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Petrography Of Crystalline Limestone And The Associated Rocks Occurred Near Uthappanaickanoor Village, Usilampatti Block, Madurai District, Tamil Nadu, India

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Abstract: *Crystalline limestones, marbles, calc-gneisses, etc., are the metamorphosed equivalents of originally sedimentary carbonate rocks changed by contact and regional metamorphism. Depending upon the original composition, they may be calcitic, or dolomitic. Impurities may occur as various calc-silicates and other minerals. The present study deals with the petrographical study of the limestone and the associated rocks occurred in the study area. The limestones and the associated rocks were collected from the study area for thin section preparation and petrographical studies. Thin sections were prepared according to the standard procedures. The Euromax Holland petrographic microscope was used for thin section studies. The mineral assemblages were identified both in plane and crossed polarised light. The petrographical investigations reveal that the rock specimens are dominated by mineral assemblage consists of diopside calcite+ plagioclase + quartz and pyroxene with granoblastic texture. The mineral assemblages and the granoblastic texture indicates the granulite facies of metamorphism.*

Keywords: *Calc-granulite, limestone, petrography, mineral assemblages.*

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I. Introduction

Metacarbonate rocks form a large and complicated group of rocks ranging from pure carbonate to almost carbonate-free calc-silicate varieties (Rosen et al. 2007). Daubrée, 1867, states that the crystalline limestone is formed by recrystallisation of limestone as a result of metamorphism. Crystalline limestone, marbles, calc-gneisses, etc., are the metamorphosed equivalents of originally sedimentary carbonate rocks changed by contact and regional metamorphism. Depending upon the original composition, they may be calcitic, or dolomitic. Impurities may occur as various calc-silicates and other minerals (Kulkarni, 1968). Crystalline limestone has been temperature-soaked for a considerable time, recrystallization results in coarsening of the grain size (1mm to 10 mm or even larger). The texture is common interlocking mosaic and rarely schistose. Mineralogy of crystalline limestone can be complex and strictly monomineralic limestone is rare. Minerals, like quartz, feldspar, phlogopite, muscovite, diopside, scapolite, grossularite, tremolite, talc, actinolite, pyrite, apatite, dolomite, chondrodite, graphite, etc., may be present and associated with calcite (NCB, 1985). The oldest limestone seen in India occurs all along with the other metasedimentary-migmatite formation as part of the Archaean Basement Complex. The temperature and pressure with a time period had altered the original textural, mineralogical and structural characteristics of the calcareous sediments to coarse crystalline limestone with other metamorphic mineral assemblages. Often gneisses, quartz veins, pegmatites and charnockitic rocks also cut across the crystalline limestone (Panda et al. 2006). The present study is deals with the petrographical properties of the limestone and the associated rocks of the Archaean Basement region.

II. Study Area

The study area is near Uthappanaickanoor Village of Usilampatti Block, Madurai District, Tamil Nadu, India. The Andipatti Reserved Forest (RF) is located in the Western part of the study area. The elevation in the study area is 275 m above MSL. In the study area, Canals are scattered. The district Madurai has a tropical climate period with inconstancy in temperature. The study area is generally hot and dry. The maximum temperature ranges from 30 to 40°C and the min. temperature ranges from 20 to 26°C. The month of May and December records max. and min. temperature respectively. During the summer months, hot and dry wind blowing from the south. The study area experiences two monsoons: the SW monsoon wind prevails during mid of June to September, the NE monsoon from the month of October to December. Usilampatti receives the max. rainfall during the NE monsoon about 966.2 mm (74.4%) of the annual rainfall. Whereas, the SW monsoon brings about 327.4 mm (25.6%) of the total rainfall. The location map of the study area is shown in Fig.1.

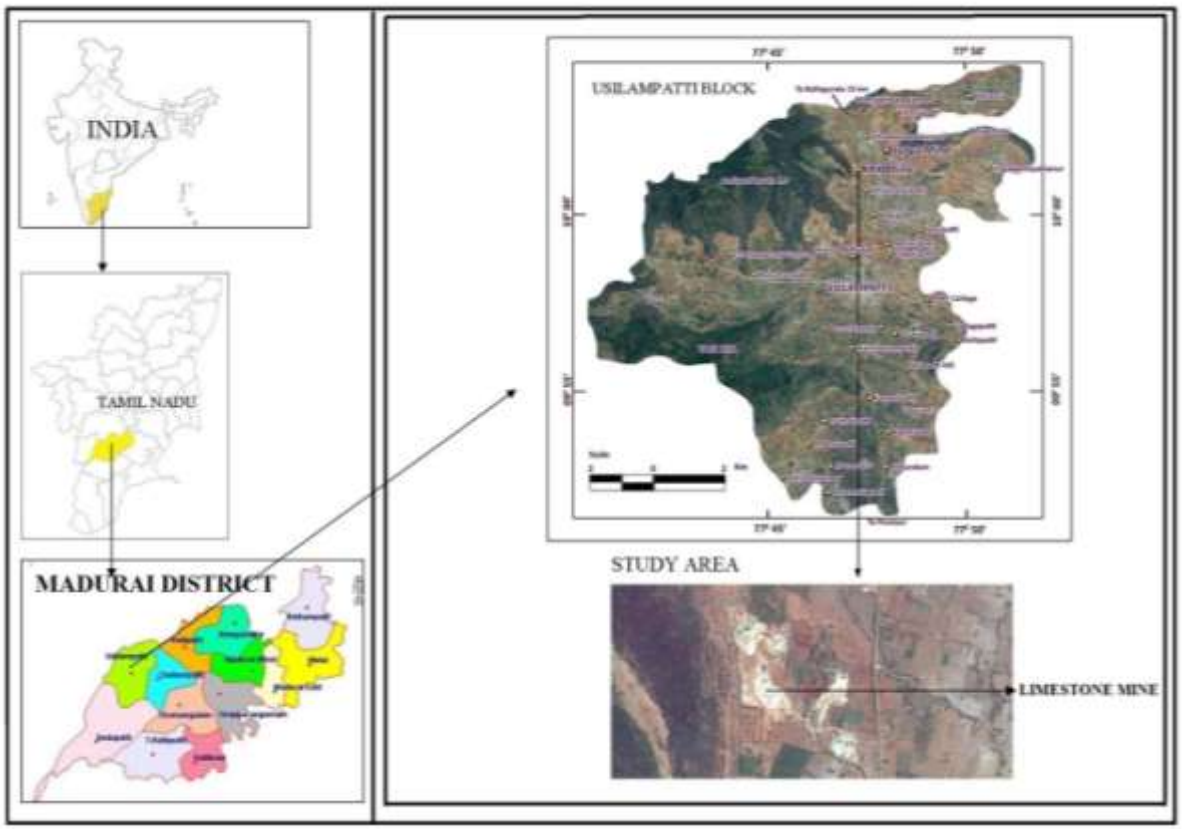

Fig. 1. Location map of the study area.

III. Materials And Methods

A. Specimen collection

During the field work ten representative specimens, including the limestone and the associated rocks, were collected from the study area for thin section preparation and petrographical studies. Two different colour limestones observed in the study area which are in white and grey colours. The limestones and the associated rocks were collected separately and packed carefully for further investigations. The collected rock specimens are shown in Figure 2.

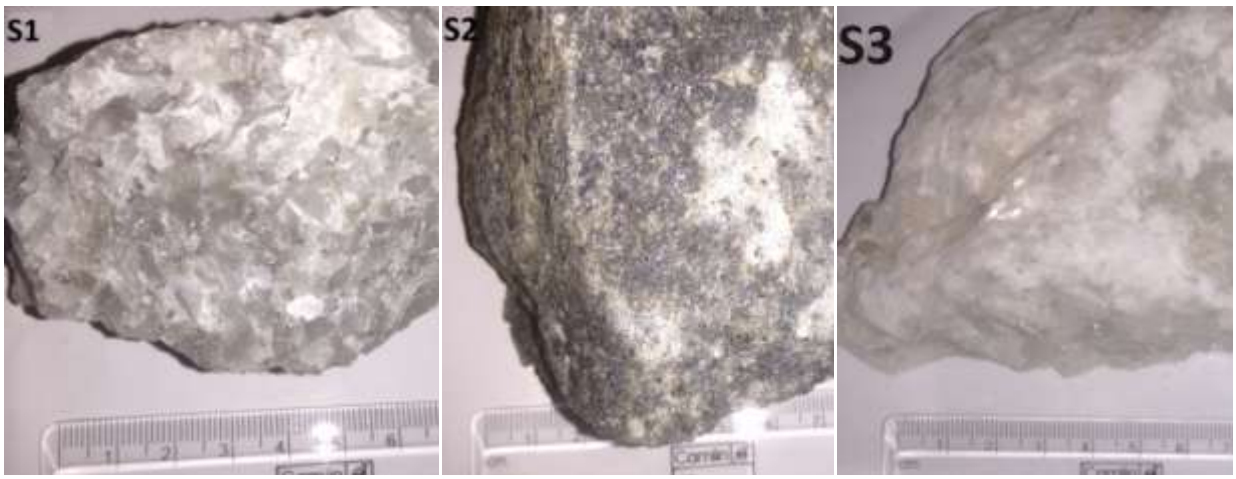

Fig. 2. *Rock specimens of the study area:* ***S1****,grey limestone;* ***S2****, pyroxene granulites;* ***S3,*** *white limestone****; S4,*** *white Limestone with yellow tint****; S5,*** *limestone with mica flakes****; S6,*** *amphibolite****; S7,*** *calc-granulites with pyrite****;S8,*** *limestone and granulite contact;* ***S9,*** *crystalline limestone.*

B. Preparation of thin sections

After washing and drying the specimens, it was dispatched to the lab for preparation of thin sections. For this study, thin sections were prepared according to the standard procedures from M/s. Lab Crystals, Lucknow, Uttar Pradesh.

C. Microscopy

The *Euromax Holland petrographic microscope* was used for petrographical studies. The mineral assemblages were identified both in plane and crossed polarised light. Based on the investigations a detailed textural and the mineralogical studies were done with the prepared slides.

IV. Results

S1: Grey limestone

Texture:

In the grey limestone most of the minerals are in subhedral form and, all the minerals are completely recrystallised, grano-blastic texture in nature (Fig.2S1).

Mineralogy:

Calcite, quartz and muscovite are found in the thin section. This thin section is dominated by calcite minerals. Calcite crystals are subhedral in shape, uniaxial native, colourless in plane polarized light and have low relief. It shows perfect rhombohedral cleavage, symmetrical extinction, polysynthetic twinning interference colour higher order blue, yellow, twinkling effect with higher birefringence. The calcite has a grey to higher order bluish interference colour. Quartz associated with the calcite, occurs as anhedral crystals with first order grey interference colour. The metamorphism imposed the quartz with wavy extinction. The other mineral is diopside, which appears to be pale green in plane polarized light and has a second order blue and yellow interference colours. Muscovite with pink interference colour third order, subhedral in shape, parallel twinning colourless under polarized light and other varieties of mica minerals are present. The mineralogical composition and textural compound comfirm that the rock is of granulitic facies (Fig.3A)

S 2: Pyroxene granulites

Texture

In pyroxene granulite most of the minerals are subhedral to anhedral form, the mode of growth, all minerals are completely crystallized, simultaneously, it is crystallo-blastic and some minerals are in a lenticular form so they are grano-blastic. Mostly degree of recrystallisation is uniform (Fig.3S2).

Mineralogy:

Augite, plagioclase, quartz, mica and iron minerals are present in the thin section. Quartz occurs as first order grey interference colour with anhedral crystals, birefringence low colourless under plane polarized, cleavage absent and non-pleochroic. The metamorphism imposed the quartz with undulatory extinction. Plagioclase is colourless, subhedral form, perfect cleavage, first order grey, lamellar twinning, inclined extinction with 29 degrees of angle; it is labradorite. Calcite occurs in very less amount. Augite occurs as colourless and non-pleochroic under the plane polarized light, pale greenish third order interference colour, polysynthetic twinning, and inclined extinction with 38 degrees angle. A few dark coloured minerals are present in a small amount which is identified as Fe mineral (Fig.3B).

S3: White limestone

Texture:

The white coloured limestone the minerals are subhedral and anhedral form, the mode of growth in all minerals are completely crystallized, crystallo-blastic texture and some minerals shows lenticular form so they are in grano-blastic texture. The degree of recrystallisation is uniform in general(Fig.2S3).

Mineralogy:

The specimen thin section is dominated by calcite mineral, completely recrystallized thus granoblastic texture. Calcite crystals occur in euhedral and rhombohedral shape. It shows perfect rhombohedral cleavage and symmetrical extinction. The calcite has a grey to higher order bluish or pinkish interference colour with lamellar twinning. Quartz shows first order grey interference colour, anhedral in shape with wavy extinction. Diopside appears to be pale green in plane polarized light and has a second order blue and yellow interference colours and an oblique, muscovite with pink interference colour third order, subhedral in shape, parallel twinning colourless under polarized light and other varieties of mica minerals are present (Fig.3C).

S4: Limestone with yellow tint

Texture:

In this limestone with yellow shades, the minerals are subhedral and anhedral form, the minerals are completely crystallized, greater pert is crystallo-blastic and some minerals are in lenticular form so they are grano-blastic in texture(Fig.2S4).

Mineralogy:

Calcite, mica, quartz and pyroxene are the minerals present in this section. Under the microscope it was observed that calcite is the dominating mineral, the other mineral is in less amount. The other minerals present in the rock are muscovite, quartz and pigeonite. Calcite exhibits grey to higher order bluish or pinkish interference colour, perfect rhombohedral cleavage and symmetrical extinction. The calcite grains show polysynthetic twinning. The muscovite is pleochroic from colourless to light brown. Muscovite shows second order green to orange interference colour, euhedral in shape and parallel extinction. Quartz occurs as first order grey interference colour with anhedral crystals, colourless under plane polarized, cleavage absent and non-pleochroic. The metamorphism imposed the quartz with wavy extinction. The pyroxene in the rock is typically pigeonite. It shows second order yellow interference colour, one set of perfect cleavage. It shows inclined extinction of about 26º. The mineral assemblage of the rock is calcite + quartz + muscovite + pigeonite (Fig.3D).

S5: Limestone with mica flakes

Texture:

Majority of the minerals are subhedral, the mode of growth of all minerals are completely crystallized. Grano-blastic and and the degree of recrystallisation is almost uniform(Fig.2S5).

Mineralogy:

Minerals calcite, mica and plagioclase are seen in this section. The majority of the grains are calcite and the remaining minerals are quartz; biotite and a minor amount of plagioclase are present. Calcite exhibits grey to higher order bluish or pinkish interference colour, perfect rhombohedral cleavage and symmetrical extinction. The calcite grains show polysynthetic twinning. Quartz occurs as first order grey interference colour with anhedral crystals, colourless under plane polarized, cleavage absent and non-pleochroic. Quartz exhibits wavy extinction. Biotite shows the higher high order interference colour. Biotite is reddish brown colour, strongly pleochroic, euhedral in shape reflective index high one set of cleavage and it shows straight extinction. The

feldspar occurring in the rock is plagioclase which is typically labradorite. Labradorite exhibits first order grey interference colour along with lamellar twinning bands. The extinction angle of the mineral is about 30º. The mineral assemblage of the rock is calcite + biotite + labradorite +quartz (Fig.3E).

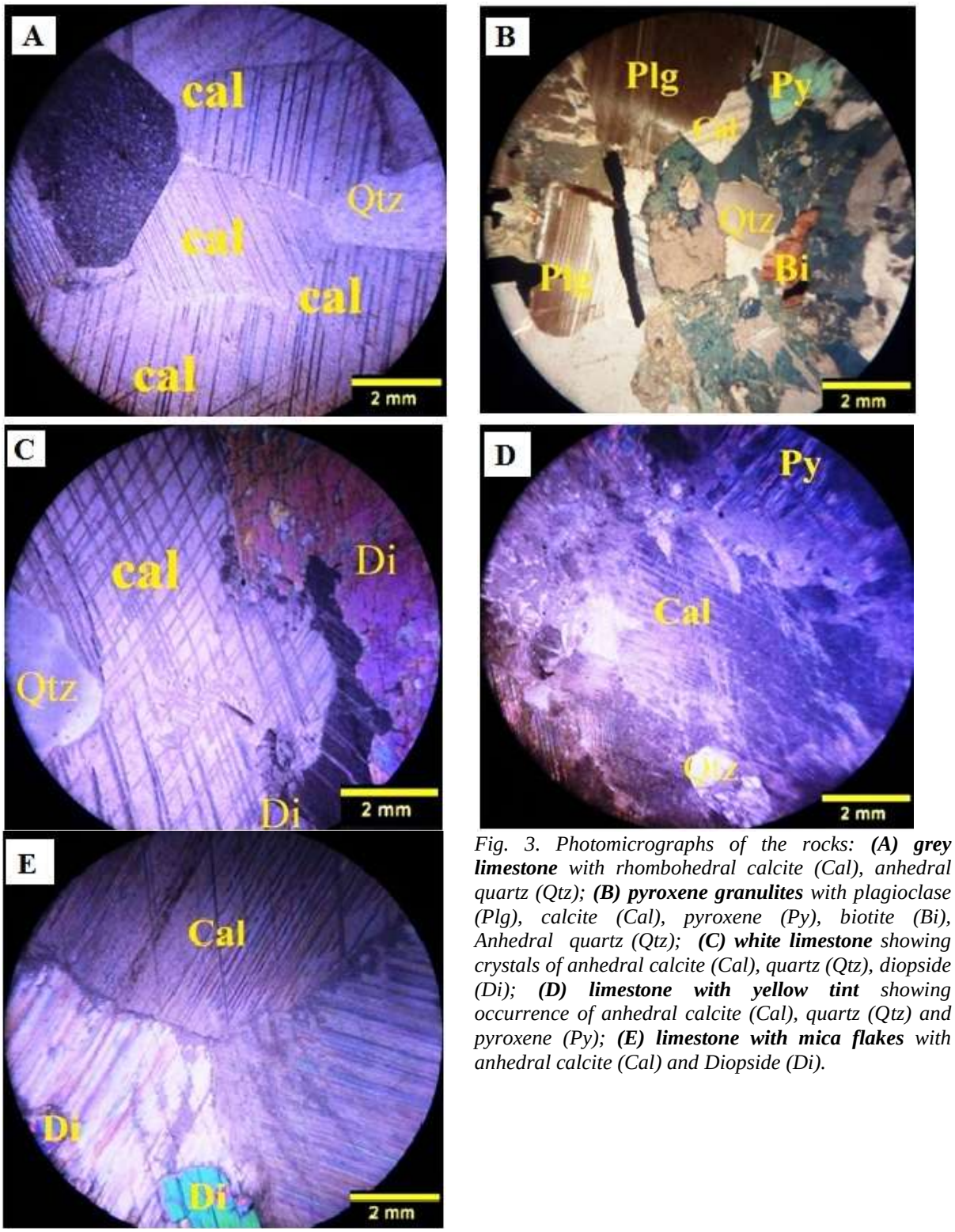

Fig. 3. Photomicrographs of the rocks: ***(A) grey limestone*** *with rhombohedral calcite (Cal), anhedral quartz (Qtz);* ***(B) pyroxene granulites*** *with plagioclase (Plg), calcite (Cal), pyroxene (Py), biotite (Bi), Anhedral quartz (Qtz);* ***(C) white limestone*** *showing crystals of anhedral calcite (Cal), quartz (Qtz), diopside (Di);* ***(D) limestone with yellow tint*** *showing occurrence of anhedral calcite (Cal), quartz (Qtz) and pyroxene (Py);* ***(E) limestone with mica flakes*** *with anhedral calcite (Cal) and Diopside (Di).*

S6: Amphibolite

Texture:

Exhibiting minerals are subhedral and anhedral formed, the minerals are completely crystallized. Minerals such as biotite, plagioclase and amphibole are present. Some varieties spotting is visible due to incipient crystallization of these minerals segregation. It is viewed as maculose in structure (Fig.2S6).

Mineralogy:

In thin section, minerals like quartz, mica (biotite), plagioclase, amphibole are present (anthophyllite). Quartz occurred as anhedral crystals with first order grey interference colour, colourless under plane polarized, cleavage absent and nonpleochroic. Biotite shows the higher high order interference colour. Biotite is reddish brown colour, strongly pleochroic, euhedral in shape reflective index high one set of cleavage and it shows straight extinction. The plagioclase feldspar present in this rock is bytownite. Bytownite shows 1st order grey interference colour, inclined extinction and albite twinning. Under plane polarized light it is anhedral, cleaved, colourless and non-pleochroic. Anthophyllite, the amphibole mineral present in the rocks presents parallel extinction, colourless, non pleochroic, subhedral shape, higher order green interference colour, high relief, one set cleavage, birefringence moderate the extinction is straight. The mineral assemblage of the rock is quartz + bytownite + biotite + anthophyllite (Fig.4F).

S7: Calc-granulites

Texture :

In calc-granulite, the minerals are subhedral formed, recrystallized. In thin section, minerals like calcite, labradorite, quartz, biotite, microcline and sillimanite are present In some parts of patches, thin section are strongly foliated. The foliated grain size differs from fine to medium. The strongly foliated part of the microscope is viewed as "micro folded" and the other part are viewed as mica minerals (biotite). The foliated pa rt gives schistose texture the other part gives the maculose texture (Fig.2S7).

Mineralogy:

Calcite displays the grey to higher order bluish or pinkish interference colour with rhombohedral cleavage and symmetrical extinction. Labradorite shows grey first order, lamellar twinning, and inclined extinction with 30 degrees of angle. Under plane polarized light, it is anhedral, cleaved, colourless and non-pleochroic. Biotite shows the higher high order interference colour. Biotite is reddish brown colour, strongly pleochroic, euhedral in shape reflective index high one set of cleavage and it shows straight extinction. Quartz occurs as anhedral crystals with 1st order grey interference colour, colourless under plane polarized, cleavage absent and non-pleochroic. Microcline exhibits first order grey interference colour, polysynthetic twinning, and subhedral in form and extinction angle of 16 º. Under plane polarized light the microcline is colourless and present perfect cleavage. Sillimanite, prismatic in the form it is colourless, non pleochroic, euhedral, reflective index high, perfect cleavage one set, biaxial negative, sillimanite exhibits lower second order brown, parallel extinction, birefringence is high and higher relief iron mineral are also present (Fig.4G).

The mineral assemblage of this rock is calcite + labradorite + biotite + quartz + microcline + sillimanite + iron minerals.

S8: Limestone and granulite contact

Texture:

The contact rocks minerals are exhibiting subhedral form and complete recrystallization. The mineral grains are medium to coarse.The grains are about the same size and it exhibits the granulose texture. In this thin section intruded mica micro veins are present (Fig. 2S8).

Mineralogy:

Calcite, quartz, biotite and feldspar minerals are found in the thin section. Under a thin section investigation the major mineral is calcite, plagioclase feldspar, pyroxene, the mica mineral is biotite, quartz, augite and sillimanite are accessory minerals. Calcite displays the grey to higher order bluish or pinkish interference colour, perfect rhombohedral cleavage, polysynthetic twinning and symmetrical extinction, it is dull while observing in the plane polarized. The plagioclase feldspar present in this section is bytownite, which is colourless under plane polarized, subhedral in form, moderate relief, 1st order grey interference colour and the angle of extinction is 43°. Biotite shows the higher high order interference colour. Biotite is reddish brown colour, strongly pleochroic, euhedral in shape reflective index high one set of cleavage and it shows straight extinction. Augite occurs as colourless to pale green and pleochroic subhedral and reflective index is high, two sets of cleavage (intersect), greenish yellow 2nd order interference colour, polysynthetic twinning, and inclined extinction with 47^{o} angle. Sillimanite exhibits prismatic form and colourless nature under plane polarized light. Under crossed Nichols sillimanite exhibits lower second order, parallel extinction, perfect cleavage and higher relief. The mineral assemblage of this rock is calcite + bytownite + biotite + quartz + augite + sillimanite (Fig.4H).

S.9: Crystalline limestone

Texture:

In the crystalline limestone, the minerals are exhibiting subhedral shape and complete recrystallization. The crystal sizes differ from medium to coarse grained. It is granular in texture (Fig.2S9).

Mineralogy:

The mineralogy of crystalline limestone contains minerals like calcite, mica, quartz and pyroxene. The thin section study shows that calcite is a dominating mineral. Other observed minerals are pyroxene, sillimanite, the mica minerals such as muscovite and biotite, the pyroxene mineral like diopside. Calcite under microscopic analysis displays the grey to higher order bluish or pinkish interference colour, perfect rhombohedral cleavage, polysynthetic twinning, symmetrical extinction colourless and under plane polarized in thin section it is cloudy. Biotite shows higher second order interference colour. Biotite is euhedral in shape and it shows parallel extinction. It is brown to reddish brown colour under plane polarized light and it is pleochroic. In plane polarized light muscovite is pleochroic from colourless to light brown. Muscovite shows 2nd order green to orange interference colour, euhedral in shape, parallel extinction. Diopside, which appears to be pale green in plane polarised light, subhedral in shape, has a 2nd order blue interference colour and an extinction angle of 39^{o}. Sillimanite, prismatic in form it is colourless under plane polarized light. Under crossed Nichols sillimanite exhibits lower second order, parallel extinction, perfect cleavage and higher relief (Fig.4I). The mineral assemblage of this rock is calcite + biotite + muscovite + diopside + sillimanite.

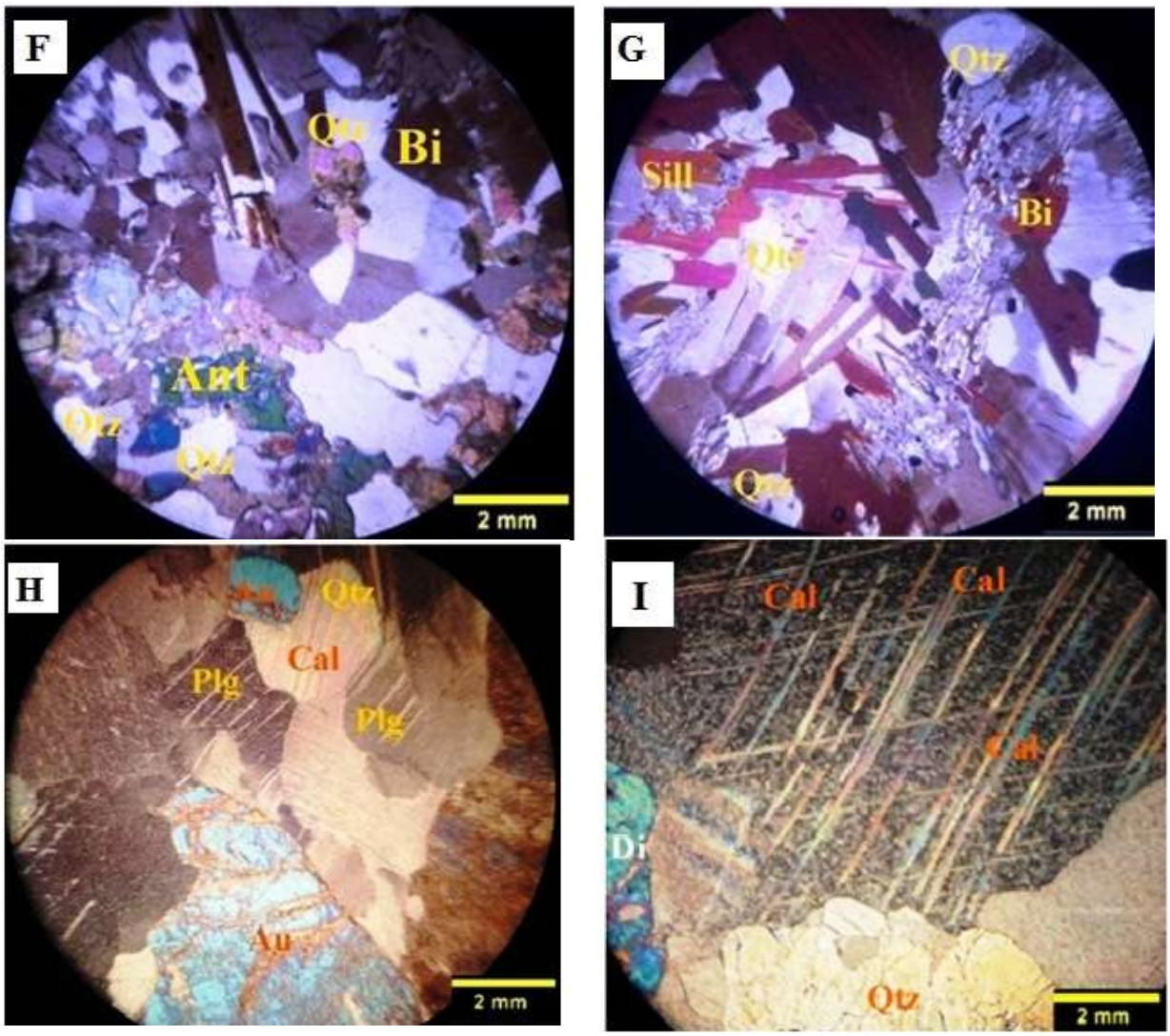

Fig. 4. Photomicrographs of the rocks: ***(F) amphibolite*** *showing the occurrence of anhedral quartz (Qtz) amphibole mineral anthophyllite (Ant)and biotite (Bi);****(G) calc-granulites*** *showing sillimanite (Sill), quartz (Qtz), biotite (Bi);* ***(H) limestone and granulite contact*** *exhibiting plagioclase (Plg), rhombohedral calcite(Cal), pale blue augite(Au) And* ***(I)crystalline limestone*** *with calcite, biotite, muscovite, diopside and sillimanite*

V. Discussion

Limestone and the associated rocks were taken near the Uthapanaickanoor Village of Usilampatti Block, Madurai District was studied under light polarized microscopy for the petrographical characteristic assessment. Among the samples, limestone samples were classified according to their colour appearance. In samples, the mineral assemblage contains calcite+diopside + plagioclase + quartz and pyroxene, which indicates amphibolites to granulite facies of metamorphism (Turner et al., 1939). The texture is mainly dominated by granular and granoblastic which is also associated with granulites facies. Yardley (1990) states that due to metamorphic process, calcite is recrystallised to produce a coarse grain size and calcite crystals are susceptible to extensive textural changes due to the recrystallisation of calcite and often a preferred orientation. Granulite is a metamorphic rock and from a granulites facies terrain exhibiting the characteristic of granulite facies mineral assemblages. Anhydrous mafic minerals are modally more abundant than hydrous mafic minerals. Muscovite is absent in such rocks. Characteristic is the occurrence of metamorphic orthopyroxene in both mafic and felsic rocks. The term is not used for marbles and ultramafic rocks in the granulite facies terrain (Bucher and Grapes, 2010). The texture in study area thin section are dominated by granuloblastic, which can arise three reasons: the regional metamorphism of low stress type that doesn't give dimensional or lattice preferred orientations, the syntectonic phase of normal regional metamorphism followed by prolonged post tectonic crystallisation which abliterates the dimensional preferred orientation and replaces by a surface energy controlled granuloblastic texture and certain minerals mainly feldspars but also quartz, scapolite and calcite displaying negligeable to slight tendencies to form elongated crystals (Spry, 1969). Lack of major element zoning in garnet analysed in the different rock types from the study area suggests that temperatures of metamorphism exceeded 650°C, the temperature at which growth zoning is typically homogenized by volume diffusion (Tracy, 1982). The occurrence of orthopyroxene in metasedimentary rocks may suggest the granulite facies conditions, typically estimated at >700°C (Turner, 1971; Philpotts, 1990) or >800°C according to Pattison et al., (2003). The gneissic rocks (gneissose texture) of the study area exhibits high stress and strain with numerous folding which indicates that the study area underwent for high deformation.

VI. Conclusion

The present paper deals with the petrographical characteristics of the crystalline limestone and the associated rocks occurring in the study area. The petrographical investigations of the study area rocks revealed that the accustomed minerals calcite, quartz, pyroxene, plagioclase, mica, amphibole etc. Majority of the samples exhibiting the mineral assemblage of calcite + diopside + plagioclase + quartz + pyroxene and hornblende which indicates amphibolite to granulite facies of metamorphism. From the petrographical studies it is observed that the rock samples grains are equigranular granoblastic texture which indicates uniform recrystallization. A few samples shows micro-folded, flaky minerals and the high variation in textures like gneissose, schistose and maculose for the reason that of strong foliation.

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