Cuddapah Basin

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CONTENTS

Introduction

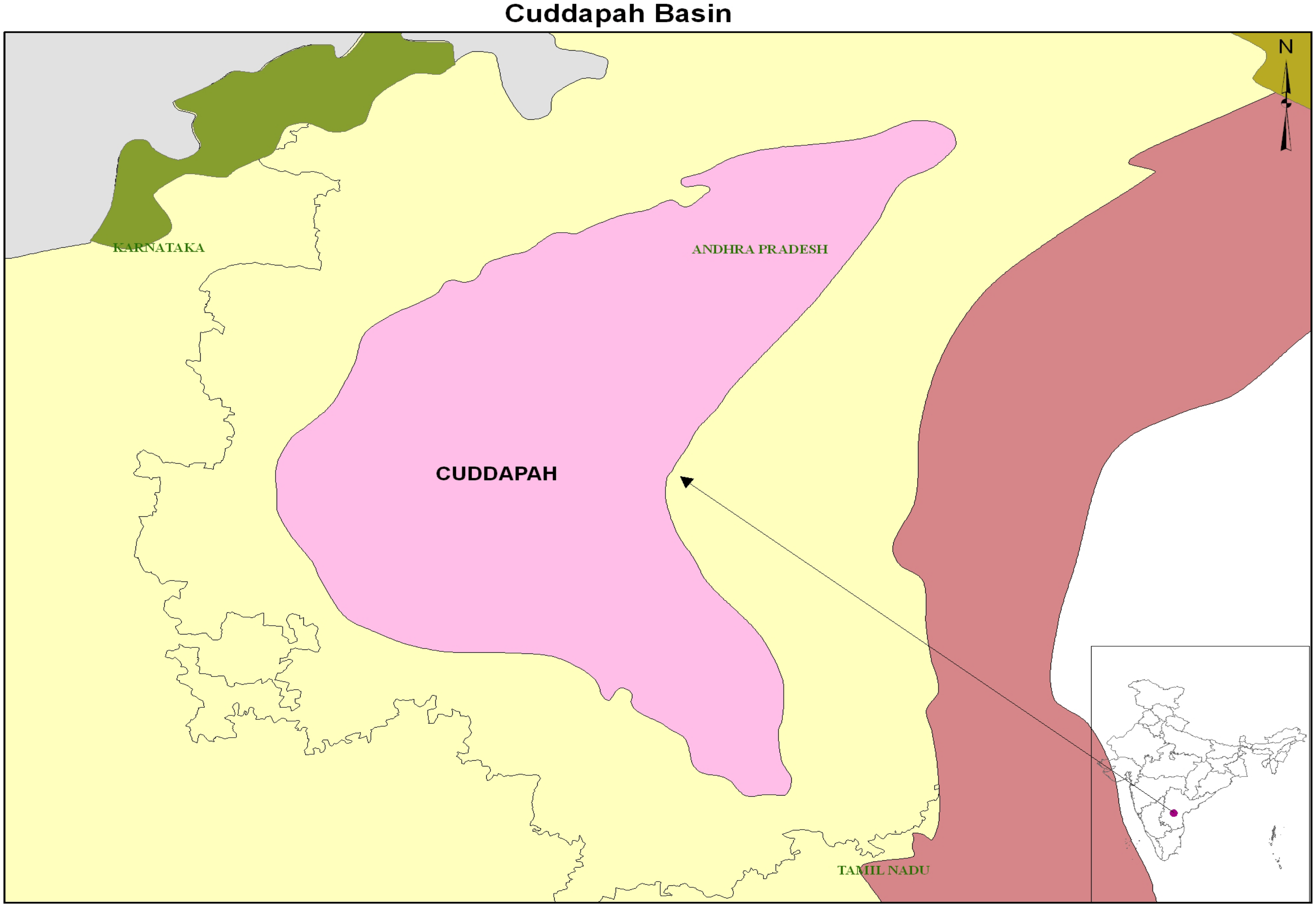
- The Cuddapah basin is a crescent shaped Proterozoic basin occupying an area covering about 44,500 sq km on the eastern part of the Dharwar Craton.

- The Cuddapah basin is an epicratonic basin located along the eastern margin of the Dharwar Craton of .Peninsular India. The basin contains a generally well preserved Palaeoproterozoic–Neoproterozoic sedimentary rocks and associated volcanic rocks. These rocks with a thickness of about 12 km rest unconformably over basement rocks consisting of granites, granite gneisses and greenstone schist belts.

- The crescent shaped basin is concave towards the east, in parallelism with the general configuration of the Coromandal coast line. Physiographically, the region is about 300 km in length and 145 km in width, characterized by few north-south parallel ridges.

- Cuddapah basin is one of the important and the oldest Purana basins of India which has been well studied on aspects like stratigraphy, sedimentology, palaeobiology, structure, igneous activity, geochronology, geophysical studies and economic geology.

CUDDAPAH BASIN

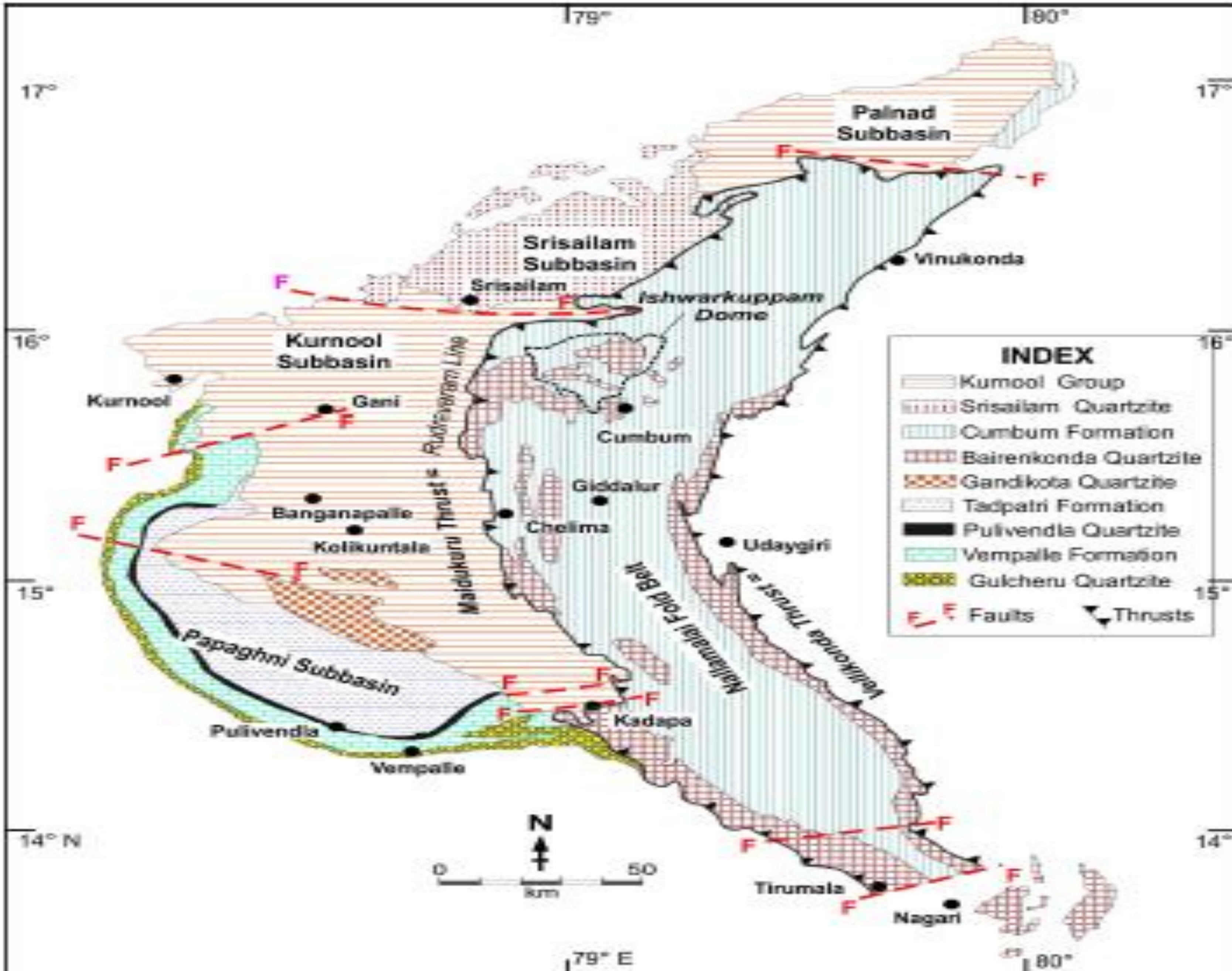


Source : Directorate General of Hydrocarbons (DGH) , Ministry of Petroleum & Natural Gas

Stratigraphy

- A four fold stratigraphic classification proposed by King (1872) remained unchallenged for over a century. He broadly classified the major lithounits of the Cuddapah basin into the older Cuddapah and younger Kurnool Formations, each being further sub-divided into four sub-groups. Thus, the Cuddapah Formation includes the Papaghni, Cheyair, Nallamalai and Kistna Groups, while the Kurnool Formation is divided into Banganpalle, Jammalamadugu, Paniam and Kondair Groups.
- Narayanaswamy (1966), proposed a revised five- fold classification comprising the Papaghni, Chitravati, Cheyair, Nallamalai and Kistna groups. Nagaraja Rao and Ramalingaswamy (1976) presented a revised stratigraphy of the basin in which the Cuddapah Supergroup is divided into three groups i.e. Papaghni, Chitravati and Nallamalai Groups with Kurnool overlying these Groups.
- A comprehensive account of the stratigraphy, structure and evolution of Cuddapah basin has been given by Nagaraja Rao et al., in 1976 (Table 1).
- The sedimentary sequence of Cuddapah Super group is divided into lower Papaghni Group (2100m), Chitravati Group (6000m), Nallamalai Group (3500m) and upper Kurnool Group (520m) comprising quartzites, limestone and shale units, separated by an unconformity (Table 1).

Each group starts with quartzite and ends with a shale unit representing cyclic repetition of quartzite and shale sequence. This is reflective of transgression and regression in an episodically sinking basin.



Geological map of the Cuddapah Supergroup, Nallamalai Group, and Kurnool Group depicting the subbasinal configuration (compiled from various sources cited in the text). Given that all of them are floored by a common basement, they may be clubbed together (sensu: Allen *et al.*, 2005; 2015) into a common basin (= Cuddapah Basin)

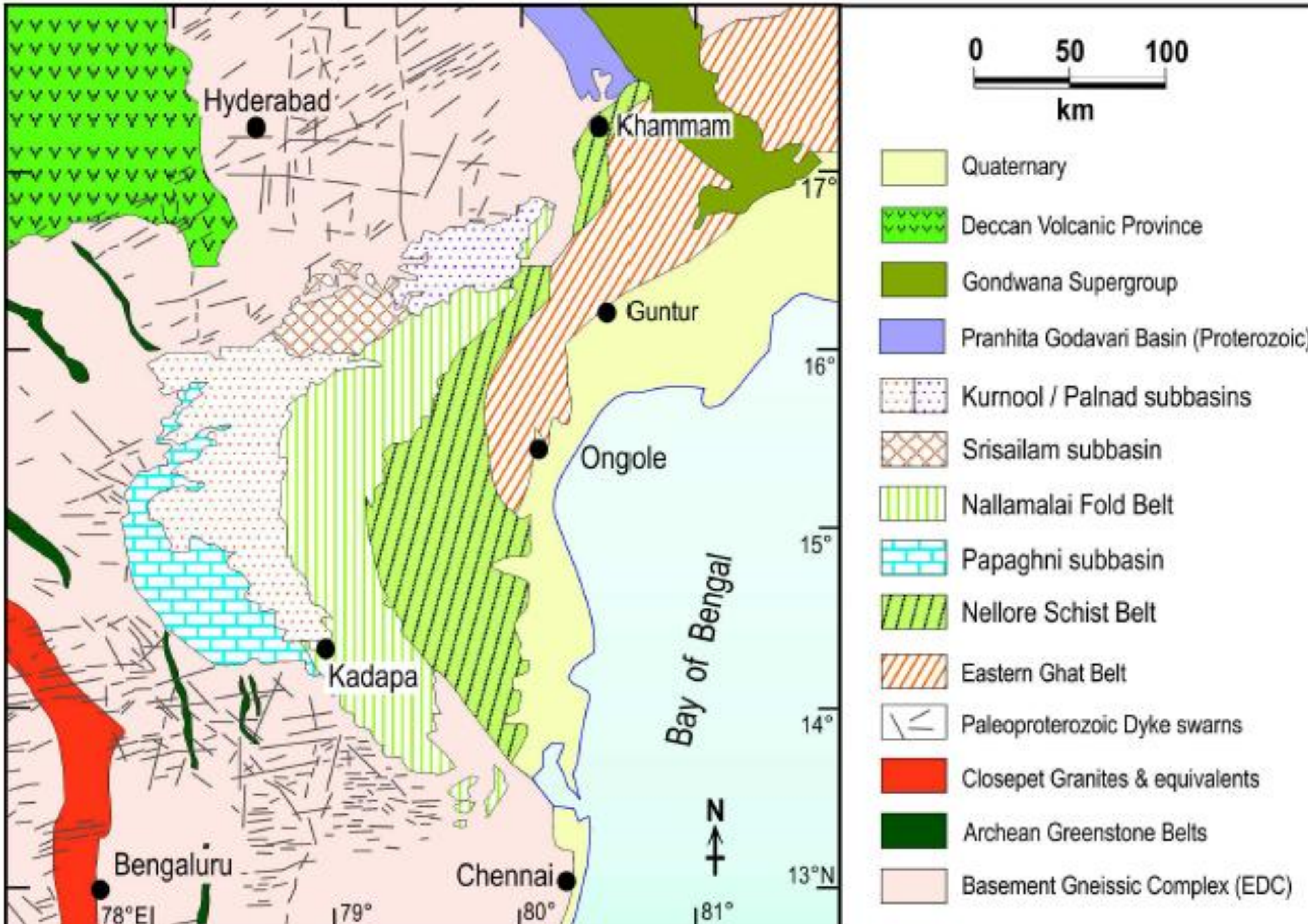


Fig. 1: Regional setting of the Cuddapah basin and adjoining terrains. The official spelling of the town 'Cuddapah' has been changed to "Kadapa."

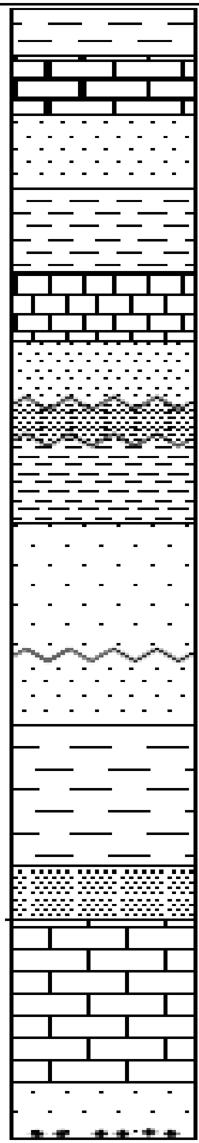
Stratigraphy

•The intrusives present in the basin are part of the large igneous province which occurred simultaneously during sedimentation. Contemporaneous igneous activities are manifested as sills, flows and other intrusives along the western periphery of the basin and the eastern Nallamalai Group. Sediments in the basin are mature in nature (Naqvi et al., 1987) and unmetamorphosed except on the eastern part due to the thrusting of Eastern Ghat Mobile Belt.

• The western half of the Cuddapah basin is less deformed with sub horizontal or gentle quaquaversally dipping beds as compared to eastern part (Nagaraja Rao et al., 1987). The general dip of beds in the basin is towards east.

• The rocks of Nallamalai Group are intensely folded, with intensity increasing from west to east. In the intensely folded Nallamalai belt, isoclinal folds are observed while the eastern margin is intensely faulted and affected by thrusts. The Iswarkuppam, a N-S elongated dome is an important structural feature in the north-ce ntral part of the basin (Ramam, 1997). Faults in the basin are mostly steep basement-rooted and pre- Cuddapah in age, mainly normal and some reverse types whose periodical reactivation played a major role in the evolution of Cuddapah basin. The Papaghni Sub-basin, where studied area in Kanampalle block of Vempalle Formation lies, has an arcuate shape paralleling the western margin of the Cuddapah basin (Fig. 1.1).

Table 1: Regional geological setting in Kurnool and Cuddapah Supergroup

Formation			Lithology	Group	Igneous Activity	Isotopic Age	Economic Minerals
		Nandyal shale	Shale	Kurnool Group	Lamprolitic dykes, Syenite stock, Dolerite sills And Granite intrusives?; Acid volcanics and tuffs	1418±8 Ma (Ar/Ar Phlogopite from chelima lamprolite)[G] 1354±17 and 1070±22Ma (Rb/Sr Chelima and Zangamarajupalle Lamprolite)[F] 1371±45 Ma (K/Ar chelima lamprolite)[A]	Limestone Diamond
		Koilkuntla Limestone	Limestone				
		Paniam Quartzite	Quartzite				
		Owk Shale	Shale				
		Narji Limestone	Limestone				
		Banganpalle Quartzite	Quartzite + Conglomerate				
C U D D A P A H S U P		Srisailam Quartzite	Quartzite + Shale	Nallamalai Group			Uranium
		Cumbum shale	Shale/Phyllite Quartzite and dolomite				Barite, Pb, Cu, Zn
		Bairenkonda Quartzite	Quartzite , Shale, Conglomerate		Dolerite sills		
		Gandikota Quartzite	Quartzite , Shale,	Chitravathi Group	Siliceous tuff and ignimbrites, Dolerite, Picrite and Gabbro sill and dykes,	1817±24 Ma (Rb/Sr Mafic sill)[E] 1899±20Ma (Ar/Ar phlogopite from mafic sill)[D] 1756±29 (Pb/Pb time of uranium	
		Tadpatri Formation	Shale, Quartzite, dolomite				
		Pulivendla Quartzite	Quartzite, Conglomerate				Uranium,

E R		Pulivendla Quartzite	Quartzite, Conglomerate			basaltic flows	mineralisation and minimum age of dolomite)[C]	Uranium,
G R		Vempalle Formation	Dolostone, Mudstone, Quartzite			Dolerite, Picrite and Gabbro, Sill and Dykes,	1885±3.1Ma (U/Pb Baddeleyite from mafic sill)[B]	Uranium, Asbestos, Barite
O U P		Gulcheru Quartzite	Quartzite, Conglomerate		Papaghni Group	basaltic flow Dolerite dykes	1841±71Ma (K/Ar mafic flow)[A] 1274Ma (Rb/Sr WR)[Z] 1253Ma (Rb/Sr MF)[Y]	Uranium

A- Murthy et al.(1987), B-French et.al(2008), C-Zachariah et.al(1999), D-Anand et.al(2003), E-Bhaskar Rao et.al (1995), F-Anil Kumar et.al (2002), G-Chalapathi Rao et. Al (1999), Z-A.K.Rai et.al (2008), Y-A.K.Rai (2008)

Cuddapah Basin			Nallamalai Fold Belt	
Group	Formation		Group	Formation
Kurnool	Nandyal Shale (100 m)	X–X–X–X–X – *Tectonic Contact* – X–X–X–X–X–X–X		
	Koilkuntla Limestone (50 m)			
	Paniam Quartzite (35 m)			
	Owk Shale (15 m)			
	Narji Limestone (200 m)			
	Banganapalle Quartzite (50 m)			
Unconformity				
	Srisailam Quartzite (300 m)		Nallamalai	Cumbum Formation
Unconformity			(~ 6000 m)	Bairenkonda / Nagari Quartzite
Chitravati	Gandikota Quartzite (300 m)			
	Tadpatri Formation (4600 m)			
	Pulivendla Quartzite (75 m)			
Unconformity				
Papaghni	Vempalle Formation (1900 m)			
	Gulcheru Quartzite (210 m)			
Unconformity				
ArcheanGranite, Undifferentiated Peninsular Gneisses, greenstone belts and Archean & Paleoproterozoic basic dykes of EDC				

Lithostratigraphy of Cuddapah basin and Nallamalai Fold Belt (compiled from GSI, 1981; Nagaraja Rao *et al.*, *1987;* with modifications by Saha and Tripathy, 2012;Patranabis-Deb *et al., 2012).*

Sedimentary Rocks

- The sedimentary rocks in the Cuddapah basin are mainly of arenaceous and argillaceous facies with subordinate carbonate facies.

- The arenaceous facies includes the Basal conglomerate-Arkose facies (Papaghni Group), quartz arenite facies (Papaghni Group and Srisailam Formation), Conglomerate - quartzite facies (Chitravati and Kurnool Groups) and Conglomerate - quartz arenite facies (Nallamalai Group). The argillaceous units are mixed with both arenaceous and calcareous facies and includes mud facies (Chitravati Group), mixed mud and quartz-arenite facies (Chitravati Group), mud and sand facies (Nallamalai and Kurnool Groups) and mixed mud and carbonate facies (Nallamalai and Kurnool Groups).

- The Carbonate facies comprising of dolostone and dolomite units are deposited in Papaghni and Kurnool sub-basins. The sedimentary environment of the Cuddapah basin is peritidal complex with shallow marine carbonate shelf and beach environment (Nagaraja Rao et al.,
1987).

Structure

- The Cuddapah basin has been divided into two broad structural sectors separated by the Rudravaram line (Meijerink et al., 1983) which is a structural divide between folded Nallamalai Group of rocks occurring east of this line and the generally flat-lying lower Cuddapah (Papaghni Group and Chitravati Group) and/or Kurnool Group of rocks occurring west of it. The arcuate belt east of the Rudravaram line is recognized as the Nallamalai Fold Belt (NFB) by Narayanaswamy (1966).

- The western half of the Cuddapah basin is structurally undisturbed and it has a highly disturbed eastern margin. The beds in the western part are nearly horizontal with low quaquaversal dips, defining an elliptical shaped Papaghni sub-basin. The rocks in Nallamalai sub-basin have experienced large scale folding known as Nallamalai fold belt.

- The intensity of folding increases from west to east with low amplitude open folds gradually turns into tight isoclinal folds (Nagaraja Rao et al., 1987). The major fold axis F1 is curved (NNW- NNE) probably due to compression from the east. Besides, Nagri outlier is situated in the southern tip of the basin and has a curved fold axis trending NNE to NNW.

Structure

- Iswarakuppam dome is a major structure exhibiting quaquaversal dips in the basin. It has a quartzitic core followed by alternating sequence of quartzite and shale/phyllite.

- There are a number of faults in this basin. Coulson (1934) and subsequently Nagaraja Rao et al., (1987) have identified Ramallakot – Gani – Kalva fault. Coulson (1934) interpreted it as basement rooted ENE-WSW trending fault, which was reactivated in post Kurnool times. A similar wrench fault called Karkambadi fault trending ENE-WSW marks the boundary of Cuddapah rocks in the southern part of the basin. Faults along the northern, eastern and southern boundaries of Kurnool subbasin have been described by Rajurkar and Ramalingaswamy (1970) and Nagaraja Rao (1972).

Igneous activity

- Several phases of igneous activity have been recorded in Cuddapah basin.

- King (1872) identified the basic sills, dykes, acid volcanic rocks and inliers in the Cuddapah basin. Lake (1890) described contemporaneous basaltic flows in Pullampet Formation. Coulson (1934), Krishnan and Venkatram (1942) and Vemban (1946) described the ‘traps’ and intrusives in Papaghni, Cheyair and Nallamalai Formations. Later, Nagaraja Rao et al., (1987) have identifed six phases of igneous activity in the basin, starting from the eruption of basic lava flows in the Vempalle Formation and terminating with the intrusion of granite in domal forms into the Cumbum Formation (Table 1).

Basin evolution

- Several theories have been proposed regarding the evolution of the basin. Narayanaswami (1966) envisaged a progressive evolution from a platform to geosynclines stage of development for the Cuddapah basin. According to Nagaraja Rao and Mohapatra (1977), the evolution of the basin is due to the sinking of crustal blocks along deep fundamental fractures. The deep seismic sounding study in Cuddapah basin by Kaila et al. (1979) supported the role of deep faults in basin evolution visualized by Nagaraja Rao and Mohapatra (1977).

- Recently, two contrasting hypotheses for the initiation of basinal subsidence and deposition have been proposed. Chatterjee and Bhattacharji (2001) suggest that the basin was formed due to a mantle induced thermal trigger. Evidence for this comes from the presence of a large subsurface mafic body in the southwestern portion of the basin that provided episodic magmatism to form the abundant dykes and lava flows in and around the basin. These mantle flows is attributed to collisional tectonics, involving the Eastern Ghats Mobile Belt. A second hypothesis suggests that deep seated basin marginal faults have played a major role in controlling the evolution of the basin (Chaudhuri et al., 2002). Evidence for the presence of deep marginal faults comes from the seismic studies as well as Bouguer gravity anomaly.

Palaeobiology

The carbonate sediments of the Cuddapah basin are the best materials for the study of early forms of life, represented as stromatolites. Stromatolites are laminated biosedimentary structures, attributed to the activity of lime-precipitating and sediment-binding micro- organisms, particularly blue green algae. Their use in local correlations and palaeo-environmental studies are well established. Gururaja and Chandra (1987) have given detailed description of stromatolite assemblages from the Vempalle and Tadpatri Formations of Lower Cuddapah Supergroup. These forms are correlatable with the Riphean columnar stromatolites and include *Colonella Fm., Collumnacollenia Fm., Cryptozoon Fm., Conophyton Fm., Jacutophyton Fm., Omachtenia Fm., Kussiella Fm., Jurusania Fm., Anabaria Fm., Gymnosolen Fm. And Inzeria Fm.*

Geophysical Studies

- The Cuddapah basin has been investigated by various geophysical techniques including deep seismic sounding (DSS) (Kaila et al., 1979, 1987), seismic tomography (Gupta et al., 2003), gravity (Verma and Satyanarayana, 1990; Ram Babu, 1993, Singh and Mishra, 2002), aeromagnetic (Babu Rao et al., 1987), ground magnetic (Kailasam, 1976) and magnetotelluric methods (Naganjaneyulu and Harinarayana, 2004).

- These studies indicate presence of:

(a) 10-11 km thick sedimentary pile over a 40 km thick crust in the eastern part of the basin,

(b) step faults in the basement,

(c) a mafic, ultramafic lopolith at a shallow depth under the southwestern part of the basin where mafic sills and volcanics are exposed, and

(d) an easterly dipping thrust fault at the eastern margin where high density lower crust of the EGMB is upthrusted.

Geochronology

- Several workers have attempted to date the Cuddapah basin, based on the age data obtained for the younger basic intrusive rocks.

- The K-Ar ages of basic rocks from Vempalle are 570±25, 700±90, 860±35, 980±110 and 1160±50 Ma and of Tadpatri Formation is 1080±440 Ma, whereas the basic amygdaloidal flows from the Vempalle Formation have been dated by Rb-Sr system as 1359±30Ma (Nagaraja Rao, 1987). The difference in ages of Rb-Sr and K-Ar systematics is attributed to episodic and continuous loss of radiogenic argon, during metamorphism. Chelima lamproite intruding the Cumbum Formation has been dated 1418 Ma (Chalapati Rao, 1999). 40Ar/39Ar plateau ages of groundmass phlogopite separated from the Kotakonda kimberlite (intruded into basement) and Chelima lamproites (intruded into Cumbum Formation) are 1401±5Ma and 1418±8Ma, respectively (Chalapathi Rao et al., 1999). The emplacement of the Kotakonda kimberlite and Chelima lamproite could have been contemporaneous; both are older than the Anantpur kimberlites (~1090Ma; Anil Kumar et al., 1993).

Geochronology

- The Pulivendla sills in the lower Cuddapah super group estimated from the Rb/Sr ratio data have an age of 1704±112 Ma (Bhaskar Rao et al., 1993). Biotite and clinopyroxene analyzed from two samples of the same sill yield an age of 1811 Ma and 1831 Ma age which are likely to be an absolute upper age limit for sedimentation of the Papaghni and the Chitravati groups into which it intrudes (Murthy et al., 1987).

- Zachariah et al., (1999) determined the Pb, Sr, Nd, isotopic compositions on uranium mineralised and barren stromatolitic dolomite samples from the Vempalle and Tadpatri Formations. Their analysis yielded a Pb-Pb age of 1756 ± 29 Ma that is interpreted as the time of U mineralisation and as a minimum age for carbonate sedimentation and dolomitization. It is therefore concluded that the Papaghni Group is Palaeoproterozoic in age with sedimentation started at around 1800 Ma (the age of Gulcheru Quartzite).

- The ages obtained in the present study on uranium mineralised impure dolomite by Pb-Pb (PbSL) method which yielded isochron ages as 1974 ± 61 Ma and 1973 ± 30 Ma are in good stratigraphic agreement and are older than the age of Pulivendla sill. As we know that uranium mineralisation in impure dolomite of Vempalle Formation is stratabound and syngenetic hence the present study ages c. 1975 Ma indicate the actual age of uranium mineralization in Vempalle dolomite as well as age of sedimentation.

Mineral Resources

- Cuddapah basin is the store house for a number of minerals. The basin is well known for its economic minerals like diamond, asbestos, barites, base metals like Cu, Pb, Zn, dolostone, phosphorite and building stones. Some of the world's finest and famous diamonds, such as Kohinoor and Regent are the products of this basin. Country's 90% of the barite reserve is present in the basin. Recently, fullerenes have been discovered in a few black tuff samples from the Mangampeta area.
- Apart from the above mineral deposits, the Cuddapah basin has potential for uranium mineralisation due to favourable factors such as its temporal, stratigraphic and tectonic position. Uranium exploration in the Cuddapah basin was initiated in the late 1950's to search for the quartz-pebble-conglomerate type uranium mineralisation. However, the basal Gulcheru conglomerates at the base of Cuddapah basin were found to be thoriferous. Subsequent exploration in the late 1980's brought out significant uranium mineralisation in Vempalle dolostone.
- In early 1990's uranium mineralisation was located along the unconformity between Srisailam Formation of Cuddapah Supergroup and the basement granites, thereby establishing in India, for the first time, the presence of unconformity related uranium mineralisation – a category considered most potential world over. The systematic and intensive exploration programme conducted by the Atomic Minerals Directorate for Exploration and Research (AMD) within the Cuddapah basin led to the recognition of three distinct types of uranium mineralisation, viz.,

1). Stratabound,

2). Fracture controlled (both basement granite and sediment hosted) and,

3). Unconformity-related type.

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THANKS