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Petrography and geochemistry study of the Thirtal lamprophyre dyke left bank of Muneru River, in eastern margin of the Eastern Dharwar Craton, Khammam, Telangana, India

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ABSTRACT

Various types of lamprophyres are very common in different part of the Cudappah Igneous Provice (CIP)/Prakasham Alkaline Province (PAP) in Eastern Dharwar Craton (EDC), southern India. Present paper reports a lamprophyre dyke near the Thirtal lamprophyre left bank of Muneru River area, Khammam District, Telangana, India (80˚08′ 12.9″:17°19′ 10.13″) at the northeastern margin of the EDC. In the present paper also discuss the detail petrography and geochemistry of the newly found lamprophyre. The study area mainly consists of granitoids of Peninsular Gneissic Complex (PGC) of the EDC. Regionally, the area is bounded by two Proterozoic sedimentary basins, i.e. in the east Pakhal basin and in the south Cuddapah basin. The lamprophyre of the study area has been intruded within granitoids of the EDC. This dyke is ~0.5 to 1 mt wide having ~50 mt exposed strike length on the bank of Pakhal River. Petrographically clinopyroxene and olivine are present as a phenocryst and biotite, plagioclase, kfeldspar, carbonate,amphibole,chlorite and epidote present in the groundmass. In some of the part carbonate replace the clinopyroxene and olivine. The mineral chemistry,whole rock, trace elements and REE geochemistry suggested that this lamprophyre belongs to calc-alkaline group (CAL).

Introduction:

In India lamprophyre rocks are very common in Dharwar, Aravalli, Bastar and Singhbhum cratons (Madhavan et al.1998). Dharwar craton hosted maximum number and the variety of lamprophyre rocks. At the region of Cudappah Igneous Provice (CIP)/Prakasham Alkaline Province (PAP) in Eastern Dharwar Craton (EDC), southern India hosted maximum number of lamprophyres.In the CIP large number of lamprophyre cluster is present which is mainly intruded within the nepheline syanite. In the other side in PAP lamprophyre cluster is found mainly intruded within the gabbro body (Madhavan et al.1998; Ratnakar et al.1980;1992;1994).

In the khammam district few isolated lamprophyre are reported which is intruded within the granite body (Appavadhanulu 1971; Subrahmanyam et al.1987; Meshram et al. 2015; Adhikary et al. 2016a). Lamprophyric magma are formed during low degree of partial melting of upper mantle at approx depth of 100-150 km (Rock 1991). Normally this kind of magmas contain high amount of volatiles (F,CO_2,H_2O) and REE (Ulrych et al.1993).Lamprophyre is a hybrid nock which can be from partial melting of upper mantle with interaction with mantle melt (Seifert 2005 and Rock 1991). Thirtal left bank of Muneru River lamprophyre dyke (Fig:1) is first reported by the Adhikary et al.2016a.Present paper is present petrographic and geochemistry study of this lamprophyre.

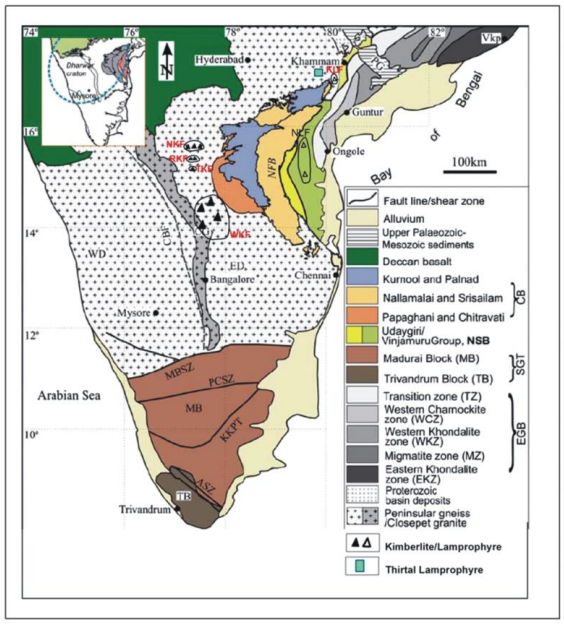

Fig.1: Location of Thirtal left bank lamprophyre in Khammam district, Telangana.

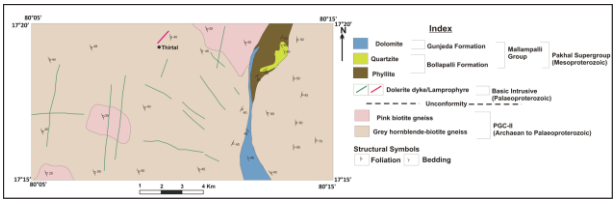

Fig.2: Geological map of the Thirtal left bank area,Khammam district,Telangana.

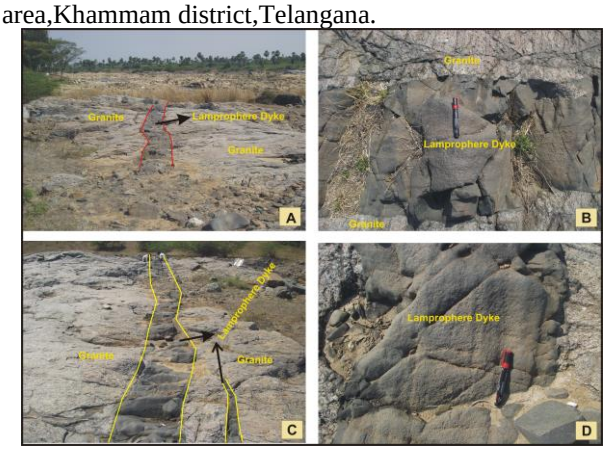

Fig.3: (A) Thirtal lamprophyre is intruded within the ECD granitoids. (B) Sharp contact of lamprophyre dyke with the granitoids. (C) Small branching of lamprophyre dyke in Thirtal area, Khammam. (D) Pitted structure with in the Thirtal lamprophyre dyke.

Regional Geology:

Thirtal left bank of Muneru River area is located in the south of the Khammam town. In the study area mainly country rock is granitoid (Fig.2). In the east of the study area proterozoic Pakhal basin and in the south proterozoic Cuddapah Basin is present. In the just south of the presently reported lamprophyre one isolated lamprophyre was reported (Subrahmanyam et al. 1987) near Polayapalle. Thirtal lamprophyre dyke left bank of Muneru River is intruded within the ECD granitoids (Fig.3A). In the lamprophyre dyke small branching also present (Fig.3C). This dyke is ~0.5 to 1 mt wide having ~50 mt exposed strike length on the bank of Pakhal River. Trend of the dyke is N35°E. It has a sharp contact with the host granitoids. In the margin of the dyke no child margin effect is present (Fig.3B & 3D). Few xenoliths of the country rock is present within the dyke body. Dyke also cut across the foliation of the granitoids, it also indicates the intrusive relationship between host rock and the lamprophyre. Megascopically, this lamprophyre dyke is mesocratic to melanocratic, fine grained in nature. Phenocrysts are present in the dyke and also uniformly distributed within matrix. Olive and clinopyroxene are present as a phanocrysts with in melanocratic matrix component. Pitted structure is also present within the rock due to the removable of mafic phenocryst.

Petrography Study:

The petrographic studies were carried out using LEICA DM RX fitted with a camera, at the Petrology laboratory, GSI, Hyderabad. Petrography study shows that, this dyke having porphyritic-panidiomorphic texture. Clinopyroxene, olivine, biotite and amphibole are present as a phenocryst in thirtal lamprophyre. In this dyke k-feldspar, plagioclase feldspar , biotite present as a groundmass. Carbonate also present in the rock, which is replaced olivine and clinopyroxene (Fig.4A to 4D).Clinopyroxene are mostly elongated shape in the rock (Fig.4F). In the ground mass portion carbonate also presents. Magnetite, monazite also present as accessory minerals in the groundmass part. In the clinopyroxene grain pleochroic nature is present from pale brown to greenish in colour. Petrography study also show that, ocelli structure is present within the rock (Fig.4F).In some portion carbonate is completely replaced the original minerals like olivine and clinopyroxene. In the biotite grain zoning also observed. From the modal study, dominance of biotite over amphibole, k-feldspars over plagioclase feldspars and presence of diopside indicates that this lamprophyre is classified as minette (Le Maitre 2002).

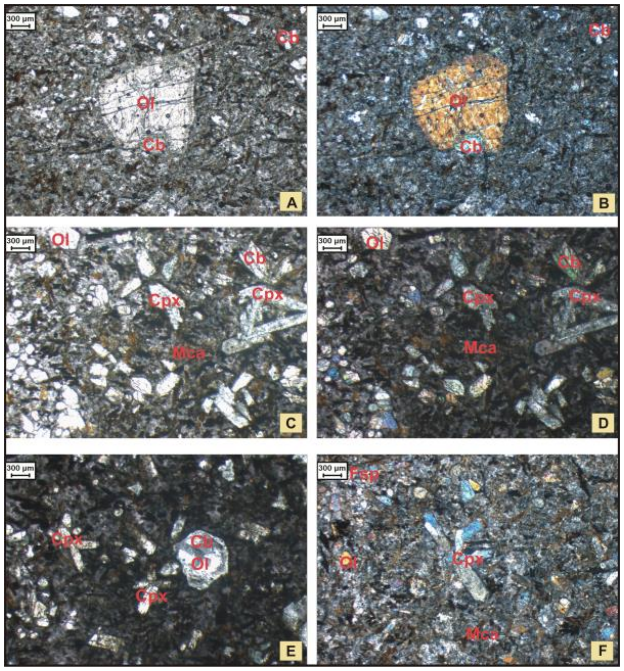

Fig.4: (A) Olivine phenocryst within ground mass in thirtal lamprophyre(PPL). (B) Olivine phenocryst within ground mass in thirtal lamprophyre (CPL). (C) Clino pyroxene-Mica phenocryst within ground mass in thirtal lamprophyre (PPL).(D) Clino pyroxene-Mica phenocryst within ground mass in thirtal lamprophyre(CPL).(E) Ocelli structute within thirtal lamprophyre(PPL). (F) Elongated clinopyroxe phenocryst with in micacious ground mass in thirtal lamprophyre(CPL).

EPMA Study:

Chemical compositions of all mineral phases were quantitatively determined by Electron Probe Micro Analyser (EPMA-CAMECA SX-100(WDS) at GSI, Petrology Division, Hyderabad, India. Point analyses were performed under the operating conditions of accelerating voltage of 15 kV, 20 nA of current intensity, a beam diameter of 1 µm and counting time of 20 s. Thallium acid phtha- late (TAP), large pentaerythritol (LPET) and large ion lithium fluoride (LLIF) crystals were employed for measurement. A number of natural and synthetic standards were used for calibration. Natural standards were used for all elements except in Mn and Ti. Analyses of the selected and representative mineral phases are given in table 1.

In the EPMA analysis (Fig.5A to 5D) it was observed that, clinopyroxene is diopside in nature and composition varies from (Wo86-90 - Fs14–10).Mica present in the rock X_{Fe} nature, composition varies from ($X_{Fe51-56}$-$X_{Mg49-44}$).Olivine present in the rock fayalitic in nature. Plagioclase present in the ground mass is albitic in nature. Presence of monazite also confirmed in the EPMA study. This mineral chemistry also indicates that this lamprophyre belongs to calc-alkaline group (Rock 1991 and Mitchell 1995).

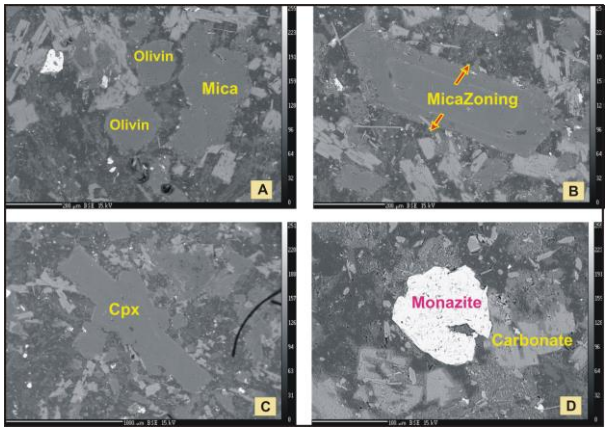

Fig.5: (A) Olivine-Mica(Biotite) phenocryst within ground mass in thirtal lamprophyre.(B)Zoning of mica in thirtal lamprophyre.(C) Clinopyroxene phenocryst within ground mass in thirtal lamprophyre.(D)Monazite grain within thirtal lamprophyre.

Table:1. Representative mineral chemistry of the Thirtal lamprophyre, EDC

	Clinopyroxene	Clinopyroxene	Biotite	Biotite	Biotite	Olivine	Olivine	Plagioclase	Kfeldspar
SiO2	53.1	49.122	33.558	33.32	36.811	32.9	33.25	64.36	61.75
TiO2	0.001	0.741	5.708	6.001	3.833	0.01	0.02	0.031	0.3
Al2O3	0.56	2.661	14.7	14.719	14.546	0.05	0.03	21.02	18.9
Cr2O3	0.029	0.257	0.257	0.257	0.257	0.02	0.01	0	0
Fe2O3	0.000	0.000	0	0	0	0	0	0	0
V2O3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MgO	17.498	16	11.923	11.71	10.351	19.9	25.78	0.009	0.2
FeO	9.442	5.408	16.646	16.763	17.993	44.12	40.12	0.13	0.26
CaO	13.477	21.693	0.045	0.037	0.131	0.28	0.19	2.176	0.3
MnO	0.191	0.089	0.201	0.211	0.167	2.02	1.96	0.004	0.03
CoO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NiO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ZnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na2O	0.198	0.271	0.267	0.34	0.277	0.26	0.27	9.874	1.05
K2O	0.022	0.019	8.136	7.507	9.056	0.06	0.05	0.213	16.45
Total	94.518	96.261	91.441	90.865	93.422	99.620	101.680	97.817	99.240
oxygen	**6.000**	**6.000**	**22.000**	**22.000**	**22.000**	**4.000**	**4.000**	**8.000**	**8.000**

basis									
# Si	2.042	1.885	5.298	5.281	5.694	0.976	0.945	2.891	2.910
# Ti	0.000	0.021	0.678	0.715	0.446	0.000	0.000	0.001	0.011
# Al	0.025	0.120	2.736	2.750	2.653	0.002	0.001	1.113	1.050
# Cr	0.001	0.008	0.032	0.032	0.031	0.000	0.000	0.000	0.000
# Mg	1.003	0.915	2.805	2.766	2.386	0.880	1.092	0.001	0.014
#total									
Fe	0.304	0.174	2.198	2.222	2.328	1.095	0.954	0.005	0.010
# Ca	0.555	0.892	0.008	0.006	0.022	0.009	0.006	0.105	0.015
# Mn	0.006	0.003	0.027	0.028	0.022	0.051	0.047	0.000	0.001
# Na	0.015	0.020	0.082	0.104	0.083	0.015	0.015	0.860	0.096
#K	0.001	0.001	1.639	1.518	1.787	0.002	0.002	0.012	0.989
Xfe	0.10	0.14							
Xen	0.00	0.00							
Xwo	0.90	0.86							
XFe			0.56	0.55	0.51				
XMg			0.44	0.45	0.49				
An								0.11	0.01
Ab								0.88	0.09
Or								0.01	0.90

Geochemistry:

Whole rock major and trace element analyses were carried out at the Chemical laboratory, Geological Survey of India (GSI), Hyderabad, India. X-ray fluorescence spectrometry was used to analyse major oxides, whereas ICP-MS was used to determine trace and rare earth element (REE) concentration. The precision is <5% for all analyzed elements when reported at 100X detection limit. Several standards were run along with the studied samples to check accuracy and precision. Table 2,3 and 4 presented the data of major oxide, trace elements and REE. Standardized CIPW norms for all samples were automatically computed using the IgROCS computer program (S.P Verma et al.2013).

Thirtal left bank lamprophyre is characterized by SiO_2 (44.56%-46.59%), Fe_2O_3 (10.20%-11.41%), MgO (7.38%-10.72%), CaO (8.71%-9.50%), K_2O (2.75%-2.89%), TiO_2 (1.34%-1.54%) and Al_2O_3(9.78%-10.37%) contents. Similarly trace elements analysis of the lamprophyre show that, its contain higher amount of Ba (2774-6552 ppm), Sr (542-738 ppm),Ni (220-235 ppm), Zr (360-443 ppm),V(20-136 ppm) and Cr(269-351 ppm). REE analysis of the samples indicates that, total REE contain of the rock is more than 1000 ppm. All the samples show this rock is enriched in LREE.

Table:2 Representative major oxide analysis of Thirtal lamprophyre

Sample No	PCS/377B/DA	PCS/377B/DA	PCS/377B/DA
SiO2	44.72	44.56	46.59
Al2O3	9.78	10.04	10.37
Total Fe as Fe2O3	11.37	10.20	11.41
MnO	0.15	0.15	0.18
MgO	10.72	7.51	7.38
CaO	9.08	8.71	9.50
Na2O	1.84	1.89	1.89
K2O	2.86	2.75	2.89
TiO2	1.37	1.34	1.54
P2O5	1.43	1.46	1.49
Or	18.06	18.29	18.26
Ab	15.82	18.00	17.10
An	10.66	12.14	12.06
Ne	0.44	0.00	0.00
Lc	0.00	0.00	0.00
Di	22.20	20.94	22.80

Ol	22.33	8.05	7.11
Mt	4.16	3.93	4.18
Il	2.78	2.86	3.13
Ap	3.54	3.81	3.69

Table:3 Representative trace element analysis of Thirtal lamprophyre (ppm)

Sample Ref. No.	PCS/377B/DA	PCS/377B/DA	PCS/377B/DA
Ba	6552	2774	4233
Ga	11	11	17
Sc	4	3.5	3.5
V	20	90	136
Th	77	25	57
Pb	2	40	37
Ni	227	220	235
Co	36	34	37
Rb	120	119	183
Sr	542	738	664
Y	22	20	28
Zr	357	360	443
Nb	75	27	34
Cr	284	269	351
Cu	48	38	55
Zn	70	73	108
Be	4.79	3.23	2.74
Ge	2.49	1.69	1.29
Sn	5.00	6.94	5.00

Table:4 Representative rare earth element analysis of Thirtal lamprophyre (ppm)

Sample Ref. No.	PCS/377B/DA	PCS/377B/DA	PCS/377B/DA
La	420.68	236.68	201.53
Ce	848.30	437.89	415.98
Pr	80.77	50.52	39.91
Nd	289.05	197.37	125.85
Eu	8.26	5.62	4.14
Sm	40.53	27.40	22.36
Tb	2.95	2.14	1.25
Gd	24.08	18.19	9.14
Dy	11.69	9.10	5.80
Ho	1.81	1.32	0.96
Er	4.52	3.28	2.30
Tm	0.61	0.41	0.32
Yb	3.61	2.65	1.99
Lu	0.50	0.39	0.28
Hf	8.96	11.29	8.28
Ta	1.37	1.95	1.15
U	13.72	10.88	7.98
Total	1761.40	1017.09	849.21

Major oxide data is plotted in the MgO(wt%) versus SiO_2 (wt%) (Lefebvre et al.2005) diagram and it shows that this lamprophyre belongs to Calc-alkaline group (Fig: 6A). SiO_2 (wt%) vs TiO_2(wt%) plot (Rock 1991) also suggest that this lamprophyre is calc-alkaline verity (Fig 6B). Discrimination diagram based on trace elements Nb/Pb vs V/Cr (Pearce et al.1973) also support the calc-alkaline nature (Fig.6C). CIPW norm calculation data also support this lamprophyre as a calc-alkaline in nature (Rock 1977) (Fig.6D).

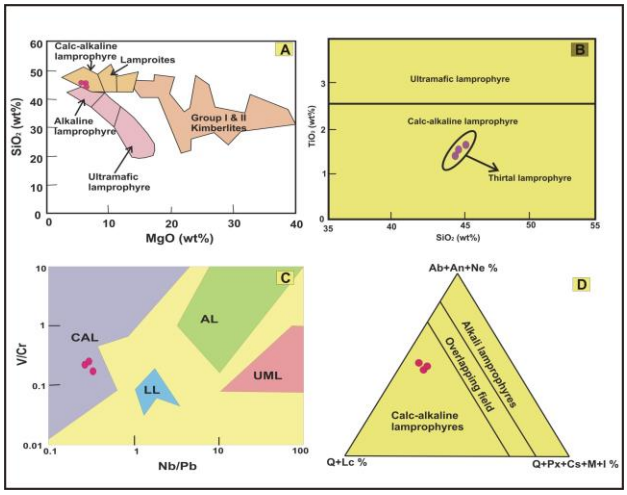

Fig:6.(A) MgO vs SiO_2 discrimination plot for various alkaline mafic potassic ultrapassic rocks (B)TiO_2 vs SiO_2 Plot suggesting calc-alkaline nature of the Thirtal lamprophyre (C)Simple discrimination between the lamprophyre branches using trace elements ratios of Nb/Pb vs V/Cr (D)Diagram for distinguishing calc-alkaline and alkaline lamprophyres using the normative parameters.

This rock is crystallized from the LREE enriched magma show from the chondrite-normalized REE pattern. The multi-element spider diagram shows that, this rock source region related to subduction-related characteristics. In the diagram sample plotted in overlapping field between subduction zone and within plate field with more affinity towards subduction- related source (Fig. 7A & 7B) (Muller D et al.1993 and Thorpe R.S 1987). Chondite normalization diagram (Nakamura 1974) shows the REE pattern of the thirtal left bank lamprophyre (Fig.7C). Primary magma responsible for lamprophyre, normally contain higher value of Sc,Cr,Ni and Co (Rock 1991).Sample of the thirtal lamprophyre also contain higher amount of Sc,Cr,Ni and Co. These phenomena suggest that thirtal left bank lamprophyre magma generated from the primary magma source. High concentration of LREE and compatible elements (Sun et al. 1989) (i.e Ni,Cr) in the samples strongly suggest that thirtal left bank lamprophyre magma generated from small degree of partial melting of peridotite mantle at greater depth in the garnet stability fields (Ferguson et al. 1971, Hirschman et al.1999).Negative Hf anomaly in multi element plots also suggest that thirtal lamprophyre magma generated from garnet stability field. Involvement of subduction related process in the origin of thirtal left bank lamprophyre indicates from the negative Ta-Nb anomalies in multi element plots (Foley 1987; Peacock 1990; Saunders 1992 and Kent 1995). Plagioclase fractionation is indicated by presence of negative Sr and Eu anomalies (Wood et al.1979) in a rock (Fig.7D). In the present studied rock show negative Sr anomaly which is indicate in the source melt residual clinopyroxene or to depletion of mantle source in Sr during a previous phase of melts extraction (Chalapati Rao 2004).

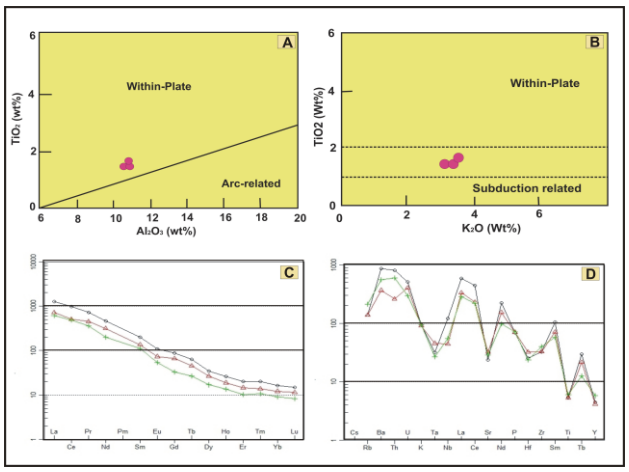

Fig:7(A)Al_2O_3 vs TiO_2 discrimination plot for distinguishing within-plate and arc related basalt (B)K_2O vs TiO_2 plot for distinguishing within-plate and subduction related K-rich mafic lavas (C) Chondite normalization rare earth pattern for Thirtal lamprophyre (D)Primordial mantle normalized multi-element pattern for the Thirtal lamprophyre.

Conclusion:

On the basis of the Petrography, mineral chemistry and geochemistry study it is considered this lamprophyre belongs to Calc-alkaline group. Comparative show that, this rock character slightly different from the Prakasam Province field (Madhavan et al.1998;Kumar et al.2008 and Meshram et al.2015) al well as Udiripikonda and Mudigubba field (Pandey et al.2017a; Pandey et al.2017b).This lamprophyre is close association with the Polayapalle lamprophyre. Presence of olivine crystal in the present lamprophyre is only difference with the Polayapalle lamprophyre . The strong correlation between major oxide and trace elements with incompatible and compatible elements indicate that crustal contamination is very limited effect in this thirtal left bank lamprophyre. This study area provides opportunity to study lamprophyre-granitoids relationship and evolution of ancient cratonic lithosphere.

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