographs showing Anorthosite rock layered with chromitite exposed at Pamagoundapalayam belongs to Sittampundi complex.

The present petrographic study for different rocks in the parts of Salem District, Tamil Nadu were carried out to expose the nature of the rock type, metamorphism and characteristics of the minerals present in the rocks.

3. Sample collection

Fresh samples were collected in the areas of Kanchamalai, Yercaud and Pamagoundapalayam which is located in and around Salem area. The present sampling covers almost all the rock types including Banded Magnetite Quartzite (BMQ), Magnesite, Dolerite dykes, Laterite and Anorthosites. The samples were processed and prepared for thin sections. The thin sections were undergone for mineral identification and petrographic study under the microscope. Analytical methods in systematic manner using different instruments for cutting the rock samples and grinding the rock samples followed by heating the samples simultaneously. After cutting, mounting of the rock samples on the glass slide is carried out. The vessels like jawless diamond cutting were used for cutting.

4. Petrography

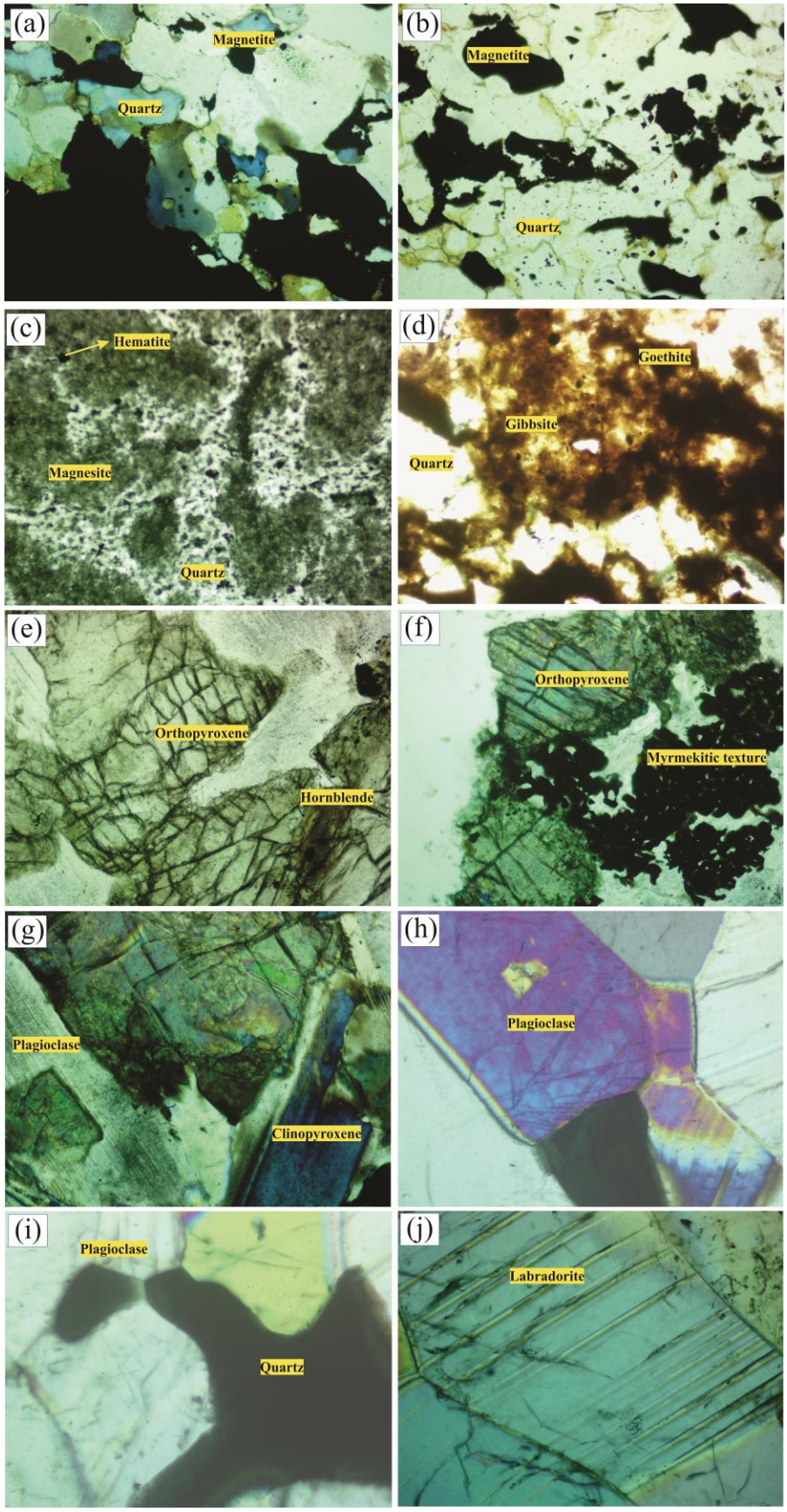

(a)
Magnetite
Quartz
(b)
Magnetite
Quartz
(c)
Hematite
Magnesite
Quartz
(d)
Goethite
Gibbsite
Quartz
(e)
Orthopyroxene
Hornblende
(f)
Orthopyroxene
Myrmekitic texture
(g)
Plagioclase
Clinopyroxene
(h)
Plagioclase
(i)
Plagioclase
Quartz
(j)
Labradorite

Fig. 5 Photomicrographs showing (a) Banded Magnetite Quartzite (BMQ) from Kanchamalai under crossed polarized light, (b) BMQ from Kanchamalai under plane polarized light, (c) Magnesite from Kanchamalai, (d) Laterite from Yercaud, (e) & (f) & (g) Dolerite dykes from Yercaud, (h) & (i) & (j) Anorthosites from Pamagoundapalayam.

Table 1. Petrographic characters for Banded Magnetite Quartzite (BMQ) and Magnesite from Kanchamalai, Dolerite dykes and Laterite from Yercaud and Anorthosites from Pamagoundapalayam in and around Salem area.

S. No	Samples	Petrographic characters
1.	BMQ	Abundant of fine to medium grained subhedral magnetite present. Black coloured magnetite shows isotropic nature. Quartz is associated with the magnetite which shows fine fractured filled with magnetite and hematite. Groundmass is very fine and porphyroblast. Quartz is laminated and surrounded with the magnetite and hematite.
2.	Anorthosite	Large plagioclase laths showing albite twinning with the Michel Lévy method. The composition of this plagioclase crystal is Ab_{38} An_{62} that forms labradorite. Plagioclase sometimes shows zoning with first and second order interference colours.
3.	Dolerite	Medium and coarse-grained plagioclase and pyroxene. Rarer accessories include olivine and anhedral quartz. Euhedral to subhedral opaque oxide minerals were noticed. The texture ranges from poikilitic, ophitic, and rarely porphyritic or glomeroporphyritic. The plagioclase laths are randomly oriented and are sometimes zoned. The clinopyroxene of some samples contain exsolved augite. Olivine is thinly rimmed by pyroxene. These features suggest disequilibrium conditions during crystallization. The clinopyroxene occasionally exhibits uralite coronas. Biotite was observed to rim either amphibole or clinopyroxene suggesting some form of alteration. It shows myrmekitic texture. Myrmekite is an intergrowth of plagioclase and quartz vermicules.

4.	Laterite	Laterites are transformed into Fe-Al oxides. Goethite is lateritized to form bauxite that is Gibbsite. Presence of Quartz and Large quantity of Goethite and Gibbsite are present. It is composed of Goethite and Gibbsite. Gibbsite is colorless to pale brown. The Gibbsite is noticed during lateritization.
5.	Magnesite	Elongated and deformed crystals of magnesite. The crystalline magnesite shows relief changes and pseudo-pleochroism. It also shows hematite and quartz present as accessory minerals. It shows diagenetic replacement and metamorphosed.

5. Conclusion

A detailed petrographic study carried out in the Salem district, brought out the identification of textural and mineralogical components present in the different types of rocks in the study area. The petrographical studies suggesting that most of the rocks types in the study area composed of distinctive mineralogical and textural characteristic propertites which may indicate the multiple stages of metamorphic and deformational activities. Through the study, the rock types identified are Banded Magnetite Quartzite (BMQ), Magnesite, Dolerite dykes, Laterite and Anorthosites in and around Salem area. The field relationship of different rock types suggest that it is the oldest formation which is highly deformed and metamorphosed sedimentary nature. These rocks manifest the distinctive textural characters of geologic processes.

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