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CUDDAPAH FORMATIONS OF ANDHRA PRADESH, INDIA A NEW REPORT OF PROSPECTS FOR RICH BANDED IRON ORE FORMATIONS

*C Kasipathi, K Arjunudu, K Sanyasi Rao and M Srinivasa Rao
Mineral Exploration Division, Department of Geology, Andhra University
Visakhapatnam-530 003, Andhra Pradesh, India

ABSTRACT

The central and southern parts of Andhra Pradesh, India are occupied by the Upper Proterozoic Basins (N Lat : 13^o 19' 20" – 17^o 56' 21" and E. Long : 76^o 03' 18'' – 80^o 11' 52"), comprising Cuddapah, Pakhal and Bhimas (Purana Basins - corresponding to the Algonkian of USA as per the article published in the Imperial Gazetter of India by Sir T.H.Holland 1904, c.f. Krishnan, 1968) within the age group of 1000 to 500 my. Among the Nallamalai, Chitravati and Papaghni Series of Kurnool Group, the Gulcheru, Vempalle, Pulivendla, Tadpatri, Gandikota, Bairenkonda, Cumbum and Srisailam quartzite-shale-phyllite-intrusive formations show varying lithology and they are found hither to be the best exploration targets for rich banded iron formations. The total thickness of the geological formations was estimated by Geological Survey of India to be about 17.5 kms. These basins cover an area of 44,500 km^2 in parts of Chittoor, Anantapur, Cuddapah, Kurnool, Mahabubnagar, Nalgonda, Guntur, Krishna and Prakasam districts of Andhra Pradesh. Potential hematitic ore formations are identified through intensive geoscientific exploration programmes (geological and geophysical electrical Resistivity surveys) in these parts and the hematitic ores show Fe content up to 69.74%, in addition to the discontinuous lenses of magnetite and their details of potentiality are presented. This paper records rich Banded Micaceous Hematitic Quartzite formations from parts of Central and Southern Andhra Pradesh for the first time and warrants a detailed geoscientific investigation for iron-ore sources, which can help in the establishment of minimum two major iron and steel plants and a minimum of two minor ports along the coastal stretch of this region for transport and marketing.

Keywords: India, Andhra Pradesh, High-grade BIF, Cuddapahs, Nallamalais.

INTRODUCTION

The lower part of the Cuddapah Supergroup (Algonkian of India) has developed in two sub-basins, viz. the Papaghni and Srisailam and the upper part in the Nallamalai sub-basin, i.e. the eastern part of the main basin. The Kurnool Group was deposited unconformably on the Cuddapah Supergroup. These formations are dominantly composed of argillaceous and arenaceous sequences with subordinate calcareous sediments. The Nallamalai Series occupy the largest area of any of the sub-divisions of the Cuddapahs and took their name from the Nallamalai hills. They are well developed particularly in the eastern part of the Cuddapah basin. The lower beds are the 'Bairenkonda Quartzites', which rest with a slight unconformity on Cheyairs. They are highly folded and contorted in the Nallamalai hills, the succeeding 'Cumbum Shales' forming the cores of synclinal folds. The Cumbum Shales comprises shales and slates of varying shades of color and degrees of hardness, intercalated with thin bands of quartzite and limestone. Well-cleaved slates of this formation are worked near Markapur and Cumbum. 'Markapur', a place has been well known for many generations for the occurrence and industrial development of slate and slab industries. They are vertically foliated and the thickness of the slate varies from about 1 cm to more than 10 m. Depending on the quality, compactness and brittleness, the Markapur slates have been used for the manufacture of slates (for the learning purpose of writing in elementary school and slabs for floor and kitchen panels).

In the same fashion of Markapur slates, many new iron ore formations have been identified in many parts of Southern Andhra Pradesh, in association with slates and phyllites, which are also in vertical foliation. They are mostly 'micaceous hematitic ores', which soils the hands, bluish-gray in color with cherry red streak. By chemistry, they are richest and of highest grade iron formations and analyses from a minimum of Fe, 67.56% to a maximum of 69.74%. Many of the deposits are covered under soil to a depth of minimum 2 to 3 m from the regional level. Fortunately, a few are found in the government wastelands and in the private lands. The deposits when estimated by geological cross-section method, shows huge reserve quantifications of 2.5 to 20.0 million tonnes in each of the ore bodies. Quartzite has been one of the other important industrial mineral component, found in succession with these iron-ore formations, and overlying

*Corresponding author email: kasigeolau@rediff.com

on the top. Some of the manganese ore samples found in these areas supports the possibility of manganese ore deposits, probably below the iron ore formations. The occurrence of a few magnetite ore deposits was to some extent known in these parts, as low-grade ores. But, the latest geoscientific surveys conducted by the author have indicated many high-grade banded micaceous – hematitic - iron ore bodies for the first time.

GEOLOGY OF THE PRESENT AREA OF INVESTIGATION

The Purana rocks and the intra-cratonic basins of the Peninsular Shield fall within the time period of Middle and Late Proterozoic (Narayanaswami, 1966). During this period, vast stretches of exposed continental crust led to the deposition of great quantities of clastic sediments associated with chemical precipitates in large platformal and continental margin basins (Ramam and Murthy, 1997). In Andhra Pradesh, the rocks of Purana age are preserved in three basins viz. the Cuddapah, the Pakhal (Pranhita-Godavari) and eastern extension of Bhima of Karnataka, India.

Cuddapah Basin is crescent shaped in the south-central part of the State covering an area of 44,500 km^2 in parts of Chittoor, Anantapur, Cuddapah, Kurnool, Mahabubnagar, Nalgonda, Guntur and Krishna districts. It is of about 12 km thick sediments with minor volcanics constitutes the Cuddapah Basin, which is of composite character as it was formed of several discrete sub-basins of deposition (Fig.1). Two litho-stratigraphic groups, each with distinctive rock assemblages and ages, constitute the Cuddapah Basin. The lower and older Cuddapah Supergroup occupying the entire basin, is overlained by the Younger Kurnool Group in the western part. The former is composed mainly of arenaceous and argillaceous sediments with minor carbonates and the latter essentially consists of carbonate sediments with minor clastics.

The lower part of the Cuddapah Supergroup developed in two sub-basins, viz. the Papaghni and Srisailam, forming the western and northern parts of the basin, and the upper part in the Nallamalai sub-basin constitutes the eastern part of the main basin. The Kurnool Group was deposited unconformably on the rocks of the Cuddapah Supergroup in two discrete sub-basins viz., the Kurnool sub-basin in the western part and the Palnad sub-basin in the northeastern part of the main basin.

LOCAL GEOLOGY

The Cuddapah Supergroup is composed dominantly of argillaceous and arenaceous sequences with subordinate calcareous sediments. Each of the three groups starts with quartzite and ends with a shale unit representing cyclic repetition of quartzite-shale sequence reflecting successive transgressions and regressions in the basin. Igneous activity contemporaneous with sedimentation is manifested as sills, flows and other intrusives. The modified litho-stratigraphy of the Cuddapah Supergroup with the estimated thickness of each unit after Ramam and Murthy (1997) is presented in Table 1.

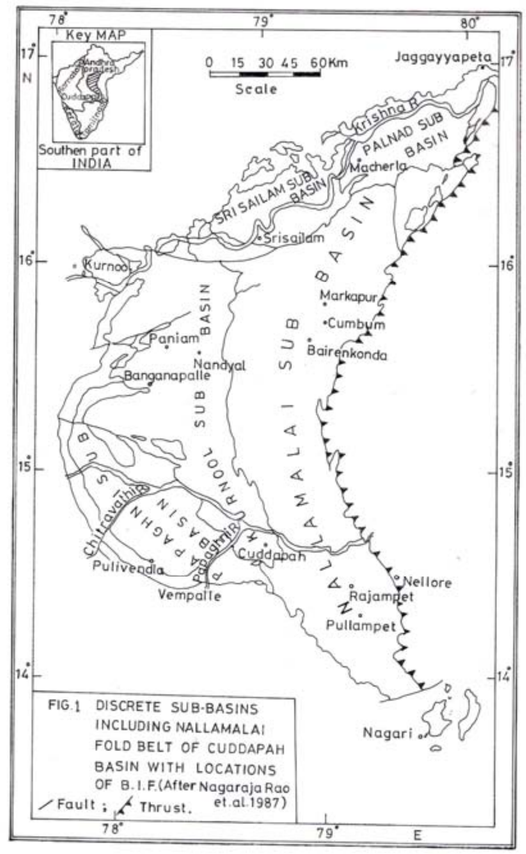

FIG.1 DISCRETE SUB-BASINS INCLUDING NALLAMALAI FOLD BELT OF CUDDAPAH BASIN WITH LOCATIONS OF B.I.F.(After Nagaraja Rao et.al.1987)

In the Nallamalai Group, the Bairenkonda (Nagari) Quartzite Formations show Banded Magnetite Quartzite (BMQ) at Naidupeta and Suluripeta of Nellore and Chittoor Districts and Cumbum (Pullampet) Formations show rich banded iron formations (BIF) comprising micaceous hematitic deposits and banded hematite phyllite/slates (BHP/S). The strike length of each of the bodies is more than 2000 m. and width of the banded iron formations varies from minimum 3.0 m to 10.0 m on the surface. The reserve estimations of each of the body through pitting, trenching, drilling and cross section method of estimation varies from 2.5 million tonnes to 20 million tonnes. The Nallamalai geological formations indicate a total thickness of 7.5 km.

EXPLORATION PROGRAMME CARRIED OUT IN BRIEF

Reconnaissance geological surveys were conducted in the central and southern parts of Andhra Pradesh for banded iron formations and found vast resources of lateritic, friable, banded hematitic ores at many places extending to kilometers together in the hill chains and along the foot-hills. Geoscientific exploration programmes were taken up at some of the interesting areas comprising geological mapping, pitting, trenching, drilling, sampling, contouring, and reserve estimations. Electrical Resistivity Surveys were also conducted in some of the interesting locations for delineating the depth factor of the deposits. The studies indicated the minimum depth persistence of the solid banded iron formations to 80 m. DTH drilling was undertaken at a few spots and it proved the data of Vertical Electricity Soundings. The collected samples showed the presence of hematite and quartzite. The samples were studied in the laboratory for their characters. The hematite is titanium-free, as understood from the ore microscopic studies and chemical analyses. The chemistry of BIF is of high-grade and quite suitable for metallurgical and paint industries. The locations of various BIF bodies surveyed and explored are presented in detail in Table 2. The laboratory work is under progress.

NATURE OF IRON FORMATIONS

The following types of iron ores are identified in the Nallamalai formations:

1. Micaceous Hematitic ores.
2. Banded Hematite Phyllite.
3. Banded Hematite Slate.
4. Banded Hematite Quartzite.
5. Banded Magnetite Quartzite, and
6. Hematitic Float Ores.

Fig. 2. Micaceous Hematite ore, Bestavaripeta, Prakasam District.

Micaceous Hematitic ores : are thick sequences of very high-grade iron ores. Their physical properties are : tabular in form, bluish steel gray colored, micaceous or foliaceous (Fig. 2), internally fibrous, cleavage poor, streak cherry-red, luster metallic and silky, opaque, fracture subconchoidal, hardness 5.8 and Sp.gr. 5.2. This type of ore is found to occur in a number of wide bands running kilometers together in length. No such type of the ore is found on the surface of the regional levels, not even in the small mounds, and covered under the soil to a depth of about minimum 3 m to 4 m. The area surrounding these locations represent deep-red colored surface soils, which is one of the exploration guide for this type of ore. They represent very high-grade ores up to 69.74% Fe.

Fig. 3. Banded Hematite Quartzite sample, representing moderate grade Hematite ore. Near Vinukonda, Prakasam District.

Banded Hematite Phyllite / Slates : are found in a few areas, where the thickness of the hematite bands (Fig. 3) vary from minimum 5 cm to 150 cm. They represent physical properties as thin tabular and granular, iron-black in color, cleavage parallel to basal pinacoid (Fig. 4), cherry-red streak, metallic luster, opaque, uneven fracture, hardness 6.0 and Sp.gr.5.1. These areas represent predominant phyllite and slate rock types, when compared to hematite. The ore : gangue ratio is approximately 1 : 9. The Banded Iron Formations show low to moderate grades in chemical composition and requires mineral beneficiation for upgradation. The iron ore looks like the well-known 'Cuddapah slabs' in platy forms. These formations can be found on the surface as part and parcel of small mounds to a surface height of about 30 m. to 50 m, but extensive in surface expression and in continuation to several kilometers of length.

Fig. 4. Platy Hematite ore. Enugulavaripalem, Prakasam District.

Table 1. Litho-stratigraphy of the Cuddapah Supergroup.

Group	Formation	Lithology	Thickness (m)
KURNOOL GROUP			
	- - - - - - - - - - - - - - - - Unconformity -		
	Srisailam Quartzite		
	- - - - - - - - - - - - - - - - Unconformity -		
	Cumbum (Pullampet)	Phyllite, slate, quartzite, dolomite, (Kimberlite, Lamprophyre, syenite) Pullampet shale (Ba Rich volcanics, tuffs) dolomite, quartzite,	2000
Nallamalai		**Micaceous Hematitic ores, and Banded Hematite Phyllite/ Banded Hematite Slate**	
	Bairenkonda (Nagari) Quartzite	Bairenkonda Quartzite, shale, Nagari conglomerate, quartzite, shale with intrusives and **Banded Magnetite Quartzite.**	1500
	- - - - - - - - - - - - - - - - - Angular Unconformity - - - - - - - - - - - - - - - - -		
	Gandikota Quartzite	Quartzite, shale (Sills of Olivine dolerite)	3300
Chitravati	Tadpatri	Shale, ash-fall tuffs, quartzite, dolomite with intrusives (flows, sills, ignimbrites, tuff)	4600
	Pulivendla Quartzite	Conglomerate and Quartzite	1.75
	- - - - - - - - - - - - - - - - - - Disconformity -		
	Vempalle	Stromatilitic dolomite, dolomite, dolomite	1900
Papaghni		mudstone, Chert breccia, quartzite with basic flows and Intrusives (Tholeiite and esite, spilite, dolerite).	
	Gulcheru Quartzite	Conglomerate, arkose, quartzite and shale	28 – 210
	- - - - - - - - - - - - - - - - - - - Nonconformity -		
		Archaean gneisses / greenstone	

(Modified, after Ramam and Murthy, 1997)

Fig. 5.Banded Iron Formation at Ramallakota, Kurnool District.

Banded Hematite Quartzites : are thick sequences of high-grade iron-ores. They are banded, massive (Fig. 5) and float ore types occurs in parts of Pagadaalapalle (Cuddapah District), and Veldurthi – Ramallakota – Pullagummi – Ghanigattu – Guttupalli – Brahmapuram – R.S.Rangapuram (Kurnool District). They record rich sequences mostly occupying the Reserve Forest areas. The ore : gangue ratio is approximately 1 : 3. The ore can be directly used in the blast furnaces. No beneficiation is required. The float lateritic ores are extended beyond 8 m. in depth at places.

Banded Magnetite Quartzites : are found at some places in equally alternate thick bands of magnetite and quartzite. The thickness of magnetite bands vary from minimum 3 m. to 12 m. and that of quartzite is about 8 m. to 15 m. They are of moderate grade ores and mostly found at Suluripeta, Naidupeta and Sirsanambedu of Nellore-Chittoor Districts.

Fig. 6. Grading of iron ore floats at R.S.Ramapuram, Near Dhone, Kurnool District.

Table 2. List of various B.I.F - bearing areas surveyed in parts of Cuddapah Basin, Andhra Pradesh, India.

S. No.	District	Village	Latitude (N)	Longitude (E)
1.	Krishna	Shermahmadpet	16^o 55’ 14”	80^o 06’ 10”
2.		Gandreye	16^o 57’ 18”	80^o 06’ 15”
3.		Jaggayyapeta	16^o 56’ 28”	80^o 06’ 13”
4.		Appalanarasimhapuram	16^o 59’ 40”	80^o 05’ 20”
5.		Takkalapadu	16^o 56’ 17”	80^o 06’ 28”
6.	Guntur	Tummurkota	16^o 33’ 42”	79^o 28’ 55”
7.	Prakasam	Ganapavaram	16^o 02’ 06”	79^o 28’ 33”
8.		Pothavaram	15^o 32’ 40”	79^o11’ 55”
9.		Byrepalli	15^o 41’ 18”	79^o 59’ 35”
10.		Konijedu	15^o 27’ 38”	79^o 55’ 58”
11.		Pernamitta	15^o 32’ 14”	80^o 00’ 10”
12.	Kurnool	R.S.Rangapuram	15^o 33’ 06”	77^o 56’ 48”
13.		Dhone	15^o 32’ 58”	77^o 56’ 04”
14.		Ramallakota	15^o 34 10”	77^o 01’ 50”
15.		Veldurthi	15^o 33’ 06”	77^o 56’ 42”
16.		Pullagummi	15^o 32’ 10”	78^o 02’ 40”
17.		Ganigattu	15^o 40’ 28”	78^o 19’ 42”
18.		Dastagirigutta	15^o 23’ 56”	78^o 03’ 02”
19.		Joshi Hill	15^o 24’ 12”	78^o 03’ 24”
20.	Anantapur	Siddapuram	15^o 03’ 24”	76^o 03’ 18”
21.		Chalapuram	15^o 03’ 32”	76^o 03’ 22”
22.		Gollapalli	14^o 26’ 18”	77^o 14’ 10”
23.		Kambadur	14^o 21’ 10”	77^o 14’ 24”
24.		Siddapuram	15^o 03’ 06”	76^o 49’ 12”
25.	Cuddapah	Pagadalapalli	14^o 27’ 18”	78^o 37’ 54”
26.		Chottapalli	14^o 29’ 30”	78^o 37’ 48”
27.		Chabali	14^o 30’ 45”	78^o 36’ 18”
28.		Rajampeta	14^o 17’ 12”	78^o 37’ 08”
29.		Tummaluru	14^o 27’ 10”	78^o 37’ 22”
30.		Pendlimarri	14^o 27’ 18”	78^o 39’ 10”
31.		P.Venkatampalli	14^o 12’ 12”	79^o 15’ 04”
32.	Nellore	Naidupeta	13^o 55’ 12”	79^o 55’ 24”
33.		P.Cheruvu	15^o 12’ 46”	79^o 42’ 16”
34.		Iresalemare	13^o 51’ 16”	79^o 56’ 04”
35.		Ircola	13^o 48’ 18”	80^o 00’ 10”
36.	Chittoor	Sirsanambedu	13^o 52’ 10”	79^o 52’ 06”
37.	Khammam	Ramagundal	17^o 39’ 22”	80^o 08’ 28”
38.		Bayyaram	17^o 35’ 18”	80^o 06’ 19”
39.		Cheruvupuram	17^o 21’ 36”	80^o 10’ 15”
40.		Kottagudem	17^o 53’ 52”	80^o 04’ 52”
41.		Motala-Timmapur	17^o 41’ 12”	80^o 07’ 26”

Unusual float ores: of hematite are found covering a few tens of square kilometers near Jaggayyapeta region of Khammam - Krishna districts. Tekkalapadu, Gandreye, Shermuhammadpeta and Appalanarasimhapuram are the important villages comprising moderate to high-grade iron ores, which are present at a distance of 10 to 15 kms from Jaggayyapeta (Krishna District). The ore is observed to be occupying most of the plains, away from the adjoining hill ranges. The float ore is limited to minimum of 3 m to maximum 5 m depth from the surface. They are all fine lateritic ores (Fig. 6).

CHEMISTRY OF THE IRON-ORES

The iron content (Fe %) mostly varies from 62.84 % to 69.74 %, except a moderate grade of 48.43% to 49.84% at places. Silica content (SiO_2 %) mostly found in the range of 0.58% to 2.68%, except in a few cases variable between 7.92 % to 8.25% and 20.87% to 30.42%. In the case of alumina content (Al_2O_3 %), it is mostly variable between 1.01% - 1.95%, except a few cases of 2.41% to 5.26%. The phosphorous content (P %) varies between 0.009 - 0.102 and sulphur content (S %) varies between

Table 3. Chemistry of Iron-Ores from parts of Central and Southern parts of Andhra Pradesh, India.

Name of the district	Sample No.	Fe %	SiO_2%	Al_2O_3%	P %	S %
Prakasam	1	67.38	2.68	1.06	0.027	0.006
- do -	2	68.45	2.36	1.02	0.018	0.007
-do -	3	69.74	1.84	1.26	0.020	0.005
-do-	4	48.43	30.42	5.26	0.069	0.009
- do -	5	48.86	27.94	3.73	0.054	0.012
- do -	6	49.84	20.87	4.08	0.052	0.008
Krishna	7	67.34	1.14	1.54	0.032	0.011
- do -	8	67.99	0.58	1.24	0.032	0.012
Khammam	9	66.53	2.18	1.70	0.030	0.009
Nellore	10	64.23	3.45	1.62	0.102	0.012
Cuddapah	11	62.84	8.25	1.95	0.037	0.011
Kurnool	12	67.56	1.34	1.35	0.018	0.008
- do -	13	65.85	2.35	2.41	0.009	0.018
- do -	14	63.75	7.92	1.65	0.011	0.015
- do -	15	65.12	5.62	1.01	0.018	0.015

Sample locations:
1-3 : Bestavaripeta Mandal, Prakasam district; 4 to 6 : Tripurantakam Mandal, Krishna district; 7 : Mootlathimmapuram, Krishna district; 8 – Appalanarsapuram, Krishna district; 9 : Bayyaram, Khammam district; 10: Sirsanambedu, Nellore district; 11 : Pagadaalapalle, Cuddapah district; 12 : Veldurthi-Ramallakota, Kurnool district; 13 : Ghanigattu (near Veldurthi), Kurnool district; 14 : Guttupalli, Kurnool district); 15 : Brahmapuram, Kurnool district.

0.005% - 0.012%. Broadly, many of the locations show high-grade iron ores and the moderate grade ores can be mostly upgraded by simple ore beneficiation techniques. The details of the major elements determined as per Bureau of Indian standards IS - 1493:1959 (Reaffirmed in 1991) is presented in Table 3.

ORE DRESSING TECHNIQUES

The Cuddapah Supergroup shows low to moderate grade iron ores. The Banded Iron Formations (BIF) of Tamil Nadu (Salem and Tiruchirapalli districts) and Karnataka (Kudremukh deposits) and Andhra Pradesh (Guntur-Prakasam Districts) record the iron (Fe) content in the range of 33-43% only. Ore dressing or beneficiation of iron ores is essentially (i) mineralogical beneficiation (for the enrichment of iron content and limiting the constituents like silica, alumina and phosphorous), and (2) sizing of the ore and agglomeration of the ore fines to prepare proper size for the consuming industry (Jain, 1986).

In general, the chief impurities in iron ore are silica, alumina, sulphur and phosphorous. The Al_2O_3 / SiO_2 ratio in the ore has an important bearing on the economics of smelting of the iron ores. Alumina has a high melting point and under blast furnace conditions goes to the slag as aluminium silicate, and, therefore, higher temperature has to be employed in the furnace to render the slag fluid. This results in a large amount of silica going to the metal. As this is undesirable, quartzite has to be included in the blast furnace burden to reduce the Al_2O_3 / SiO_2 ratio. Because of this, a low Al_2O_3 / SiO_2 ratio (approximately 0.5) in the ore is desirable. Sulphur and phosphorous in the ore are in the form of FeS_2 or $CaSO_4$ and $Ca_3(PO_4)_2$ respectively. These elements, if present in the ore, go into the metal produced and have an injurious effect on the properties of iron and steel. Sulphur up to one percent can be removed in the blast furnace, but this requires increased fuel and flux. Thus, sulphur lowers the value of the iron ore. Phosphorous can also be removed in the blast furnace in a similar manner. A small amount of manganese from traces to about 1.5% is usually present in the ore and this in fact helps in eliminating the injurious effect of sulphur by forming MnS, which is less harmful than FeS. For beneficiation of iron ores, processes such as sizing, washing, jigging, heavy media separation and magnetic separation may be used. Using these techniques, the iron content can be increased and other ingredients like SiO_2 and Al_2O_3 can be minimised.

FURTHER POSSIBILITIES OF ORE SEARCH

The above data indicates that there are ample chances to explore rich iron-ore deposits in the central and southern parts of Andhra Pradesh, provided an extensive detailed geoscientific exploration programme is chalked out. It is very unfortunate to report that much of the region is covered under Reserve Forest Category lands (Nallamalai Series). When all the actual reserves of the iron ores (BIF) are measured and calculated, the government may consider development of even the Reserve Forest (RF) regions for iron-ore mining. But, for the present, the non-Reserve Forest regions may be utilized for mining.

CONCLUSIONS

The reconnaissance and preliminary geoscientific exploration study shows enriched BIF bodies with the Cuddapah formations and especially with Nallamalai Series. If detailed geoscientific exploration programmes and studies are taken up in the central and southern parts of the State for the Banded Iron Formations (BIF) in the lines of geology, lithology, mineralogy, chemistry, geochemistry, grade, reserves and lateral and depth-wise limitations of the mineralization, more useful geological information can be gathered for techno-economic feasibility studies. The results of the work will further the iron-ore mining and mineral based industrial development for mega steel plants or a number of mini steel plants, pelletisation plants, sponge iron plants and many ancillary iron ore down-stream industries in this region. The results will provide all infrastructural development, employment generation, industrial development, trade and marketing and may offer opening/development of the adjoining minor ports in the nearby coastal region for foreign trade. Detailed exploration and laboratory studies are in progress and it may be published later.

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