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Research Paper

DIAGENESIS OF GLAUCONITE BEARING QUARTZITES OF THE CUDDAPAH BASIN, ANDHRA PRADESH, INDIA

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Cuddapah Basin is the unique basin that has the attracted many earth scientists. The litho stratigraphy and the structure of the basin have been studied in detail by various authors. However, the research on the sedimentological aspect of the basin was comparatively less. There are number of ferruginous quartzites that occur has interbeds within the formations at all stratigraphic levels, including the rocks of Kurnool Group. These ferruginous quartzite are all glauconite bearing. Hence, the diagenetic aspects of the glauconite and the quartzite have been studied in detail. The field maps are prepared with the help of satellite data. Extensive field work was carried out and number of samples has been collected for laboratory studies. Wealth of literature is also presented for better understanding.

Keywords: Cuddapah basin, Diagenisis, Glauconite bearing quartzites

INTRODUCTION

The term diagenesis was introduced by Von Guembel in 1888 to designate processes which act on the sediment after deposition (Amstutz and Bubenicel, 1967). Correns (1950) and Rankama and Sharma (1950) were of the idea that the term diagenesis means the front formation which the sediment undergoes between deposition and metamorphism. Pettijohn (1957) defined the term orthogenesis as the formation of new sedimentary minerals *insitu,* within the enclosing sediment during and after deposition.

Dapples (1959) used the term diagenesis the modifications, which sediment experiences during the deposition and lithification. He (1962) described three stages of diagenesis (a) Redexomorphic stage - characterized by mineral changes primarily due to oxidation and reduction, (b) locomorphic stage – characterized by prominent mineral replacement and typical lithification of clastics sediment, and (c) Phyllomorphic stage – characterized by the authigenesis of micas and also of feldspars.

Fairbridge (1967) described three phases of diagenesis, i.e. (a) Syndiagenesis (sedimentation phase), (b) Anadiagenesis (the compaction-maturation phase) and Epidiagenesis (the emergent-pre erosion phase).

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The diagenetic aspect of the quartzites in addition to the glauconite bearing quartzite is also detailed.

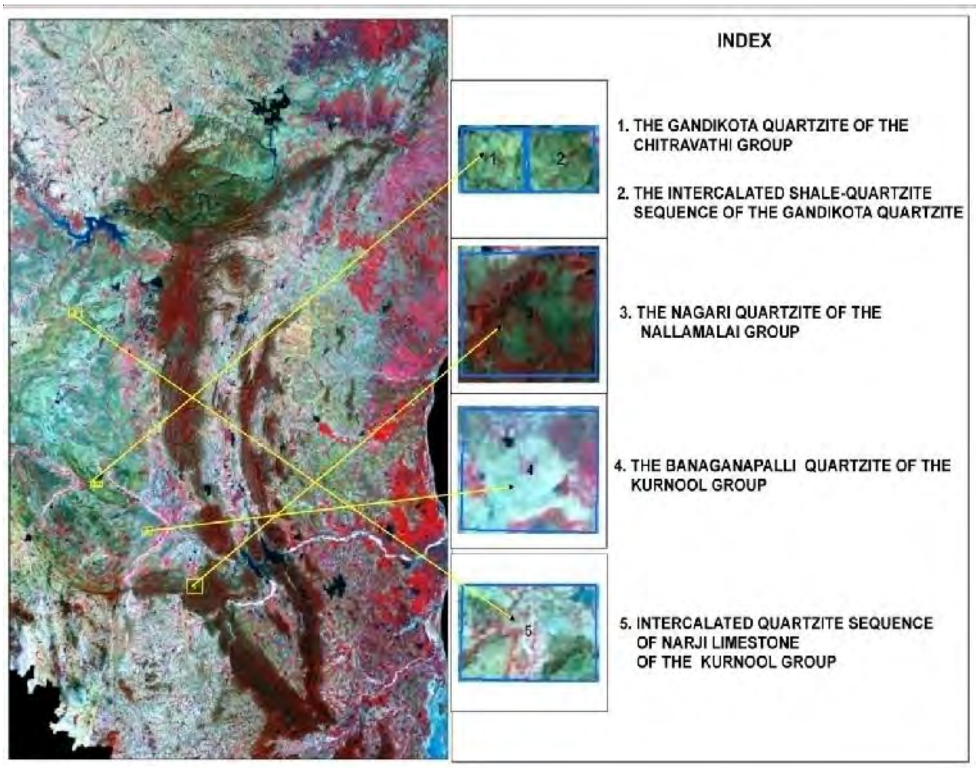
Under the head diagenesis, the style of the contacts, the development of authigenic minerals, matrix/cement alterations and the diagenetic stages of glauconite bearing quartzites are all dealt with. The description followed in this part of the chapter is after Dapples (1959).

STUDY AREA

The Cuddapah basin is located in the southern part of the Andhra Pradesh. The basin is named after the district head quarters, i.e., Kadapa. Kadapa can be reached by the South - Central Railway and from there number of buses belonging to Andhra Pradesh Road Transport Corporation is plying to different places. Kadapa is well connected by all weather roads from all the places. The basin can be divided into three sub-basins, viz., the western Papagni sub-basin, the eastern Nallamalai sub-basin and the northern Srisailam sub-basin. The Papagni and the Srisailam sub-basins have the glauconite bearing quartzites.

Glauconite bearing quartzites are identified at five (3) places. The first four occurrences viz. are located at 1. The Gandikota Quartzite of the Chitravati Group, 2. The intercalated shale – quartzite sequence of the Gandikota Quartzite. These two occurrences are easily approachable from Muddanur 3. The Nagari Quartzite of the Nallamai Group. This can be reached from the Kadapa town. It is located about 25 km SSW of the town.

Figure 1: Locations Map Showing the Presence of Glauconite Bearing Quartzites



METHODOLOGY

Diagenesis Aspect of the Other Quartzites

The associated quartzites along with the glauconite bearing quartzites are ferruginous quartzite and orthoquartzites. Besides these, there are ferruginous quartzites that do not have glauconite.

Style of Contacts

The higher degree of alteration affects the grain-grain alterations between detrital grains resulting in the development of irregular grain margins. The competent quartz grains have developed a variety of complex boundaries.

The grain-to-grain contacts are studied to understand the changes that the rocks have undergone. The contacts can be described as under.

Line Contact

The contact between the two adjacent grains is like a line. The line contacts are conspicuous when the intergranular material is insignificant (Figure 2). The point contact (Figure 3) is clear when the grains are of floated nature. Floated grains occur when the matrix in high.

Figure 2: Line Contact in the Glauconite Bearing Quartzite

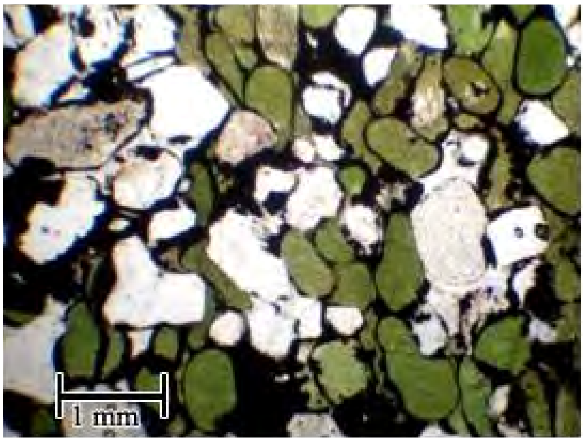
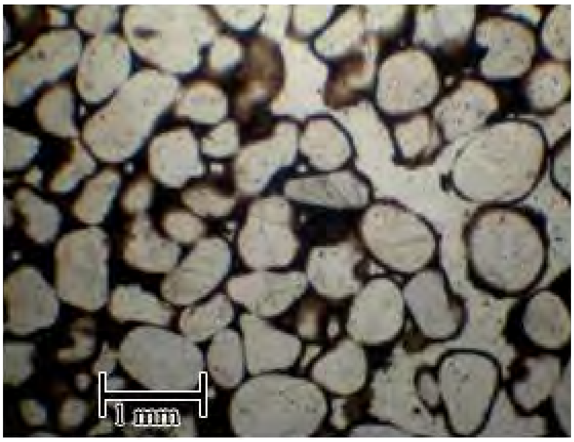


Figure 3: Point Contact in the Ferruginous Quartzite



Concavo – Convex Contact

The contact between the two rounded grains is concavo – convex style. In this also the intergranular material is very less (Figure 4). The quartz grains are well rounded and along the concavo-convex contact the authegenic quartz is much less.

Crystal Face Contact

Crystal face contacts are produced largely by extensive formation of overgrowths to the point of mutual interference (Figure 5) and are

Figure 4: Concavo-Convex Contact

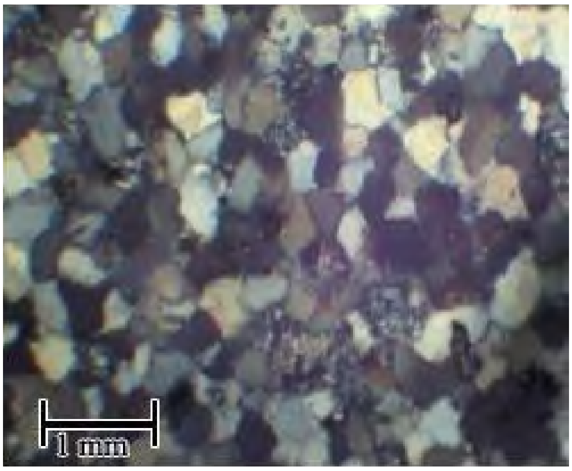
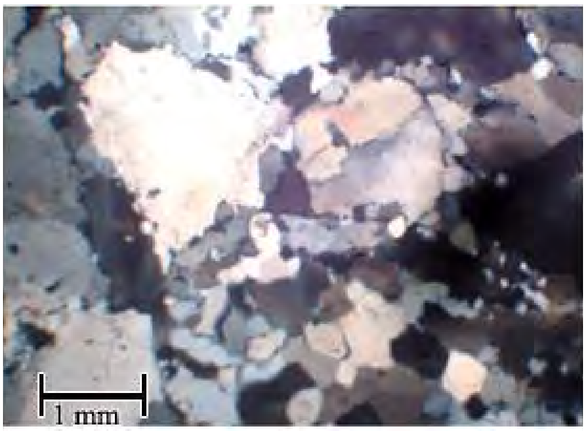


Figure 5: Crystal Face Contact

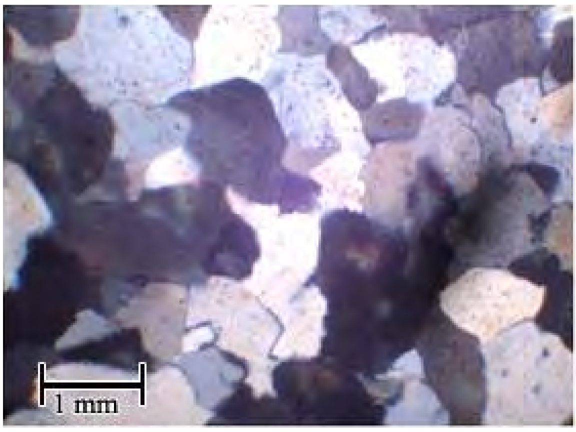


particularly characteristic of clean orthoquartzites. Imperfectly formed crystal face contacts may appear as simple line contacts

Stylolite Contact

In this, the grain boundaries have sutured contact having slightly wavy nature. In a broad sense, it resembles seismograph. This can also be termed as micro stylolite (Figure 6). This type of contact reflects the affect of tectonics and can also be considered and as microstylitic contacts that include simple wave form, sutured form, and sharp-peaked–form of stylolites of Park and Schot (1968), also uncommon granulated contacts. Both simple irregular penetration and microstylolitic contacts reflect deformational history.

Figure 6: Micro-Stylolitic Contacts



Matrix and Cement

The change and the formation of complex grain to grain contacts can be due to pore deformational history and due to the affect of iron oxide during epi-diagenesis.

Comparatively coarse grained rock exhibit simple irregular penetration contacts and microstylolitic contacts. The rocks exhibiting the above said types of contacts have more polycrystalline quartz and will have insignificant floating grains and very less percentage of matrix, (Figure 7).

Further, quartzites that reflect simple line and concavo-convex contacts are generally fine grained and have less polycrystalline quartz. Floating grains with higher percentage of matrix are common (Figure 8).

Crystal face contacts have more over growth quartz (authigenic quartz) (Figure 9). If the matrix is more, authigenic quartz will be less. However, there can be certain exceptions to the above said facts.

Figure 7: Less Matrix and Cement with Microstylolitic Contracts, Note the Poly Crystalline Quartz

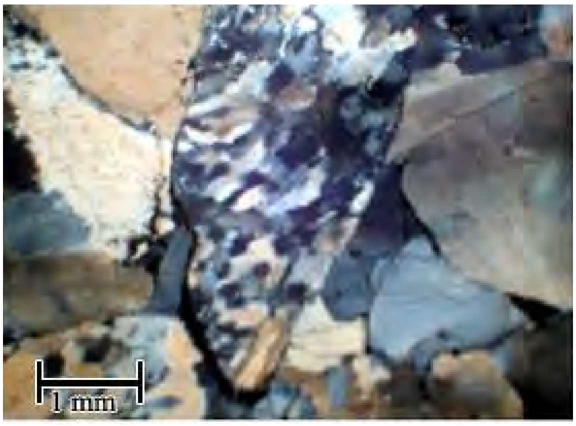


Figure 8: Floating Grains

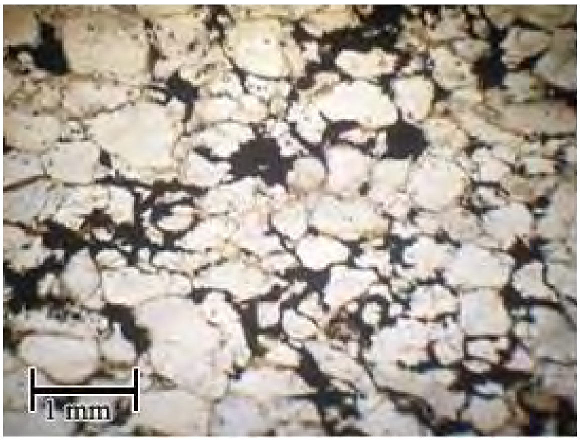
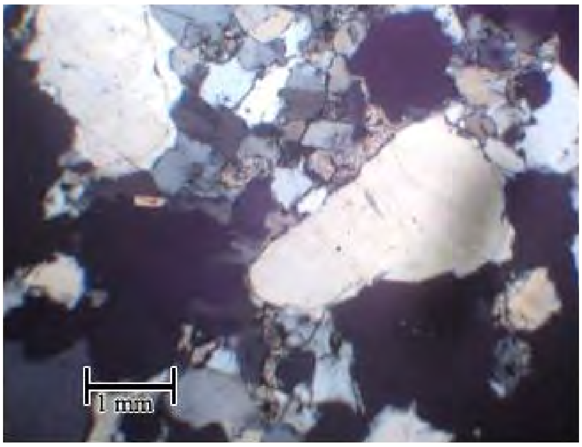
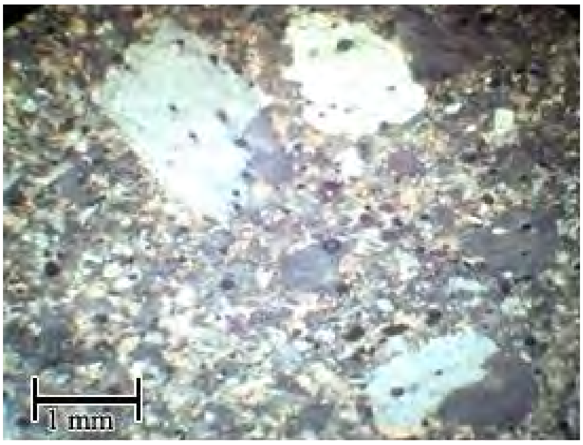


Figure 9: Quartz Overgrowths



As stated earlier, the microstylolitic contacts and irregular contacts indicate deformational history of the area. Association of highly irregular contact is expected to be, when there is sericite matrix. In the floating grains it can be said that grain to grain stress will be less. Whatever stress that develops will be absorbed by the matrix and it will not be transmitted to the other grains. When the quartzites are bimodal, the coarse grains show the microstylolitic and interpenetration feature. The smaller grains do not reflect the affects of deformational stress (Figure 10).

Figure 10: No Affect of Deformational Stress on Smaller Grains



Matrix-Cement Alteration

The matrix-cement alteration is a common feature of diagenesis. Sericite formation is mostly by the degradation of illite that might have been derived from kaolinite. Sericite in some of the rock grades into muscovite.

In this the alteration of quart grains depends upon the composition of matrix and cements. When there is no matrix authegenic overgrowths occupy the intergranular space (Figure 11). The silica needed for the formation of the overgrowth

Figure 11: Quartz Overgrowths Occupying the Intergranular Space

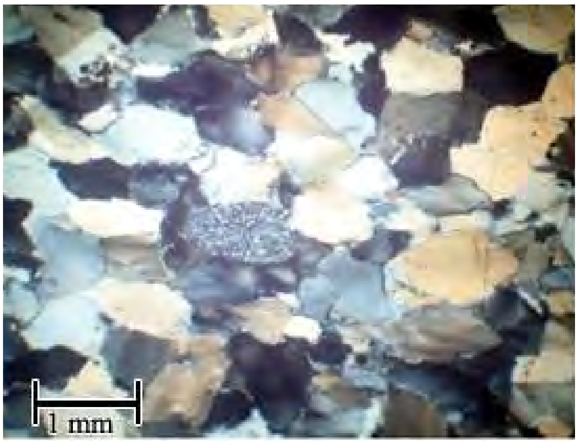
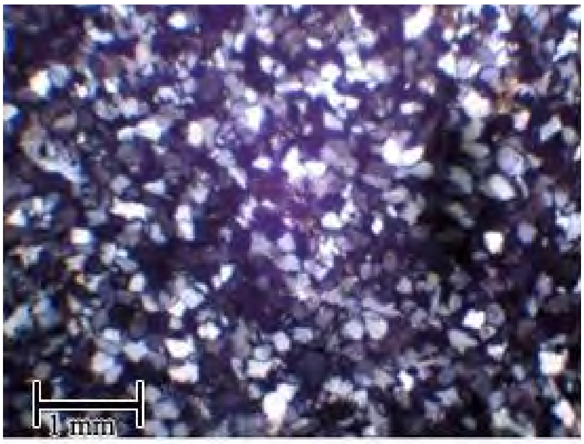


Figure 12: Volcaniclast Like Rock



might have been derived from the solution of fine quartz. In the deep burial stage the silica needed for overgrowth might have been derived from the pressure solution affect.

As already stared the overgrowths will be insignificant when the clay/argillaceous matrix is more. In such a situation considerable etching takes place, giving embayed margins to the grain. This some time may mislead to be a volcaniclast (Figure 12). Carbonate can also replace quartz.

The various patterns of quartz grain solution and replacement by sericite or carbonate include:

1. Etching of grain surfaces, with possible overgrowth penetration.
2. Major grain replacement in unevenly distributed spots or patches, or by calcite crystals.
3. Replacement between the grain and overgrowth.
4. Replacement along grain boundaries.
5. Preferential replacement along crystallographic or deformational planes of weakness.
6. Replacement between crystal members of polycrystalline grains.
7. Replacement along inter and intragranular fractures.
8. Complete grain obliteration.

Alteration along the grain margins, along fractures and between the grain and the overgrowth commonly has occurred first, followed by alteration between individual crystals of polycrystalline quartz. The order of alteration among the several varieties of quartz can be seen in many quartzites.

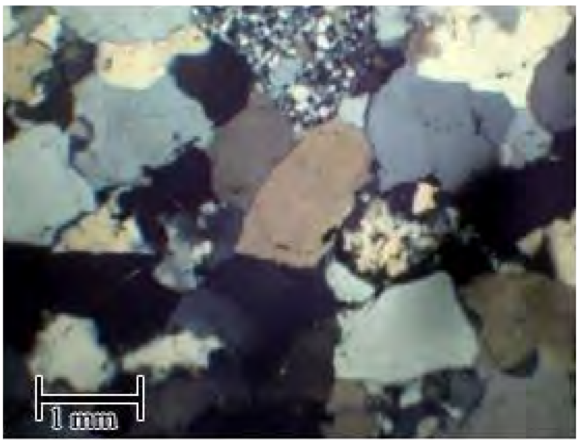
Evidences of Diagenesis

Etching and embayment of detrital grains by crystalline mosaic is an important evidence of diagenesis (Pettijohn *et al.*, 1973). Pore filling is yet another evidence of diagenesis. The development of authigenic quartz grains is also an evidence of diagenesis (Figure 13).

Authigenic Minerals

The main authegenic minerals are quartz. sericite, chlorite, glauconite and calcite.

Figure 13: Development of Authigenic Quartz



Quartz

The authigenic overgrowth of quartz is observed in many sections. This is more conspicuous when the cementing material is all siliceous. When the grains are coated by thick clay the overgrowth is prevented by the thick coating (Carozzi, 1960). The prism type of the overgrowth (Carozzi, 1960) is noticed in almost all the quartzites.

This is more conspicuous in the coarse grains of the Nagari Quartzite. The prismatic overgrowths are indicative of partially cemented grains. In many cases the overgrowth are in optical continuity with the detrital grains. Even the polycrystalline grains exert their influence on the overgrowths causing optical continuity. In certain cases the overgrowths have given complete euhedral nature to the detrital grains.

Feldspars

Feldspars show authigenic overgrowth, which is best observed in the upper part of the Nagari Quartzite. The overgrowth and the detrital feldspars are also kaolinised. Because of the overgrowths the grains have attended subhedral to euhedral nature.

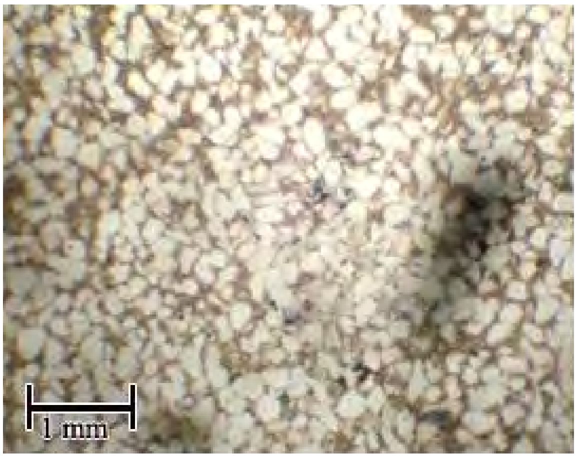
Sericite and Chlorite

These are authigenically developed in the rocks having argillaceous matrix (Figure 14). Chlorite is mainly noticed in the iron rich quartzites that contain argillaceous matrix.

Glauconite

This is well developed in arenaceous partings of Tadpatri Fomation, Gandikota and Nagari Quartzites. These occur as pellet and lobate grains and also as cementing material. These occur as authochothonous and allocothanous grains (Carrozzi, 1960). Glauconite is observed in the contact rocks between the Nagari Quartzite and Pullampet Formation.

Figure 14: Argillaccous Matrix in a Quartzite



Matrix and Cement

As stated earlier silica is the main cementing material. In many cases the argillaceous cementing material, is converted to sericite. Muscovite is noticed along the grain margin. Degradation of illite, formation of sericite and eventually of muscovite has occurred most extensively along the grain margins. This feature is conspicuous when there is argillaceous matrix material, as in the Gulcheru and Nagari Quartzites.

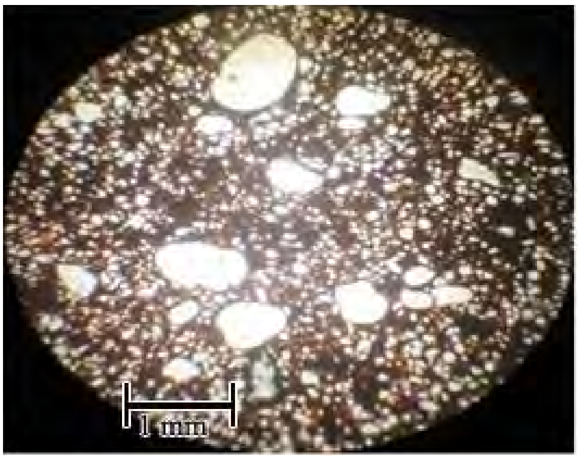
Iron in many cases has replaced the earlier siliceous and argillaceous matrix/cement. In the Gulcheru Qurtzite, the magnetite is seen occurring as ring like structure. Under the microscope it is clear that the iron oxide has replaced the earlier siliceous cementing material and formed a ring like feature. The borders of the Quartz grains are completely corroded by the iron solutions.

As the iron has replaced the authigenically growth quartz, if reflects, that the iron is secondary to the authigenically growth quartz. This replacement is indicative of locomorphic stage of diagenesis (Dapples, 1967). The feature of iron replacing the quartz overgrowths and corroding the grain boundaries is very common in the iron rich quartzites of Gulcheru, Gandikota and Nagari.

In some of the thin sections studied, certain detrital quartz grains are floating in the ferruginous matrix (Figure 15). These do not show the authigenic overgrowth. The grain-matrix boundary stands out and is clearly defined. Dapples (1967) stated that no mineralogical reaction is noticed between the iron oxide and the sand grains. But it is found that the ferruginous material replaces the detrital quartz grains which show corroded margins, suggesting that mineralogical reaction is possible in such cases also.

Sericite, noticed in the quartzites having argillaceous cementing material is seen replacing authigenically grown quartz. Dissolutions of quartz grains by sericite and calcite are also observed. The development of chlorite and sericite are indicative of phyllomorphic stage of diagenesis (Dapples, 1967).

Figure 15: Bi-Modal Floating Grains



Diagenesis of Glauconite Bearing Quartzites

Almost all stratigraphic horizons of Cuddapah Supergroup are glauconite bearing.

Glauconite grains in most of the cases are lobate (Hadding, 1932) pellet shaped with green (Figure 16) and dark brown color (Figure 17). The outer margin is marked by ferruginous material, thus making the glauconite boundary distinct from the rest of the grains. The glauconite occurring as cementing material shows pressure solution effects. When the ferruginous rim is thick, the glauconites have an overall brownish coating. The

Figure 16: Green Glauconite

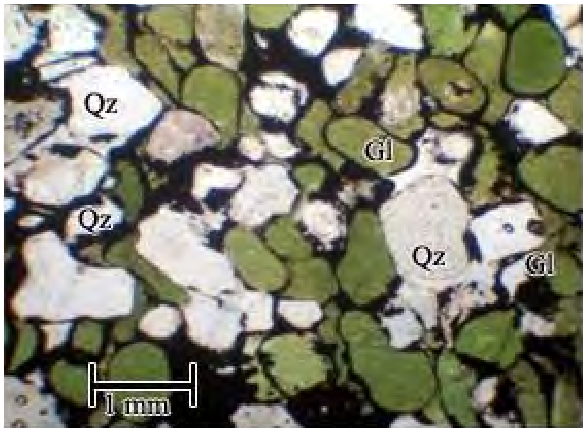
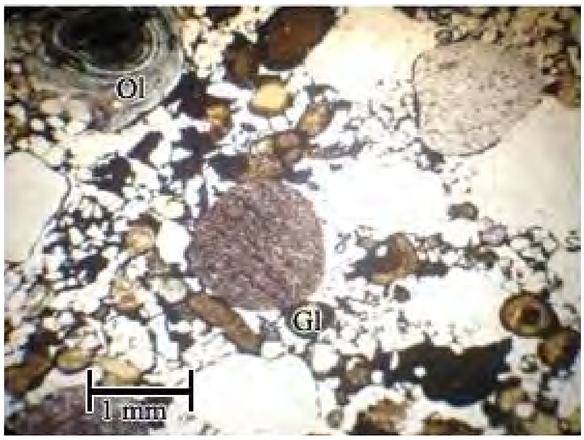


Figure 17: Brown Glauconite



lobate grains show radial cracks. This is more common in the Nagari Quartzite.

The radial cracks clearly result from the dehydration of strongly hydrous and gelatinous glauconite (Carozzi, 1960). Lobate grains are indicative of primary origin.

It is possible to observe the outline of the original glauconite grain where the peripheral zone was dark pigmented by pyrite and has not been affected by replacements (Carozzi, 1960). Traces of completely transformed grains may also be recognized by the same pigmentation zone.

Certain chert grains which have the pellet shape with a ferruginous rim on the boundary must be originally glauconite which is completely chertified. So it may be erroneous to attribute detrital origin to all the chert grains. When two or more glauconites are in close proximity and the ferruginous boundary is thin the chertification does not confine to only one grain but crosses on to the other grains.

There are oolitic chert pebbles in the Nagari Quartzites, which might have been derived from Vempalle Formation. These cherts have crystal opal and microcrystalline quartz (Carozzi, 1960) whose boundaries are invariably corroded. The chert grains have glauconite grains and these glauconites are being chertified.

The degree of chertification varies from grain to grain. The chertified glauconites have microcrystalline quartz, when compared with cryptocrystalline quartz in the main chert mass. Calcification of glauconites is also observed. The calcification extends beyond the grain boundaries of the glauconite into the oolitic chert.

Clay grading into glauconite is clearly noticed in these quartzites. In some cases it appears that the biotite gives rise to glauconite. While glauconite is being chertified, the glauconite replaces the detrital quartz grains and authigenitic quartz. The original boundaries of the detrital quartz and glauconite invading into it are easily recognizable in the Nagari Quartzite.

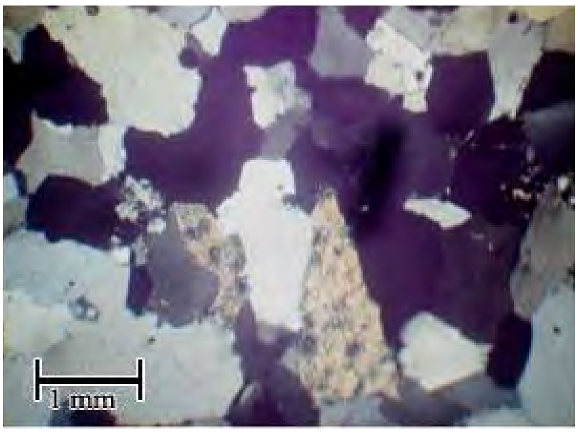
Dapples (1967) has shown (by equation) that Clay mineral + Quartz + K can give rise to glauconite and that the glauconite can form under reducing environment in which small amounts of iron oxide were present principally as $Fe2^{++}$ ions and the pH is approximately 8.

Chlorite (Figure 18) is an authigenic product of glauconite and is rather common. It is abundant and is favored over biotite. This is generally indicative of low temperature (Dapples, 1967).

Glauconite apparently forms under conditions of slow sedimentation in partially restricted environment (Galliher, 1935a and 1935b) Cloud (1955) reviewed the subject and concluded that glauconite formation required marine waters and reducing conditions.

Substitution of chalcedony or chert for clay for clay matrix and interstitial claly is a locomorphic change of common occurrence. Locally chert can be recognized to have replaced part or all of such

Figure 18: Chlorite as an Authigenic Mineral



interstitial clay. The nature of this substitution is not entirely clear (Dapples, 1967). He favoured the simple precipitation of silica with the openings between individual clay mineral crystals.

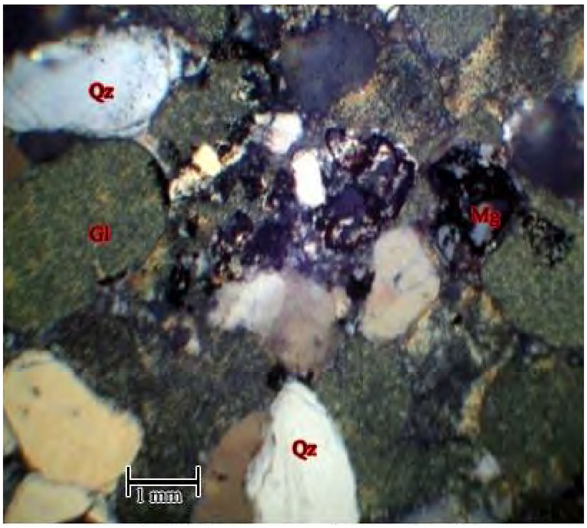
Precipitation of chert in the matrix is normally an early locomorphic process and is considered to follow closely, if not to be contemporaneous with the processes of the redoxomorphic stage. In as much as the clay size interstitial material is known to contain small particles of quartz, these could act as nuclei for precipitation of additional silica (Dapples, 1967).

The chert that developed as stated above has replaced the glauconite (clay) in the quartzites and has given rise to more silicified quartzites.

Most of the glauconite bearing rocks in the area are ferruginous quartzites. The ferruginous material occurs as cementing material and as a rim around glauconite and quartz grains. The formation of this iron material may be the result of oxidation or reduction, i.e., redoxmorphic stage. According to Dapples (1962) this is formed in the early burial stage, i.e., during initial compaction and prior to lithification. This stage gives final color of the rock body strikingly noted in sediments which have the total iron content of more than 7%.

The formation of glauconite represents the phyllomorphic stage of Dapples (1967). This is the late burial stage when there is a slight metamorphic effect. Probably the most characteristic of all halmyrolytic phenomena is that of glauconitisation (Fairbridge, 1967). The most similar and characteristic product of halmyrolysis is glauconite. It forms during the pre-burial stage of diagenesis (Muller, 1967). Muller opined that genesis of glauconite extends from pre-burial stage into shallow burial stage.

Figure 19: Partial Replacement of Glauconite and the Recrystallised Idiomorphic Magnetite



The locomorphic stage of diagenesis (Dapples, 1967) is reflected by the replacement features, i.e., the replacement of quartz, the chertification of glauconite, etc. It is observed that magnetite occurs as idiomorphic crystals in the glauconite grains that are partially replaced (Figure 19). The iron must be the released product of the replacement of glauconite by cherts. Diagenesis in concept is metamorphism. It is inferred that the temperature and pressure conditions during the processes of replacement could be congenial for the recrystallisation of iron into idiomorphic magnetite crystals. Thus, the iron material noticed in the glauconite is different in origin when compared with the material that occurs as cementing material in the rock.

The three distinct episodes described by Dapples (1967) need not occur in a cyclic order. The reaction typical of the early stage can occur during the later stages. Some replacement reactions occur later than the onset of the phyllomorphic stage as indicated by the mineral paragenesis (Dapples, 1967). The present study supports the statement of Dapples. As the burial progresses, the sediment is compacted and content of dissolved oxygen diminishes. For these reasons, reactions characteristic of the redexomorphic stage play increasingly smaller role as diagenesis progresses (Dapples, 1967). The formation of magnetite within the glauconite grains reflects reaction of deep-burial stage of diagenesis.

CONCLUSION

Diagenesis of Glauconite Bearing Quartzite

The coarser clastics of the Cuddapah Basin are termed as quartzite. These rocks cannot be disintegrated by any processes. They are compact are hard because of diagenesis. Hence, the term is quartzite is used. Dapples (1962) described different stages diagenesis of clastics. The description adopted under this is mainly after Dapples. This has been studied under the heads, viz., style of contact, matrix and cement and there alteration, development of authigenic minerals and finally the stages of the diagenesis glauconite.

Based on the above presentation number of conclusions have been drawn that are detailed below:

- Glauconite is also observed in the ferruginous quartzite.
- Matrix/cement in most of the cases are ferruginous and siliceous.
- Diagenesis in concept is metamorphism. The quartzites of Cuddapah Basin are hard and compact because of advanced stage of diagenesis.
- The quartz grain exhibits line contact, cancavo-convex contact, crystal face contact, irregular penetration contact and stylolitic contact.
- The cement in most of the cases is siliceous and occasionally ferruginous.
- The point contact is more conspicuous when the matrix is more. The concavo-convex contact and line contacts are prominent when the cementing material is much less.
- The authigenic minerals are quartz, glauconite, sericite, chlorite and calcite.
- The authigenic quartz is seen as overgrowth and acts as the cementing material. It exhibits optical continuity with the detrital grains. When the matrix is more the development authegenic quartz is much less.
- Sericite is authigenically developed where there is argillaceous matrix. Chlorite is noticed in the iron rich quartzite that contain argillaceous matrix.
- Glauconite is noticed as pellet and lobate grains. It is also seen as cementing material.
- The lobate grain show radial cracks and indicate primary origin. Glauconite is more conspicuous when it-bordered by thin ferruginous rim.
- Glauconite can form when clay mineral, quartz and potash are present under reducing environment.
- All the three stages of diagenesis described by Dapples namely redexomorphic stage, phyllomorphic stage and locomorphic stage are vividly present.
- The redexomorphic stage is represented by the formation of authigenic quartz and the development of iron.
- The phyllomorphic stage is marked by the formation of glauconite.

- The locomorphic stage is indicated by the replacement phenomena.
- The locomorphic stage of diagenesis in respect of the glauconite has been clearly indicated by the formation of idiomorphic magnitude within the glauconite. The released non due to diagenesis is converted into idiomorphic magnetite. This clearly explains that diagenesis in concept is metamorphism.
- The three distinct episodes described by Dapples (1967) need not occur in a cyclic order. The reaction typical of the early stage can occur during the later stages. Some replacement reactions occur later than the onset of the phyllomorphic stage as indicated by the mineral paragenesis (Dapples, 1967). The present study supports the statement of Dapples. As the burial progresses, the sediment is compacted and content of dissolved oxygen diminishes. For these reasons, reactions characteristic of the redexomorphic stage play increasingly smaller role as diagenesis progresses (Dapples, 1967). The formation of magnetite within the glauconite grains reflects reaction of deep-burial stage of diagenesis.
- The diagenetic aspect of glauconite in the Banaganapalle Quartzite and intercalated ferruginous quartzite of the Narji Limestone are similar to the glauconite bearing quartzites of the Cuddapah Supergroup.
- The presence of glauconite indicates shallow water slow deposition under marine condition.
- Glauconite that in formed *insitu* (though not studied for geochronological purpose) can be used extensively for dating the sediments by k–Ag method.

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