JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.86, August 2015, pp.131-136

# New 1.9-2.0 Ga, Pb-Pb (PbSL), Age of Dolomites from Vempalle Formation, Lower Cuddapah Supergroup, Eastern Dharwar Craton, India

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**Abstract :** Uranium mineralised and non-mineralised dolomites from Vempalle Formation, Lower Cuddapah Supergroup, were analysed by Pb-Pb systematics (Pb Sequential Leaching-PbSL), to ascertain the age of deposition, uranium mineralization, diagenesis and dolomitisation. PbSL technique is a well established tool to be used for direct dating of carbonate rocks world wide. Based on present study, using PbSL technique, it is established that the age of deposition, diagenesis, dolomitisation and syn-diagenetic uranium mineralization, in the Vempalle dolomites, is c. 1900-2000 Ma. Such older ages were not reported earlier from any part of the Cuddapah basin.The present age is within the existing stratigraphic time frame, as mafic sill intruding the Vempalle Formation is dated as c.1885 Ma and this indicates that Vempalle dolomites and syn-diagenetic uranium mineralization in it, have to be older than c.1885 Ma. The deposition of carbonate sediments, diagenesis, dolomitisation and syn-diagentic uranium mineralization in the Vempalle Formation took place in a short duration of 100 Ma, similar to the Wittenoon Formation and Carawine Dolomite of Hamersley Group, Western Australia, in which time between initial deposition, diagenesis and late dolomitisation is 100-150 Ma. The Cuddapah basin might have formed during the period c. 2200–2100 Ma, as evidenced by widespread mafic dyke activity around Cuddapah basin during that time. Present study infers that the minimum age of the onset of sedimentation in the Cuddapah Supergroup was at around c. 2000 Ma and the diagenesis, dolomitisation and syn-diagenetic uranium mineralisation took place up to 1900 Ma.

**Keywords:** Dolomites, Vempalle Formation, Cuddapah Supergroup, Eastern Dharwar craton.

## INTRODUCTION

Exploration for uranium, in and around the Cuddapah basin for over two decades, has resulted in identifying a new and potential uranium province, namely "The Cuddapah Uranium Province". This province hosts five distinct types of uranium mineralisation differing in time and geological settings and out of which stratabound stromatolitic dolomite hosted uranium mineralization, in Vempalle Formation, is a unique type of uranium deposit in the world reported only in Cuddapah basin (Dhana Raju et al., 1993; Rai et al., 2002). Earlier age data related to the Vempalle Formation, have been reported by many workers (Bhaskar Rao et al., 1995; Zachariah, et al., 1999; Anand et al., 2003; French et al., 2008) but precise geochronological data, related to the age of sedimentation, diagenesis, dolomitisation and uranium mineralisation, are not known. In this paper new ages have been obtained by Pb-Pb isotopic systematics (PbSL-Pb sequential leaching) by directly dating dolomites from Tummalapalle area, Kadapa district, Andhra Pradesh, India, belonging to Vempalle Formation of Papaghni Group, Cuddapah Supergroup. The aim of this study is to understand the age of deposition, diagenesis, dolomitisation and uranium mineralisation, by derectly dating the uranium mineralised and non-mineralised dolomites that are exposed along the southwestern margin of the Cuddapah basin. Present study is of paramount interest from the point of view of uranium exploration.

## SAMPLING AND METHODOLOGY

The dolomite samples are mostly borehole core samples from two different blocks of Tummalapalle area, Kadapa district, A.P.. The samples are fresh as they have been collected from the borehole depths of 150 to 450 meters over the stike length of 6 km and have both horizontal and vertical distribution, hence, representing whole Vempalle Formation. Location of the study area is shown in the Fig.1. Methodology followed for the geochronological study

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(PbSL), is mainly after Frei et al., 1997 and Pandey et al., 2011, with slight modification. The powdered, fresh and representative dolomite samples of -200# size were subjected to leaching initially with ultra pure water and thereafter by HCl of different molarities (1M and 2.5 M) with two minutes (1M HCl, 3 fractions) and five minutes (2.5M HCl, 2 fractions) leaching time. The residue left over after leaching as well as whole rock samples were dissolved separately using conc. HF and 8M $HNO_3$. Pb was separated from the solution (in 0.5MHBr), by anion exchange AG1x8 resin, with 1M $HNO_3$. Loading of Pb sample was done on single Rhenium filament using silica gel bedding technique and their isotopic ratios determined on multicollector Thermal Ionisation Mass Spectrometer (TIMS-VG-354). The mass fractionation factor of 0.15% per AMU obtained, based on analyses of SRM981 Pb standard, were applied to

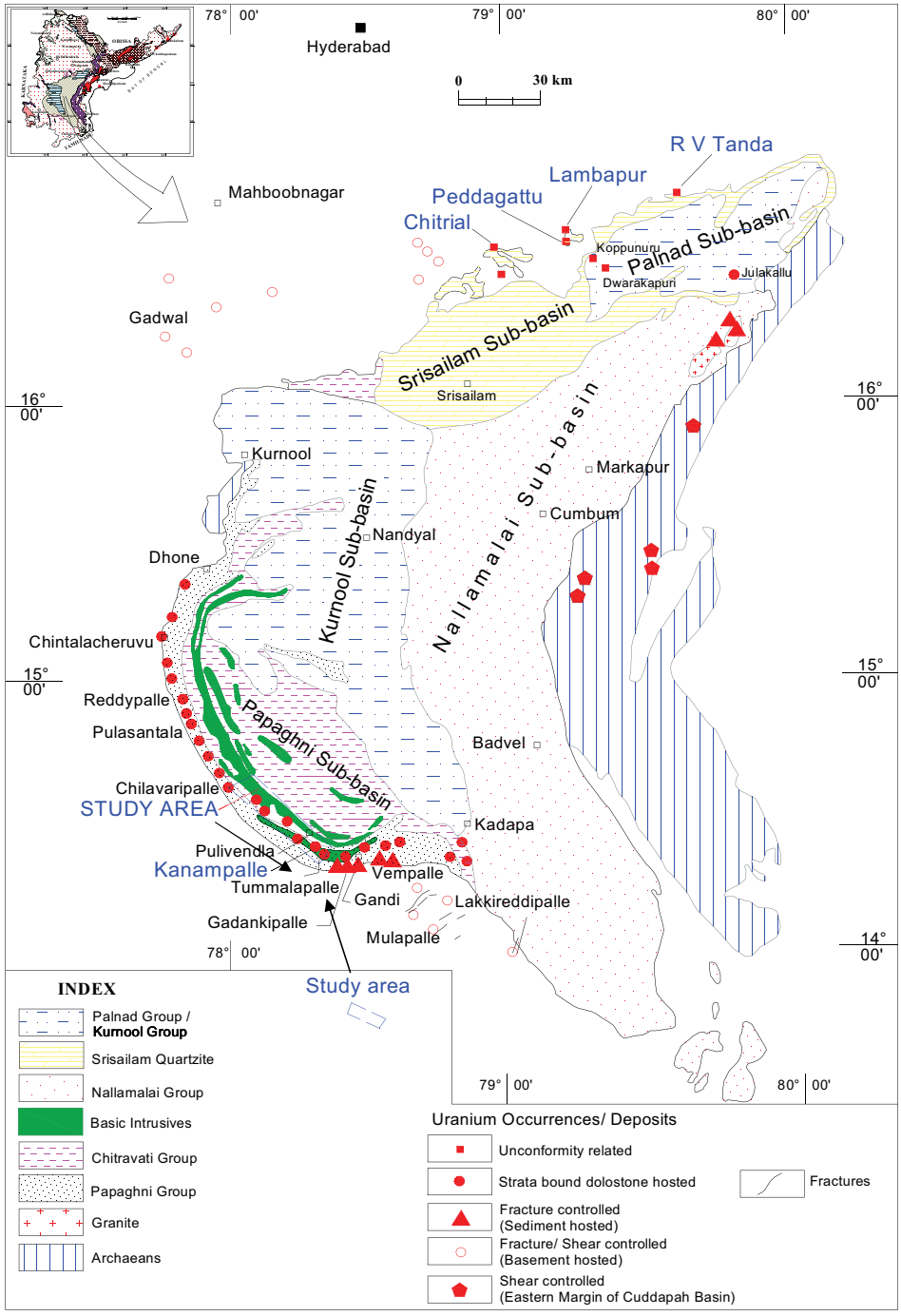


**Fig.1.** Geological map of Cuddapah basin with location of study area.

correct Pb isotopic ratios. The 2σ analytical error, in $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios, are 0.2%, based on number of duplicate analyses. The radiogenic SRM 983 standard was run during sample analyses which gave $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios as 2697.5±7, 191.97±0.5 and 36.770±0.09 respectively (n=10) and total analytical Pb blank was 2 ng. $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ ratios were regressed using ISOPLOT program of Ludwig, 1993, to get isochron age.

## GEOLOGY

The intracratonic Cuddapah basin occurs in the Eastern Dharwar Craton (EDC) and is part of it (Ramakrishnan and Vaidyanadhan, 2008). The ages of detrital zircons in the EDC reveal presence of widespread Archaean crust (3.1–3.3 Ga) which are subsequently affected by later geological activities notably at 2.8 and 2.5 Ga (Maibam et al., 2011). Nagaraja Rao et al., 1987, presented detailed stratigraphy of the basin in which the Cuddapah Supergroup is divided into three groups i.e. Papaghni, Chitravati and Nallamalai groups. The present study area, i.e. Tummalapalle block, is part of the Vempalle Formation belonging to Papaghni Group, which is arcuate in shape, paralleling the southwestern margin of the Cuddapah basin (Fig.1). A mafic/ultramafic sill, intrusive into the base of the Tadpatri Formation (Chitravati Group), was dated as c.1817 to 1885 Ma, from near Pulivendla, using Rb-Sr, U-Pb and Ar-Ar systematics (Bhaskar Rao et al., 1995; Anand et al., 2003; French et al., 2008) and provided timing of mafic magmatism associated with early development of the Cuddapah basin in the EDC. Zachariah, et al.,1999, first attempted to get the age of uranium mineralization and sedimentation in the Vempalle Formation (Papaghni Group, Cuddapah Supergroup) and concluded that PbSL age of c. 1756 Ma (errorchron with high MSWD) is the age of diagenesis/ uranium mineralization and minimum age of deposition of carbonate rocks in the Cuddapah basin. High MSWD in carbonate rocks using Pb-Pb(PbSL) technique is common (Jahn and Cuvellier, 1994**)**. Later Anand et al. (2003) and French et al. (2008) based on the Ar-Ar and U-Pb dating of phlogopite and baddelyite from Pulivendla sill opined that 1.9 Ga is the major episode of intraplate mafic magmatism in the Cuddapah Supergroup and start of deposition of sediments in the Cuddapah basin must have occurred prior to c.1900 Ma. Nevertheless precise age for diagenesis/uranium mineralization/dolomitisation, related to the dolomites of the Vempalle Formation, are not yet known. Present study is an attempt to further resolve this issue and will be helpful in constraining the age of uranium mineralization and the time of onset of sedimentation in Cuddapah Supergroup.

## RESULTS OF Pb-Pb (PbSL) GEOCHRONOLOLOGICAL STUDIES

The details of the ages obtained, on dolomites of the Vempalle Formation, are given in the Table 1 and are briefly explained below:

**Uranium mineralised dolomites (U=210 to 1160 ppm):** 4 whole rock (WR) and 44 leach fractions (LF) from 6 WR samples were analysed by Pb-Pb systematics (Pb Sequential Leaching-PbSL). The isochron ages obtained are 1930 ± 6 Ma, with MSWD=1.6 (GC3830- WR, 3LF and Residue, Fig. 2), 1882 ± 13 Ma, with MSWD=1.4 (GC3825-WR, 1LF and Residue), 1978±18 Ma, with MSWD = 2.1( GC3809-WR and 4LF, Fig. 3), 1902±26 Ma, with MSWD=6.8 (GC3813- 5LF and Residue), 2000± 58 Ma with MSWD = 23 (GC3805-WR and 5 LF) and 1839± 44 Ma, MSWD = 11.5 (GC3973- 4 LF and Residue).

**Table 1.** Pb-Pb(PbSL) data on dolomites from Vempalle Formation, Tummalapalle, Kadapa district, A.P., India.

| Sample No. | Rock | Age (Ma) | MSWD |
|---|---|---|---|
| **Mineralised dolomite (U=210 to 1160 ppm)** | | | |
| GC3973 | Dolomite (4 LF and Residue) | 1839±44 | 11.5 |
| GC3830 | Dolomite (WR, 3LF and Residue) | 1930±6 (Fig. 2) | 1.6 |
| GC3825 | Dolomite (WR, 1LF and Residue), | 1882±13 | 1.4 |
| GC3813 | Dolomite (5LF & Residue) | 1902±26 | 6.8 |
| GC3809 | Dolomite (WR and 4LF) | 1978±18 (Fig. 3) | 2.1 |
| GC3805 | (WR and 4LF) | 2000±58 | 23 |
| **Non-mineralised dolomite (U=11 to 42 ppm)** | | | |
| GC3939 | Dolomite (WR, 4LF & Residue) | 1830±26 | 14 |
| GC3940 | Dolomite (4 LF) | 1999±7 (Fig.4) | 0.78 |
| GC3952 | Dolomite (2 LF+WR+Residue) | 1917±13 | 1.7 |
| GC3954 | Dolomite(4 LF) | 1924±91 | 22 |
| GC3956 | Dolomite ( 3LF and Residue) | 1994±130 | 34 |
| GC3959 | Dolomite (4LF and Residue) | 2012±74 | 14 |
| GC3960 | Dolomite (3 LF and Residue) | 1718±64 | 4 |
| GC3966 | Dolomite (5 LF) | 1761±43 | 3 |
| GC3969 | Dolomite (5 LF and Residue) | 1943±44 (Fig. 5) | 9.5 |

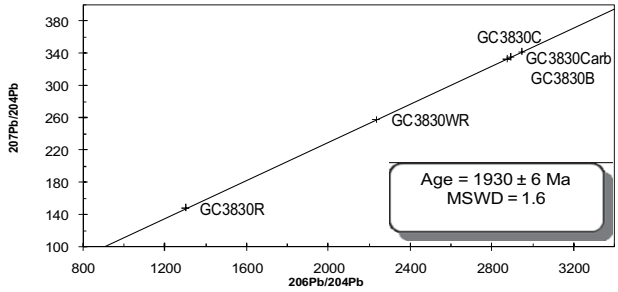


**Fig.2.** Pb-Pb isochron for U min. dolomite, Tummalapalle Block I (GC3830- B,C,Carb are HCl leach fractions, R=Residue and WR=Whole Rock).

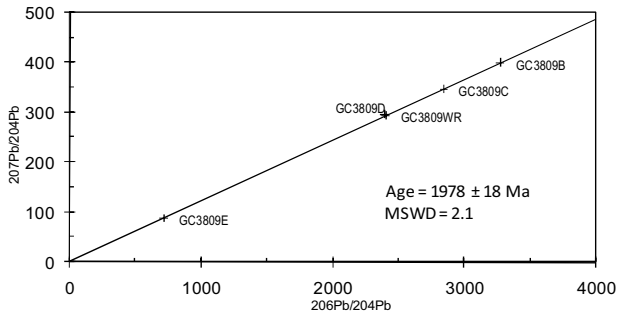


**Fig.3.** Pb-Pb isochron for U min. dolomite, Tummalapalle Block I (GC3809- B,C,D and E are HCl leach fractions and WR=Whole Rock).

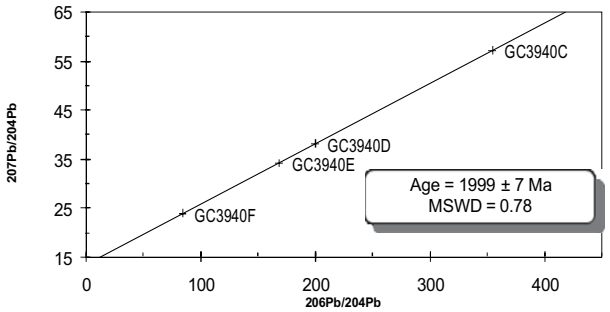


**Fig.4.** Pb-Pb isochron for Non-Min. Dolomite, Tummalapalle Block I (GC3940- C,D,E and F are HCl leach fractions)

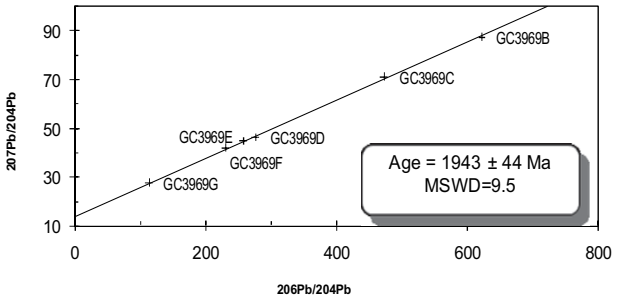


**Fig.5.** Pb-Pb isochron for Non Min. Dolomite, Tummalapalle Block II (GC3969- B, C, D,E , F are HCl leach fractions and G = Residue)

**Non-mineralised dolomites (U=11 to 42 ppm):** 3 WR and 43 LF from 9 WR samples were analysed by Pb-Pb systematics (Pb Sequential Leaching-PbSL). The isochron ages obtained are 1830 ± 26 Ma, MSWD = 14 (GC3939- WR, LF and Residue), 1999 ± 7 Ma, MSWD = 0.78 (GC3940- 4 LF, Fig. 4 ), 1917 ± 13 Ma, MSWD = 1.7 (GC3952- WR, 2LF and Residue), 1924 ± 91 Ma, MSWD = 22 (GC3954-4 LF ), 1994 ± 130 Ma, MSWD = 34 (GC3956- WR,2LF and Residue), 2012 ± 74 Ma, MSWD = 14(GC3959- 4 LF and Residue), 1718 ± 64 Ma, MSWD = 4 (GC3960- 3 LF and Residue), 1761 ± 43 Ma, MSWD = 3 (GC3966- 5 LF) and 1943 ± 44 Ma, MSWD = 9.5 (GC3969- 5 LF and Residue, Fig. 5).

## DISCUSSION

The direct dating of sedimentary carbonates, especially unmetamorphosed limestones or dolomites, has been done worldwide using Pb-Pb (PbSL) systematics (Moorbath et al., 1987, Jahn and Cuvellier, 1994 and Zachariah et al.,1999) to infer age of deposition, diagenesis, dolomitisation and uranium mineralisation. The Pb sequential leaching technique in carbonates can be applied with great ease due to high and variable U/Pb ratios in these rocks. Using such technique, in the present study, on both uranium mineralized and non-mineralized dolomites, ages of deposition, diagenesis, dolomitisation and syn-diagenetic uranium mineralization have been obtained as c. 1900 to 2000 Ma (Table 1). Such older age is being reported for the first time from within the Cuddapah basin. Similar ages for lower Gwalior and Bijawar group of rocks were reported earlier (Absar et al., 2010 and Pandey et al., 2012). These ages support the fact that most of the Purana basins as opined earlier as of Neo to Mesoproterozoic age are now considered as minimum 500 Ma older and are of Meso to Paleoproterozoic age.

The younger ages i.e. c. 1718 to 1882 Ma, obtained from both uranium mineralized and non-mineralized dolomites (Table 1), are the result of open system due to thermal events, like intrusion of Pulivendla sill in these dolomites and this is having petrographic evidences such as presence of secondary veins and displaced micro-fractures in these samples.

The ages reported earlier, from Vempalle Formation of lower Cuddapah Supergroup, are from intrusive Pulivendla sill, as c. 1817 Ma (Rb-Sr) (Bhaskar Rao et al 1995) and c. 1885 Ma by U-Pb and Ar-Ar methods (French et al 2008; Anand et al 2003), (Table 2). Zachariah et al.

**Table 2.** Chronostratigraphic sequence of Cuddapah Supergroup

| Group | Formation | Age/Method | Reference |
|---|---|---|---|
| | Srisailam Formation | Lambapur uraninite 1327±0.170 Ma (Sm-Nd), (primary crystallization age)<br>480-500 Ma (Pb radiogenic age)<br>(age of recrystallisation) | Pandey et al. (2009) |
| Unconformity | | | |
| Nallamalai | Cumbum Formation<br><br>Bairenkonda Formation | 1. Chelima lamproite 1418±8 Ma (Ar-Ar);<br>2. Vinukonda Granite 1615±25 Ma (Rb-Sr) | Chalapathi Rao (1999);<br>Gupta et al. (1984) |
| Angular disconformity | | | |
| Chitravati | Gandikota Quartzite<br>Tadpatri Formation<br>Pulivendla Quartzite | 1. Mafic Sill 1817±24 Ma (Rb-Sr)<br>2. Mafic Sill 1885-1899 Ma (U-Pb and Ar-Ar) | Bhasker Rao et al. (1995);<br>French et al. (2008);<br>Anand et al. (2003) |
| Disconformity | | | |
| Papaghani | Vempalle Formation<br><br><br><br><br>Gulcheru Quartzite | 1. Mineralised dolomite - 1756±29 Ma (Pb-Pb)<br>2. Mineralised and non-mineralised dolomite-1900-2000 Ma (Pb-Pb)<br>3. 1841 ± 71 Ma (K-Ar)<br>4. 1879 ± 5 Ma (Ar-Ar)<br>1.U mineralization Gandi 1336±14 Ma and 446±29 Ma (U-Pb, representing the primary crystallization age and age of subsequent Pb loss in a secondary event). | Zacharia et al. (1999)<br>*Present study*<br>Murthy et al. (1987)<br><br><br>Pandey et al. (2009) |
| Unconformity | | | |
| Basement | | 1. 2176 Ma (age of pre-Cuddapah mafic dyke)<br>2. Granitic emplacement 2400-2500 Ma | Murthy et al. (1987)<br>Pandey et al. (1997)<br>Pandey et al. (1995)<br>Pandey et al. (1999) |

(1999), dated uranium mineralised stomatolitic dolomite, from Tadpatri and Vempalle formations, and an age of 1756 ± 29 Ma (Table 2) has been assigned as the age of uranium mineralization in the dolomite of Vempalle Formation. Uranium mineralisation in impure dolomite of Vempalle Formation is statabound and syn-diagenetic (Rai, 2012). Whereas the age of Pulivendla sill (c. 1885 Ma), which is intrusive into Vempalle Formation, suggests that the age of uranium mineralization (syn-diagenetic) and sedimentation of dolomites of Vempalle Formation cannot be younger than the age of intrusive in it i.e. c.1885 Ma. This suggests further that the present age i.e. c. 1900-2000 Ma, obtained for uranium mineralised and non mineralised dolomites, are in agreement with the existing stratigraphic time frame of Cuddapah Supergroup in general and Vempalle Formation in particular. It appears that in Vempalle Formation of Cuddapah Supergroup deposition, diagenesis, dolomitisation and uranium mineralization might have taken place in a short duration of 100 Ma. The 1800 to 2100 Ma period coincides with the wilson cycle of the Palaeoproterozoic Supercontinent (COLUMBIA). Along with other continents, Indian part also experienced rifting at c. 2200 to 2100 Ma, during breakup of COLUMBIA, as evidenced by widespread mafic dyke activity around Cuddapah basin during this period (Murthy et al., 1987 and Pandey et al., 1997), which was responsible for its development and later deposition of Cuddapah Supergroup of rocks took place, most probably, between c. 2000-1400 Ma.

## CONCLUSIONS

In Vempalle, dolomite age of deposition, diagenesis, late dolomitisation and uranium mineralization is c. 1900-2000 Ma (PbSL), and the ages are in agreement with the existing stratigraphic time frame. This happened in a short time span of 100 Ma. This is similar to the age of initial deposition, diagenesis and late dolomitisation in a time span of around 100 to 150 Ma, reported from Wittenoom Formation and Carawine Dolomite of Hemersley Group, Western Australia (Jahn and Cuvellier, 1994). Present study infers the minimum age of onset of sedimentation in the Cuddapah Supergroup as around c. 2000 Ma and total time period of Cuddapah Supergroup as c. 2000 to 1400 Ma.

*Acknowledgement:* Authors are thankful for the analytical support from Geochronology Laboratory, Atomic Minerals Directorate for Exploration and Research, Begumpet Hyderabad.

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*(Received: 17 April 2014; Revised form accepted: 4 May 2015)*