Petrological and Mineralogical Characteristics of different rock types exposed in Northern Northern part of Southern Granulite Terrain, TamilNadu, India

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Abstract

The Salem Mafic–Ultramafic Complex (SMUC) is a major complex in Southern Granulite Terrane (SGT), in the northern part of the Cauvery Suture Zone (CSZ), India, also known as the Chalk Hills of Salem. The present study aims to review the petrographic characteristics of the mafic- ultramafic rocks which forms the northern part of the Southern Granulitic terrain of peninsular India. Petrographic study of these 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) occupies a major position in numerous Gondwana reconstruction models in South India. The important crustal blocks 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 expected in the SGT (Sam et al., 2017). The shear zones within the SGT are occupied by the occurrence of ultramafic-mafic suites. These rocks' minerals have the ability to preserve chemical evidence of igneous processes and metamorphism (Sam et al., 2017). Significant magnesite deposits are seen in the designated 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 described the petrography primarily focusing on SGT. Earlier workers (Howie, 1955; Rama Rao, 1945) reported various petrographic descriptions of SGT. Thus, the present study was to highlight the important 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 Sq. km. It has an average elevation of 278 m. The

town i s surrounded by hills on all sides: Nagaramalai to the north, Jarugumalai to the south, Kanjamalai to the west, and Godumalai to the east. It is divided by the river Thirumanimuthar in the main division. Yercaud is located in the northern part of Salem district. It is in the Shevaroy hill range of the Eastern Ghats. It is at an altitude of 1515 meters (4969 feet) above the mean sea level. It is located between 11°46' to 11°77' N latitudes and 78°12' to 78°20' E longitudes (Pandian et al., 2014). Bauxite mines found in Yercaud which shows the presence of Lateritic Bauxite and Weathered Charnockites Irregular lenses and pockets of bauxite / 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.

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-Archaen 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). Interlayered BMQ and thick mafic bands of Kanjamalai complex record a supracrustal shallow basinal sedimentation accompanying tholeiitic magmatism followed by repeated deformation (Bose et al., 2001).

1.2 Yercaud:

Bauxites of yercaud area formed by the charnockite suite of rocks. 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). SIMS zircon U-Pb age dating of these anorthosite reveals 2522±12 Ma. These ages revealed that the anorthosites were formed during the cratonization of Dharwar and has been derived from mantle magma underplated to extensive lower crustal melting in Dharwar Craton (He et al., 2021). Similarly, Sm–Nd isotope studies of Sittampundi anorthosite complex had given an age of 2935 ± 60 Ma indicating Archean period (Bhaskar Rao et al., 1996). Zircon U-Pb geochronology for the anorthosite gives 2541 ± 13 Ma considered as magamtic crystallization age for Sittampundi anorthosites (Ram Mohan et al., 2013).

2. Geological setting

The study area is located at the northern part of the Southern Granulite Terrain (SGT) in Tamil Nadu. The Salem area identified is a part of high grade metamorphic rocks – mainly hypersthene bearing gneiss/granulite and hornblende biotite bearing banded dioritic gneiss. 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 that are recorded in the area. The main rocks can be classified as follows. The area forms a part of north-central Tamil Nadu and lie between the two near E – W trending lineaments, namely the Palar Lineament (PL) in the north and the Moyar-Bhavani-Attur Lineament (MBAL) in the south. It is in turn 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 narrow NNE-SSW zone which extends from Gudiyattam in the north and Bhavani in the south is named 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. 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. 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. 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. 1. 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) Bauxite mines (where laterite was collected) at Yercaud, (d) Impure Bauxite (e) Magnesite mines at Chettichavadi area.

2.2 Yercaud:

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. 2c) . 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 a zone of detrital laterite, derived from them by the process of erosion. At places, this detrital material is found to be recemented. Mode of occurrence of the valley laterites at places suggests that it is not an alteration product of charnockites, but it is of detrital origin. 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”. Since iron and magnesium remain with alumino silicate the bauxite is 90% impure.

The dolerite mine is exposed on the slope of the hill of Yercaud. 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”.

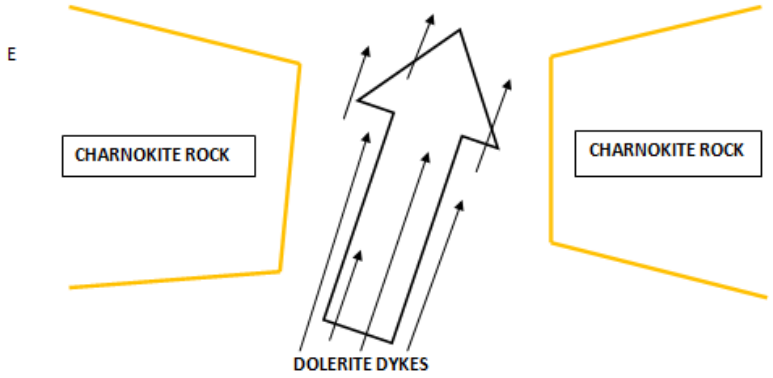

Fig. 2. Field photographs showing (a), (b) Dolerite dykes exposure at Yercaud, (c) Bauxite mines (where laterite was collected) at Yercaud

2.3 Pamagoundapalayam:

The anorthosite is closely layered with chromitite (Mono-minerallic rock of chromite) (Fig. 3). 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. 3. Field photographs showing (a) Anorthosite rock layered with chromitite exposed at Pamagoundapalayam belongs to Sittampundi complex.

In the present study, the petrography for the different rock types in the parts of Salem District, TamilNadu 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 and unaltered samples were collected covering the areas of Kanchamalai, Yercaud and Pamagoundapalayam which is located in and around Salem area, covering the part of SGT, Tamil Nadu. The present samples cover almost all the rock types including Banded Magnetite Quartzite (BMQ), Magnesite, Dolerite dykes, Laterite and Anorthosites. The collected samples

were processed for preparing thin sections and undergone for mineral identification and petrographic study. Systematic methods and different instruments were used for cutting and grinding the rock samples and heating the samples which were undergone after cutting followed by mounting the glass slide. Thin jawless diamond cutting vessels were used for cutting.

4. Petrography

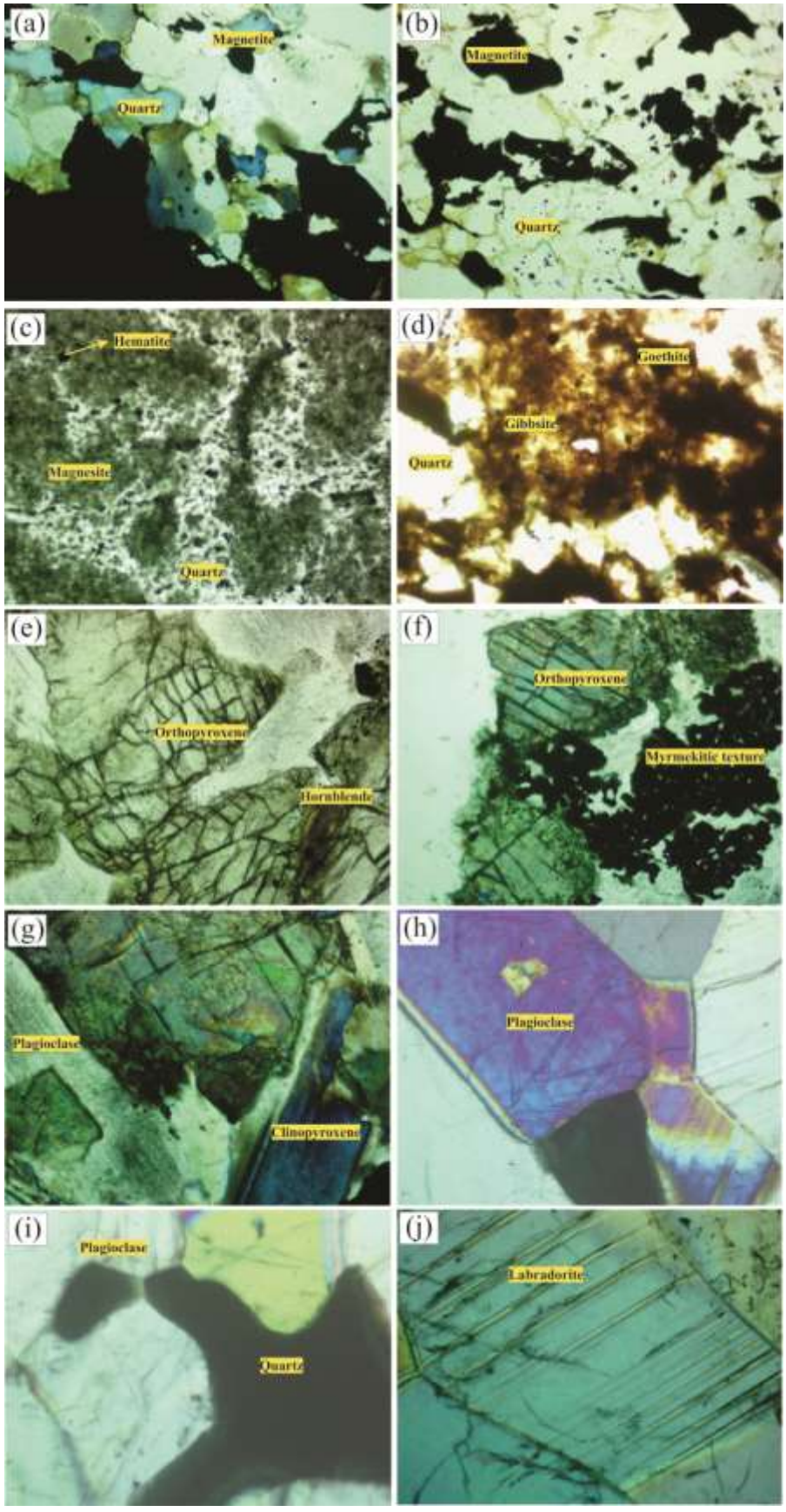
(a)
Magnetite
Quartz
(b)
Magnetite
Quartz
(c)
Hematite
Magnesite
Quartz
(d)
Goethite
Gibbsite
Quartz
(e)
Orthopyroxene
Hornblende
(f)
Orthopyroxene
Myrmekitic texture
(g)
Plagioclase
Clinopyroxene
(h)
Plagioclase
(i)
Plagioclase
Quartz
(j)
Labradorite

Fig. 4 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 to coarse grained plagioclase, orthopyroxene and clinopyroxene. 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 have been transformed to a mixture of Fe and al oxides. Goethite minerals which underwent for lateritization and formed bauxite minerals that is Gibbsite. Quartz behaves as resistant mineral. 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 where the lateritization is taken place.
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 rock types in the study area. The petrographical studies suggest 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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References

Ashwal, L. D. (2000). Anorthosites. Springer-Verlag Edition.

Bose, M.K., Maitra, M., Das, D., Ray, J 2001. Structure and petrology of the mafic granulites and associated rocks of the Kanjamalai complex, Salem district, Tamil Nadu. Indian Minerals 55(3):119-132

Devaraju, T.C. (1995). Mafic Dyke Swarms of Peninsular India. Geological Society of India, Bangalore, 33.

Gopalakrishnan, R., Chandrasekaran, V. (1993). Regional surveys for gold in banded iron formations of Tamil Nadu. Records of the Geological Survey of India, (5): 164-166

He, H., Wang, Y., George, P.M., Sajeev, K., Guo, J., Lai, C., Zhai, M., (2021). Formation of ~2.5 Ga Sittampundi anorthosite complex in southern India: Implications to lower crustal stabilization of the Dharwar Craton. Precambrian Research, 354.

Hoffmann, J. E., Svahnberg, H., Piazolo, S., Scherstén, A., and Münker, C. (2012). The geodynamic evolution of Mesoarchean anorthosite complexes inferred from the Naajat Kuuat Complex, southern West Greenland. Precambrian Res. 196–197, 149–170.

Howie, R. A. (1955). Charnockites and their Colour. Journal of Geological society of India, 8.

Jayabalan, M., Umamaheswaran, G., Suresh, a. (2012). Petrology and Geochemistry of Dolerite dykes of Dharmapuri and Salem Districts of Tamil Nadu. Journal of Applied Geochemistry, 14 (1): 52-68.

Krishnaswamy, V. S. (1958). Records of the GSI volume, annual reports of the Barytes.

Kutty, T. R. N., Anantha Iyer, G. V., Rama- Krishnan, M., And Verma, S. P., 1986. Geochemistry of meta-anorthosites from Holenarsipur, Karnataka, South India: Lithos, v. 17, p. 317-328.

Pandian, M., Amrutha, D.E., Sakthivel, G. (2014). Lithological, Structural and Geomorphological Mapping using Remote Sensing and Gis – A Field Based Mapping Part Of Salem, Tamilnadu, India. African Journal of Geo-Sciences Research, 2(1):16-22

Rajendran, S., Chandrasekaran, V.A., 2000. Geology and Geochemistry of Banded Magnetite quartzite in Kanjamalai region, Salem, TamilNadu, India. Indian Journal of Geochemistry, 15: 1-20.

Ram Mohan, M., Satyanarayanan, M., Santosh, M., J. Sylvester, P., Tubrett, M., Lam, R. (2013). Neoarchean suprasubduction zone arc magmatism in southern India: Geochemistry, zircon U-Pb geochronology and Hf isotopes of the Sittampundi Anorthosite Complex, Gondwana Research, 23 (2): 539-557

Rao, Y., Chetty, T., Janardhan, A. et al. (1996). Sm-Nd and Rb-Sr ages and P-T history of the Archean Sittampundi and Bhavani layered meta-anorthosite complexes in Cauvery shear zone, South India: evidence for Neoproterozoic reworking of Archean crust. Contrib Mineral Petrol 125, 237–250.

Srivastava, R.K. and Ellam, R.M. and Gautam, G.C. (2009) Sr-Nd isotope geochemistry of the early Precambrian sub-alkaline mafic igneous rocks from the southern Bastar craton, Central India. Mineralogy Petrology, 96 (1-2), 71-79.

Srivastava, R., Ahmad, T., (2008) Precambrian mafic magmatism in the Indian shield: An Introduction. Journal Geological society of India, v. 72, pp. 9-13.

Srivastava, V. (2011) Structural control of Lead and Zinc mineralization in a part of Tons River valley, Uttarakhand- Himachal Lesser Himalaya. Journal of Scientific Research, 55 (1&2), 1-10.

Subramaniam, A.P. (1956). Mineralogy and Petrology of the Sittampundi Complex, Salem District, Madras State, India. GSA Bulletin, 67 (3): 317–390.

Yellappa, T., Venkatasivappa, V., Koizumi, T., Chetty, T.R.K., Santosh, M., Tsunogae, T. (2014). The mafic–ultramafic complex of Aniyapuram, Cauvery Suture Zone, southern India: Petrological and geochemical constraints for Neoarchean suprasubduction zone tectonics, Journal of Asian Earth Sciences, 95: 81-98.