PETROGRAPHY AND FLUID INCLUSION STUDIES ON LATE PROTEROZOIC PALNAD SILICICLASTICS, KURNOOL GROUP, ANDHRA PRADESH

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Petrographic studies of Palnad siliciclastics reveal medium to fine grained, subrounded to rounded detrital quartz grains cemented by silica mostly as authigenic overgrowth. Fluid inclusions trapped in the quartzites of Kurnool Group (Palnad Basin) are of aqueous saline type. The melting temperature indicates salinity values of 5-17.2 wt% NaCl equivalent and the density of these saline fluids vary from 0.889-0.952 gcm^{-3}. The entrapment of fluids in quartz grains took place between the temperature range of 76.5° to 202°C. Petrography and microthermometric data of these quartzites points to granites and granitic gneisses as the source rocks. The presence of secondary inclusions indicates probable tectonic activity during the deposition of the sediments in the study area.

Introduction

Late Proterozoic Kurnool Group of rocks are exposed in Kurnool as well as in Palnad sub-basin The Palnad sub- basin forms NE part of the crescent shaped Cuddapah basin, covering an area of about 3600 sq kms in the Krishna valley. The Kurnool Group was first classified by King (1872) into four formations Banaganapalle, Jammalamadugu, Paniam and Kundair (Table 1) Subsequently, Dutt (1962), Meijerink et al (1983) and Nagaraja Rao et al (1987) modified the stratigraphy of the Kurnool Group The lithological sequence of Kurnool Group is of orthoquartzite-limestone-shale association with two cycles of sedimentation (Rao and Gokhale, 1975) The chief lithological units in the Kurnool Group are conglomerates, quartzite, shale and limestone

Petrography and fluid inclusion studies have been carriedout in quartzites of Kurnool Group in the SW part of Palnad basin There are several reports of the fluid inclusion studies on siliciclastics from different parts of the world (Morad et al 1991, Walderhaugh, 1994, Wojcik et al 1994, Sachan and Ghosh, 1996, Weedman et al 1996, Sharma and Misra, 1998) In the present study, quartzite samples were collected from different localities of the SW part of the Palnad basin and investigated for petrography and fluid inclusion to evaluate the provenance of the Palnad siliciclastics

Geology of the Area

Tectonically the Kurnool Group of rocks rests unconformably over the Archaean granitic gneisses, BFQ and hornblende Schists in the NW, West and SW part of the basin In the SE part, the Kurnool sediments rest unconformably over the Bairenkonda quartzites and Cumbum phyllites belonging to Cuddapah Formation

The major lithologic formation of the Kurnool Group in the study area are quartzites belonging to Banaganapalle and Paniam Formation These are widespread extending over the north and western parts with ridges running from west to east in the central part of the area Banaganapalle quartzite forms the lower siliciclastic sequence lying unconformably over the Archaeans in the west, north and east along the periphery of the basin (Fig 1) The unit is succeeded by Narji Limestones and the latter in turn by the Auk shales, all bearing mutually conformable relations.

Table 1. Lithostratigraphy of the Kurnool Group (*after* King, 1872)

Group	Formation	Members	Lithology
KURNOOL	Kundair	Nandyal	Shale
		Koilkuntla	Limestone
	Paniam	Plateau	Quartzite
	- - Unconformity - -		
	Jammalamadugu	Auk	Shale
		Narji	Limestone
	Banaganapalle	Banaganapalle	Quartzite, Sandstone
- - Unconformity - -			
Cuddapah	Nallamalai	Cumbum	Slates, Phyllites
		Bairenkonda	Quartzites
Dharwar (Archaean)			Granitic Gneisses BFQ Hornblende Schist

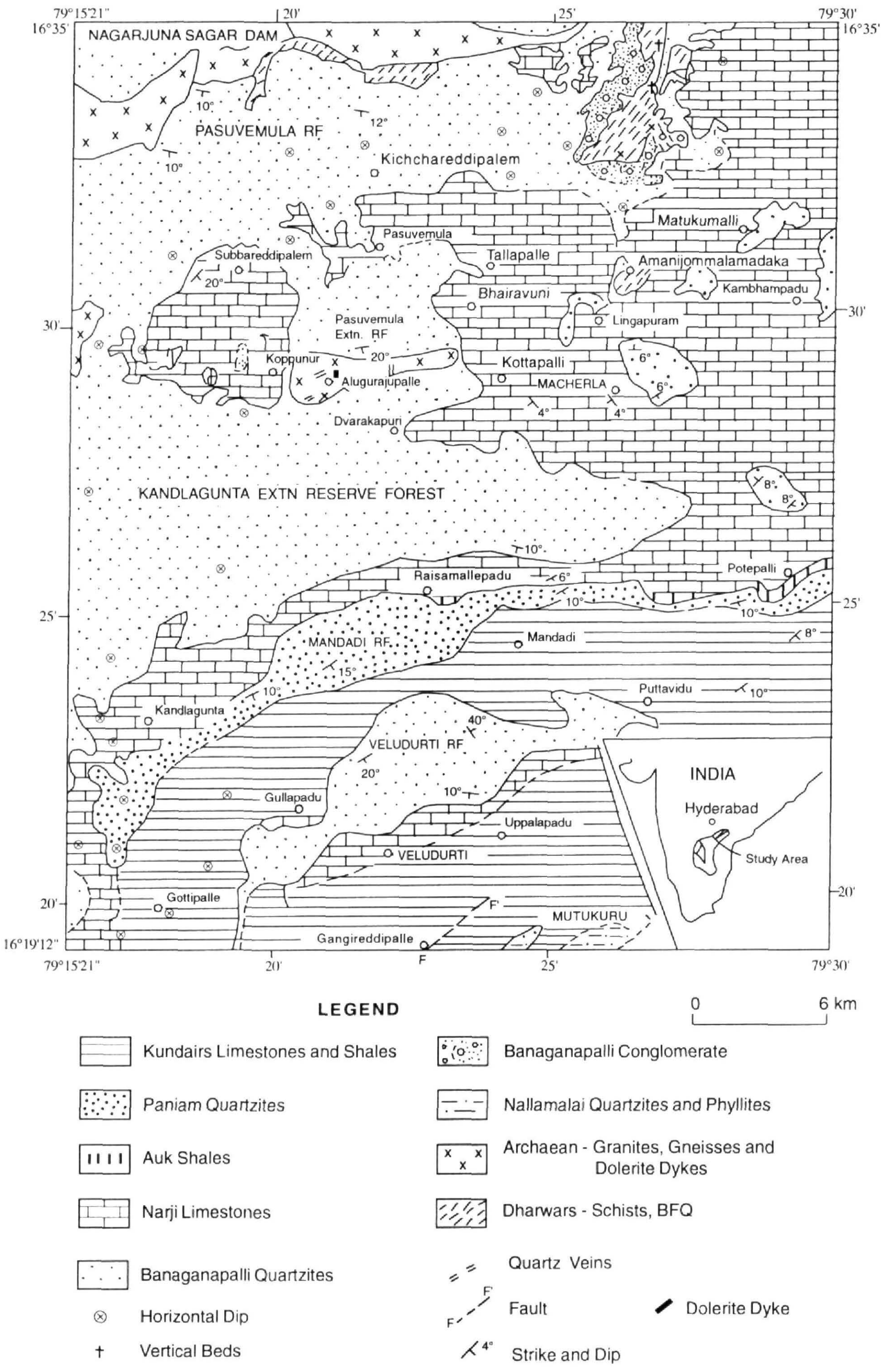

Fig.1. Geological Map of the southwestern part of the Palnad basin (*after* Vijayam and Reddy, 1976).

The Banaganapalle Quartzite consists of orthoquartzites with a few intercalations of shales in the bottom and top sections. There are also thin basal arkose beds at the bottom and the upper horizon is of orthoquartzite. Some of the beds, particularly in the lower horizon, are ferruginous with a coating of iron oxide over the quartz grains. Quartzites are highly compact and medium grained having a thickness of about 50 m. Paniam quartzite which is the upper silici-clastic sequence of the Kurnool Group lie unconformably over the Auk Shales. The sequence consists mainly of quartzarenites, medium to fine grained with a thickness of about 10-15 m.

Petrography

Petrographically quartzites show a comparatively simple mineralogy. Banaganapalle Quartzite is medium to fine grained subfeldsarenites and quartzarenites. The framework constituents consist mainly of quartz and subordinate feldspar and rock fragments. Quartz is the dominant mineral varying between 95-98%, represented mostly by monocrystalline non-undulatory, undulatory and polycrystalline varieties. Individual crystal units of the polycrystalline quartz detritus are usually characterised by non-undulatory extinction. Grains are euhedral, mostly rounded to subrounded in nature. Some of the grains show inclusion vacuoles and corroded grain margins. Feldspar consists of rounded to subrounded microcline and orthoclase. Feldspar together with rock fragments forms less than 1% of the detrital constituents. Interstitial clay minerals are present in some thin sections. A red film of iron oxide is coated on most of the grains and clay on some grains. The authigenic quartz overgrowth is very well developed and it covers most of the depositional pore space. An interlocking quartz mosaic is developed due to silica overgrowth on the grains. The primary quartz occurring in the form of rounded to subrounded grains are separated from the secondary quartz by well defined dusty rings (Harish and Basavarajappa, 1999). Usually fringes of ferruginous impurities occur bordering the quartz grains as dust rings by means of which they can be easily distinguished from the authigenic growth.

Paniam Quartzite is medium to fine grained quartz-arenite exhibiting saccharoidal texture. Quartz constitutes 97-98% of the modal composition of the quartzite. Quartz grains are of monocrystalline non-undulatory, undulatory and polycrystalline varieties and are rounded to subrounded in nature. The individual crystal grains of the poly-crystalline quartz are mostly non-undulatory. The quartz grains show different types of grain contact. Authigenic quartz overgrowth is faintly developed because of the high degree of perfection. Feldspar and rock fragments are rarely seen. Quartzite is free from clay minerals and mica.

Fluid Inclusion Studies

Fluid inclusion petrography was carriedout on carefully prepared doubly polished thin wafers of the Banaganapalle and Paniam Quartzite. The study was carriedout using *Linkam* heating-freezing stage attached with Leitz-Laborlux microscope.

Quartz grains which are highly resistant, dominantly hosts the fluid inclusions. Optical studies have shown that aqueous fluid inclusions present in quartz grains are of biphase type and very few are monophase at room temperature. The biphase inclusions found in quartz grains show random as well as arrayed distribution indicating their primary and secondary nature (Figs. 2 and 3). The monophase inclusions are inert to heating and freezing experiments, indicating that these inclusions are not filled with metastable stretched water solutions (Roedder, 1984). The size of the inclusions vary from less than 1 μm to 10 μm and are oval to subrounded in shape. Fluid inclusions are mainly confined to original primary quartz grains and are not found in the authigenic quartz overgrowths. The data on the phase transition temperatures of fluid species of both Banaganapalle and Paniam quartzite are presented in Table 2. The density and salinity

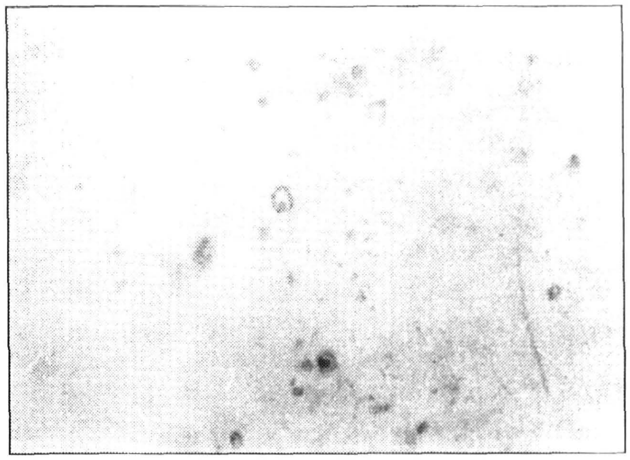

Fig.2. Randomly distributed biphase aqueous fluid inclusions in quartzites

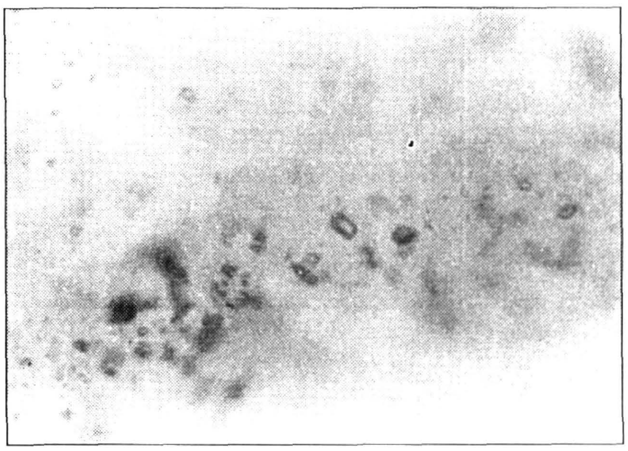

Fig.3. Arrayed biphase and monophase aqueous fluid inclusions in quartzites.

Table 2. Microthermometric results of Banaganapalle and Paniam quartzites

Sl No	Rock Type	H_2O Inclusions (In Quartz)							
		Primary				Secondary			
		Tm (°C)	Salinity Wt% NaCl eq	Th (°C)	d (gcm⁻³)	Tm (°C)	Salinity Wt% NaCl eq	Th (°C)	d (gcm⁻³)
1	Banaganapalle Quartzite	-11 9	16 3	121 4	0 934	-10 1	16 5	92 5-97 3	0 946-0 941
2	Banaganapalle Quartzite	-10 8	15 3	140 6	0 929	-10 3	17 0	93 - 99 7	0 945-0 939
3	Banaganapalle Quartzite	-11 4	15 9	131 2	0 931	-10 4	17 2	92 9	0 946
4	Banaganapalle Quartzite	-11 0	15 5	185 6	0 915	-10 1	16 5	94 6	0 942
5	Paniam Quartzite	-6 3	9 4	98 -157	0 941-0 924	-11 1	15 6	76 5-89	0 952-0 943
6	Paniam Quartzite	-2 9	5 0	116 4	0 935	-6 1	9 0	116 1-146 8	0 935-0 925
7	Paniam Quartzite	-3 1	5 5	125 6	0 933	-3 9	6 2	101 1-145 0	0 940-0 926
8	Paniam Quartzite	-6 1	9 0	152 8-202	0 928-0 889	-10 7	15 0	118 0	0 934

data have been calculated after the method of Lemmlein and Klevtsov (1961), Sourirajan and Kennedy (1962) and Brown and Lamb (1989)

Measurable biphase aqueous fluid inclusions are found in the isolated rounded to subrounded primary quartz grains belonging to Banaganapalle Quartzite. These biphase aqueous inclusions show eutectic melting temperatures varying from -14.9 to -13.6°C which suggest the composition of trapped fluid as H_2O-NaCl (Sourirajan and Kennedy, 1962; Roedder, 1962a; Linke, 1965 and Potter et al. 1978). The aqueous inclusions show final ice melting between (Tm°C) temperature range of -11.9 to -10 8°C with a mean peak between -12 to -9°C (Fig. 4a) indicating salinity values of 16.3 to 15 5 wt% NaCl equivalent. Temperature of homogenization (Th °C) of primary aqueous inclusions varies from 121 4-185 6°C with a mean peak between the temperature range of 100-150°C which indicates density values of 0.915 to 0.934 gcm⁻³ (Fig.4b). Trail bound secondary aqueous inclusions show first melting temperatures (Tm°C) which ranges between -11 to -11.8°C Final melting temperatures (Tm°C) range from -10.1 to -10 4°C with a mean peak between -12 to -9°C which yield salinity values of 16.5 - 12.5 wt% NaCl equivalent. Homogenization temperatures (Th °C) vary from 90-100°C indicating density values of 0.987 to 0.981 gcm⁻³.

Aqueous inclusions present in the quartz grains of Paniam quartzite are biphase at room temperature and occur as isolated inclusions. These primary inclusions show initial melting temperature of -11.1 to -11.8°C. Final melting temperature range from -6 3 to -2 9°C with a mean peak between -6 and 0°C (Fig. 4c) which suggest that the system of inclusions belongs to NaCl-H_2O. This melting temperature corroborates with the salinity values of 11.0 wt% NaCl equivalent. Homogenization of the biphase primary inclusion took place between the temperature range of 90-140°C (Fig. 4d). This homogenization temperature corresponds to the density values of 0.975 to 0 941 gcm⁻³.

Secondary trail bound biphase aqueous inclusions present in quartz grains of Paniam quartzite show initial melting temperature of -12 to -6.4°C which suggest that they belong to NaCl-H_2O system. Range of melting temperatures show mean peak between -12 to -6°C which yields salinity values of 16.5 to 11 gcm⁻³. Homogenization temperature recorded for these aqueous fluid species show a range of 76.5 to 146.8°C with a mean peak between the temperature range of 70 to 120°C which yields density values of 0.989 to 0.960 gcm⁻³.

Discussion

Petrographically the siliciclastics of the SW part of the Palnad basin have been classified as quartzarenites and subfeldsarenites. Based on the quartz, feldspar and rock fragments ratio the Banaganapalle and Paniam Quartzites are mature and supermature in nature. The near absence of rock fragments in the quartzites indicates that they are derived from coarse grained plutonic rocks (Pettijohn et al. 1972; Pettijohn, 1975). Basu et al. (1975) and Young (1976) have shown the usefulness of quartz types namely monocrystalline non-undulatory quartz, monocrystalline undulatory quartz, polycrystalline quartz with 2-3 crystal units and polycrystalline quartz with more than 3 crystal units in deciphering the ultimate source rock for a detrital quartz population. Based on the above mentioned four types of quartz, Basu et al. (1975) published a diamond diagram for deciphering source rock types. Most of the points fall in the plutonic field (Fig. 5) indicating the granites and granitic

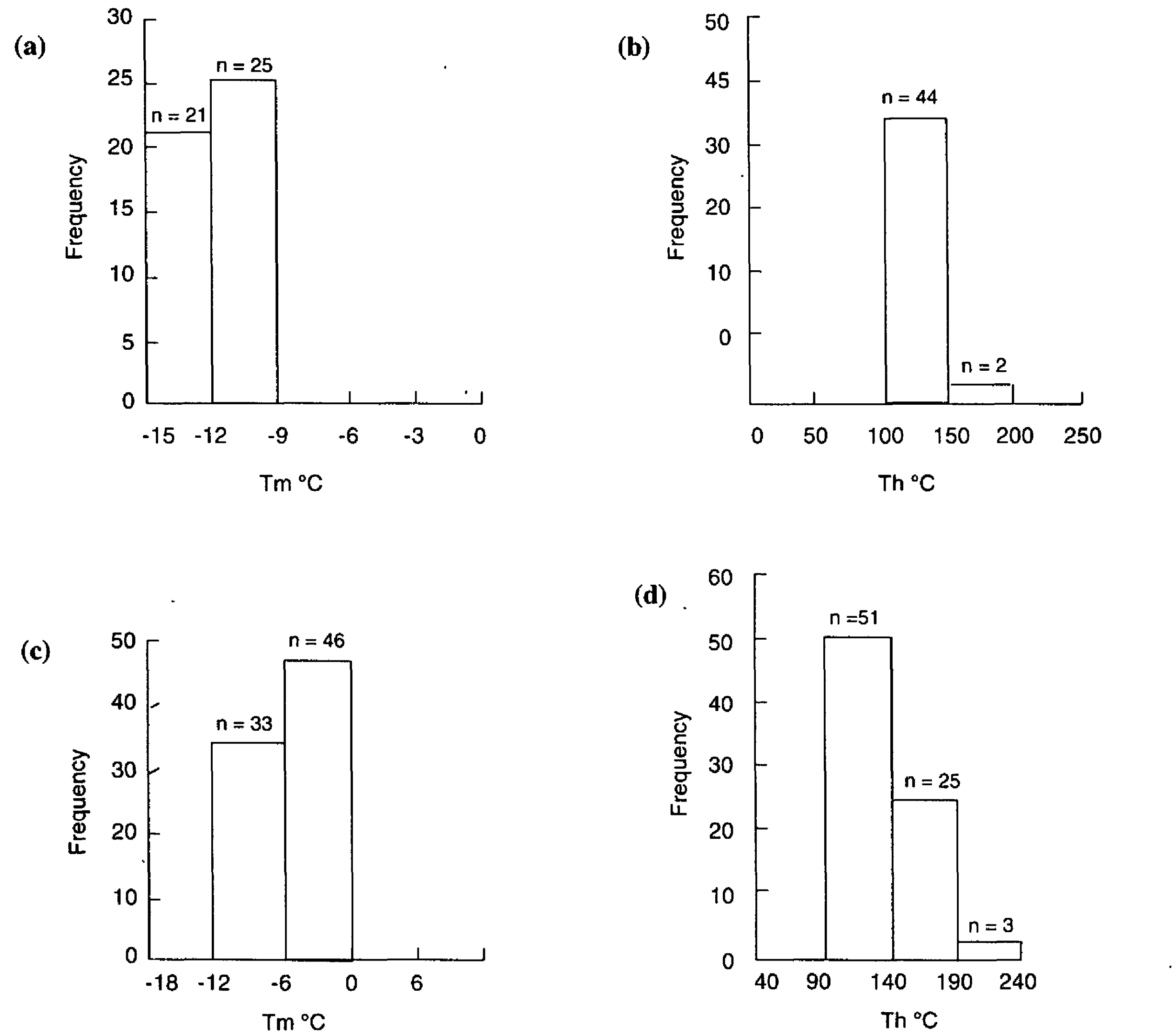

Fig.4. (a) Histogram showing melting temperature (Tm °C) of primary biphase aqueous inclusions in Banaganapalle quartzite. (b) Histogram showing homogenization temperature (Th °C) of primary biphase aqueous inclusions in Banaganapalle quartzite. (c) Histogram showing melting temperature (Tm °C) of primary biphase aqueous inclusions in Paniam quartzite. (d) Histogram showing homogenization temperature (Th °C) of primary biphase aqueous inclusions in Paniam quartzite.

gneisses as the source rock for the Palnad siliciclastics. According to Blatt et al. (1980) the non-undulatory quartz grains are indicative of fine grained schists, phyllites and slates; volcanic and hypabyssal igneous rocks and pre existing sedimentary rocks as the source rock for these quartzites.

From the above fluid inclusion study it is revealed that the entrapment of fluid in quartz took place in the range 76.5-202°C. The melting temperature for both Banaganapalle and Paniam Quartzite indicates the composition of the trapped fluid as H_2O-NaCl (Roedder, 1962a; Potter et al. 1978; Linke, 1965). The density data for both Banaganapalle and Paniam quartzite (0.987 to 0.934 gcm^{-3} and 0.975 to 0.941 gcm^{-3}) obtained from the statistically treated Th frequency histogram as well as relatively high salinity values possibly indicate that the fluids are derived from the crystalline basement rocks which are made up of Archaean granites and granitic gneisses. This is because, the fluid inclusion studies on granites and granitic gneisses (Shoji and Zaw, 1990; Srikantappa et al. 1992) have indicated approximately same density and salinity values elsewhere. Also, from the sedimentological studies the provenance for these quartzites is inferred as Archaean granites and granitic gneisses and the Cuddapah sediments

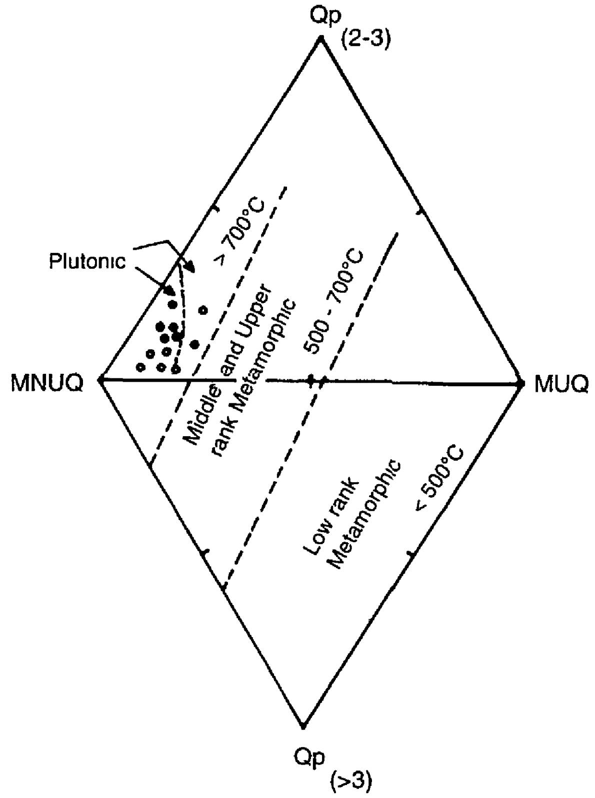

Fig.5. Diamond pattern plot (Basu et al 1975) showing the nature of source rock types for Banaganapalle and Paniam Quartzite MNUQ - Monocrystalline non-undulatory quartz MUQ - Monocrystalline undulatory quartz Qp - Polycrystalline quartz

(Reddy, 1972) The secondary inclusions found along the fractures of original detrital quartz grains possibly indicate their entrapment during tectonic activity From structural studies it is known that the Palnad basin has experienced two tectonic episodes of pre-Kurnool and post-Kurnool nature In the study area, the Cumbum Formation (Cuddapah Group) rests over the Narji Limestone with a thrust contact which has to be post Kurnool (Setti and Rajurkar, 1964, Rajurkar, 1976, Ramalingaswamy, 1976 and Natarajan and Rajagopalan Nair, 1977)

Conclusions

Based on the detailed petrographical and fluid inclusion studies of quartzites of SW part of the Palnad basin it is suggested that the Archaean granites, granitic gneisses and sedimentary formations belonging to Cuddapah Group are the source rocks for the Palnad siliciclastics The trails of secondary inclusions indicate the tectonic activity during the deposition of the sediments in the study area

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References

Basu, A , Young, S W , Suttner, L J , James, W C and Mack, G H (1975) Re-evaluation of the use of undulatory extinction and polycrystalline in detrital quartz provenance interpretation Jour Sed Petrol , v 45, pp 873-882

Blatt, H , Middleton, G V and Murray, R C (1980) Origin of sedimentary rocks Prentice Hall Inc

Brown, PE and Lamb, W M (1989) P V-T properties of fluids in the system $H_2O + CO_2 + NaCl$, New graphical presentations and implications for fluid inclusion studies Geochim et Cosmochim Acta , v 53, pp 1209-1221

Dutt, N V B S (1962) Geology of the Kurnool system of rocks in Cuddapah and the southern part of the Kurnool districts Rec Geol Surv India, v 87(3), pp 549-604

Harish, V and Basavarajappa, H T (1999) Diagenetic transformations in quartzites of Kurnool Group (Precambrian), Andhra Pradesh, Jour Indian Assoc Sedimen , v 18(1), pp 15-22

King, W (1872) The Cuddapah and Kurnool Formations in the Madras Presidency Mem Geol Surv India, v 8, pp 1-320

Lemmlein, C C and Klevtsov, P V (1961) Relations among the principal thermodynamic parameters in a part of the system H_2O-NaCl Geochemistry, v 2, pp 148-158

Linke, W F (1965) Solubilities of inorganic and metal organic compounds Am Chem Soc , v 2, Washington D C , 4th Edn , 1914p

Meijerink, A M J , Rao, D P and Rupke, J (1983) Stratigraphic and structural development of the Precambrian Cuddapah basin, SE India Precambrian Res , v 26, pp 57-104

Morad, S , Bhattacharyya, A , Al-Aasm, I S and Ramseyer, K (1991) Diagenesis of quartz in the upper Proterozoic Kaimur sandstones, Son valley, central India Sedimentary Geology, v 73, pp 209-225

Nagaraja Rao, B K , Rajurkar, S T , Ramalingaswamy, G and Ravindra Babu, B (1987) Stratigraphy, structure and evolution of the Cuddapah basin Mem Geol Soc India, no 6, pp 33-86

Natarajan, V and Rajagopalan Nair, S (1977) Post Kurnool thrust and other structural features in the northeast part of the Palnad basin, Krishna district, Andhra Pradesh Jour Geol Soc India, v 18(3), pp 111-116

PETTIJOHN, F.J., POTTER, P.E. and SIEVER, R. (1972) Sand and sandstones; Springer, New York.

PETTIJOHN, F.J. (1975) Sedimentary Rocks, Harper and Row, New York, 717p.

POTTER, R.W., CLYNNE, M.A. and BROWN, D.L. (1978) Freezing point depression of aqueous NaCl solutions. Econ. Geol., v.73, pp.284-285.

RAJURKAR, S.T. (1976) Pre-Kurnool age of the Cuddapah orogeny. Ind. Mineralogist, v.18, pp.32-39.

RAMALINGASWAMY, G. (1976) Geology of the Irlakonda plateau and the western part of the Srisailam Plateau, Cuddapah basin, Kurnool and Mahaboobnagar districts. GSI Progress report for the field season (1975-76). Unpublished.

RAO, D.M. and GOKHALE, K.V.G.K. (1975) Clay mineralogy of Kurnool sediments in Cuddapah basin (India). Proc. Int. Clay Conf., Appd. Pub. Ltd., Wilmette, Illinois, USA.

REDDY, P.H. (1972) Unpublished Ph.D Thesis, Osmania University

ROEDDER, E. (1962a) Studies of fluid inclusions I: Low temperature application of a dual purpose freezing and heating stage. Econ. Geol., v.57, pp.1045-1061.

ROEDDER, E. (1984) Fluid Inclusions. Miner. Soc. Am., Washington D.C., v.12, pp.58-59.

SACHAN, H.K. and GHOSH, S.K. (1996) Fluid inclusion study of the Neoproterozoic Nagthat siliciclastic sediments, NW Kumaun Lesser Himalaya: Implications to quartz cementation history. Jour. Geol. Soc. India, v.47, pp.107-114.

SETTI, D.N. and RAJURKAR, S.T. (1964) Correlation and structure of Cuddapahs and Kurnools in Palnad area, Cuddapah basin. Jour. Geoscience Assocn., v.4, pp. 37-42.

SHARMA, R. and MISRA, D.K. (1988) Evaluation and resetting of the fluids in Manikaram Quartzite, Himachal Pradesh: Application to burial and recrystallisation. Jour. Geol. Soc. India, v.51, pp.785-792.

SHOJI, T. and ZAW, T. (1990). Fluid inclusions of granitoids and their bearing on mineralisation in South Korea. Jour. Korean Inst. Mining Geol., v.23(2), pp.127-133.

SOURIRAJAN, S. and KENNEDY, G.C. (1962) The system of H_2O-NaCl at elevated temperature and pressure. Amer. Jour. Sci., v.260, pp.115-141.

SRIKANTAPPA, C., PRAKASH NARASIMHA, K.N. and BASAVARAJAPPA, H.T. (1992) Highly saline fluid inclusions in Chamundi granite, South India, Curr. Sci., v.62(3), pp.307-309.

VIJAYAM, B.E. and REDDY, P.H. (1976) Tectonic framework of sedimentation in the western part of the Palnad basin, Andhra Pradesh. Jour. Geol. Soc. India, v.17(4), pp.439-448.

WALDERHAUGH, O. (1994) Temperatures of quartz cementation in Jurassic sandstones from the Norwegian continental shelf: evidences from fluid inclusions. Jour. Sed. Res., v.64, pp.311-323.

WEEDMAN, S.D., BRANTLEY, S.L., SHIRAKI, R. and POULSON, S.R. (1996). Diagenesis, compaction and fluid chemistry modelling of a sandstone near a pressure seal: Lower Tuscaloosa Formation, AAPG Bull., v.80, pp.1045-1064.

WOJCIK, M., GOLDSTEIN, R.H. and WALTON, A.W. (1994). History of diagenetic fluids in a distant foreland area. Middle and upper Pennsylvanian, Cherokee basin, Kansas, USA; Fluid inclusion evidence. Geochim. et. Cosmochim. Acta, v.58, pp.1175-1191.

YOUNG, S.W. (1976) Petrographic textures of detrital polycrystalline quartz as an aid to interpreting crystalline source rocks. Jour. Sed. Petrol., v.46, pp.595-603.

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