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Petrology and Geochemistry study of the new finding of Shoshonitic lamprophyre from South of Polshettigudem, Khammam District, Eastern Dharwar Craton, South India

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ABSTRACT

Lamprophyre dykes are widely distributed in the Eastern Dharwar Craton (EDC) of southern India. The present communication reports a new lamprophyre dyke occurrence south of Polshettigudem village, Khammam District, Telangana (80° 09' 59.10": 17° 21' 58.95"). The petrography and geochemistry of the newly identified lamprophyre are also covered in this communication. The study area is predominantly composed of granitoids belonging to the Peninsular Gneissic Complex-II (PGC-II) of the EDC. The granitoids of the EDC have intruded by lamprophyre of the study region. Petrographic studies indicate that the lamprophyre exhibits a porphyritic-panidiomorphic texture. The lamprophyres contain phenocrysts of amphibole, biotite, and clinopyroxene. These dykes have a groundmass of spinel, chromite, plagioclase feldspar, and biotite. The lamprophyre is characterised by SiO2 (49.87%-50.62%), Fe2O3 (9.46%-9.56%), MgO (10.34%-11.06%), CaO (7.76%-7.93%), K2O (3.55%-3.62%), TiO2 (1.28%-1.32%), and Al2O3 (11.28%-11.94%). Similarly, the lamprophyre's trace element examination reveals that it has greater concentrations of Ba (3799 ppm), Sr (1667 ppm), Ni (1056 ppm), Zr (498 ppm), V (187 ppm), and Cr (1374 ppm). The total REE content of the samples exceeds 1000 ppm, and the rock is enriched in LREEs. It is evident from geochemistry and petrology research that this lamprophyre is classified as a member of the Shoshonitic lamprophyre group.

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Introduction:

The Eastern Dharwar Craton (EDC) hosts the greatest number and diversity of lamprophyre occurrences in India, ranging in age from Precambrian to Cretaceous. Lamprophyres of calc-alkaline and/or shoshonitic nature have been reported from two broad domains within the EDC: (i) toward the western margin of the Cuddapah Basin within the EDC, primarily known as Wajrakarur Kimberlite Field (WKF) (Pandey et al., 2017a, 2017b)., and (ii) the Prakasam Alkaline Province (PAP) or the "Cuddapah intrusive province" (Madhavanet al., 1998), which is located east of the Cuddapah Basin at the intersection of the Eastern Ghats Mobile Belt (EGMB) and the EDC. The lamprophyres in the latter region are predominantly of the alkaline variety, although some exhibits shoshonitic characteristics (Madhavanet al., 1998; Chalapathi Rao, 2008).

he lamprophyres in the EDC are known to be associated with greenstone belts, granite gneisses and in particular with Kimberlite clan of rocks (KCR). Lamprophyres in EDC have been reported from Wajrakarur kimberlite field, the Precambrian Penakacherla schist belt, the Mudigubba lamprophyre at the western margin of the Cuddapah basin, the Bayyaram Lamprophyre at the northeastern margin of the EDC at the western margin of Pakhal basin, Khammam district and lamprophyres of Prakasam Alkaline Province(PAP). Some lamprophyres have been reported in the NE margin of the EDC, north of Khammam at Polayapalli. In the Nallamalai fold belt of the Cuddapah basin, earlier K.Appavadhanulu classified certain mafic intrusives as lamprophyres but, Scott Smith confirmed these rocks as lamproites. Dominantly two generations of lamprophyres are found in EDC viz. Neo-Archaean age and Meso-Proterozoic ages.

A small number of isolated lamprophyre intrusions within granites have been recorded in the Khammam district (Fig:1) (Appavadhanulu 1971; Subrahmanyam et al. 1987; Meshram et al. 2015; Adhikary et al. 2022 and Adhikary et al. 2024). In this communication, a lamprophyre dyke near Polshettigudem Village is reported for the first time, together with its petrographic and geochemical analysis (Fig:2).

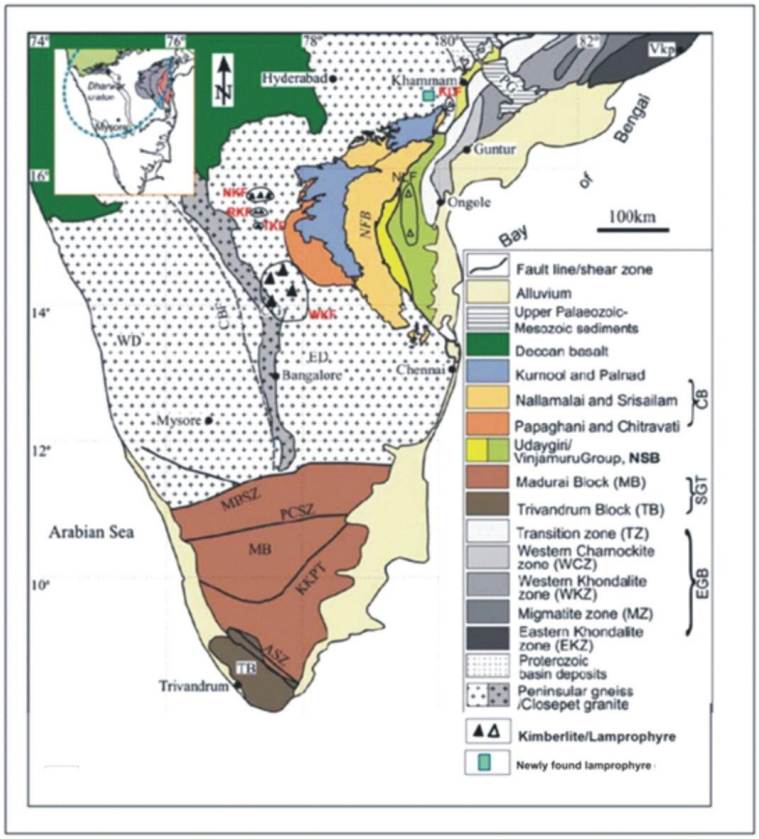


Fig:1-Location of study area in Khammam district, Telangana (after Naqvi, 2005)

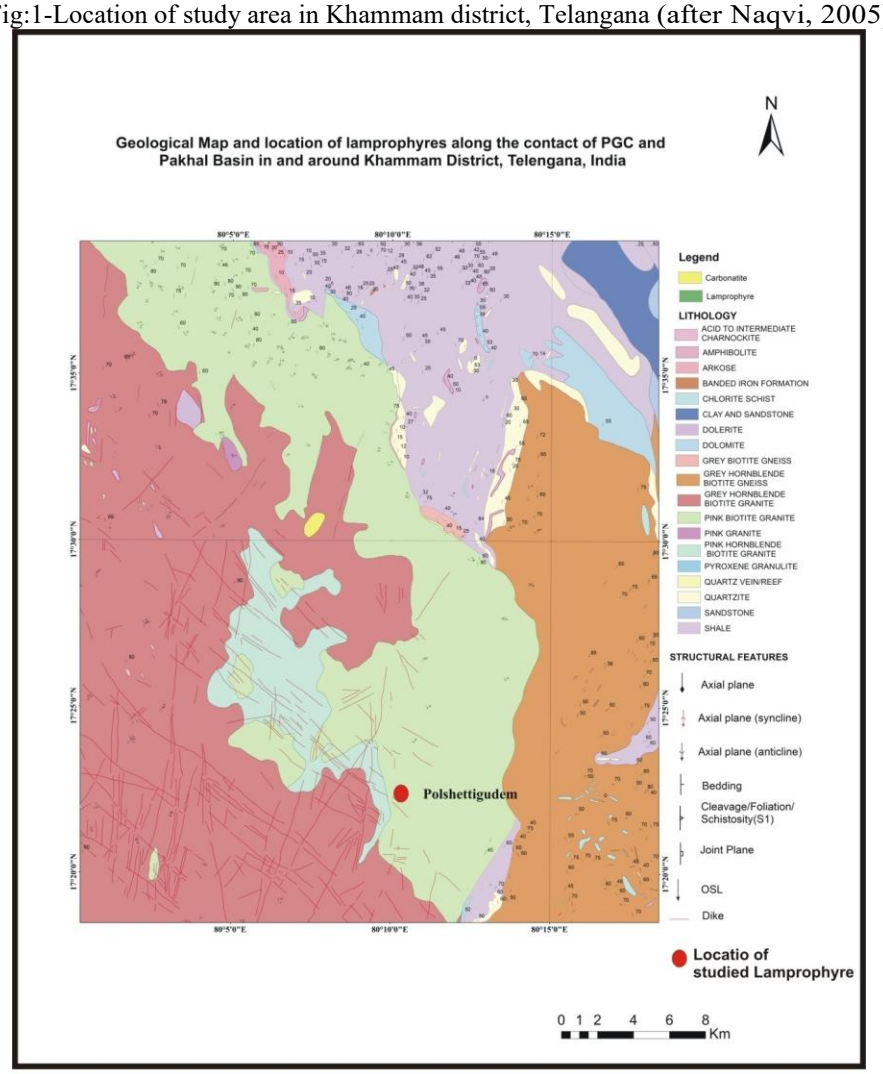


Fig:2 Geological map of the study area (Adhikary,2022)

Regional Geology:

There are several lamprophyre dykes occur in various cratons of India. The greatest quantity and variety of lamprophyres are found in EDC. Lamprophyric rocks are widely distributed along the eastern and western margins of the Cuddapah Basin, a region referred to as the Cuddapah Intrusive Province (CIP)/Prakasam Alkaline Province (PAP). Lamprophyre clusters, which are mostly intruded into the nepheline syenite, are abundant in the CIP. Lamprophyre clusters are primarily found intruded into the gabbro body on the opposite side of the PAP (Madhavan et al. 1998; Ratnakar et al. 1980; 1992; 1994). The granitoid body was identified to have invaded the lamprophyre (Fig. 3c).This dike has an exposed strike length of approximately 30 meters and a width of about 0.5 to 1 metre. The granitoid foliation is cut by the lamprophyre's N35°E trend (Fig:3b). This lamprophyre dyke is fine-grained and mesocratic to melanocratic, with a porphyritic texture.

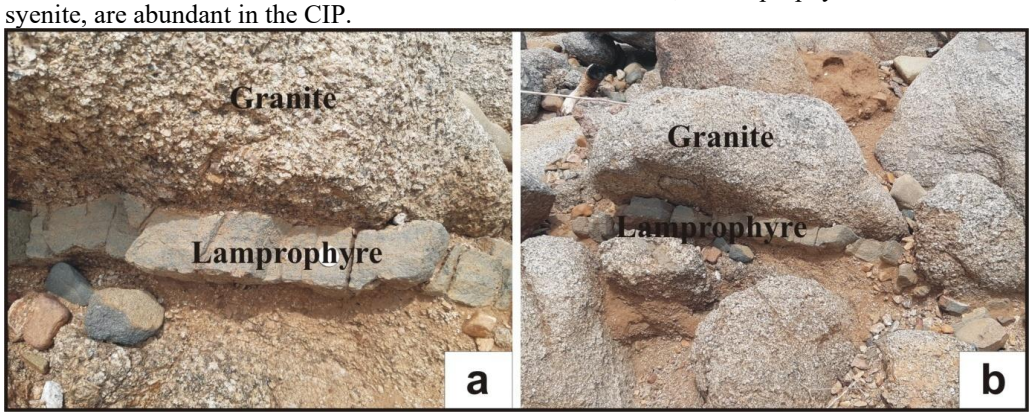


Fig:3a Intrusive Lamprophyre dyke in and around Garla area. Fig:3b Field photo show that sharp contact between Granite and Lamprophyre.

Analytical techniques:

The mineral chemistry of various phases of the Garla lamprophyre was analysed by CAMECA SX100 Electron Probe Micro Analyzer (EPMA) housed at GSI, Faridabad. An acceleration voltage of 15 kV, a beam current of 20 nA, a beam diameter of 1 µm and a counting time of 10 s were used. The microprobe was calibrated using (Na) on Albite,(Al) on Corrundum, (Mn) on Rhodonite (Ca, Si) on Wollastonite, (Ti) on TiO_2,(Mg) on Periclase, (K) on Orthoclase, (Cr) on Chromium (Fe) on Fe_2O_3. Analyses of selected and representative mineral phases are given in Table:1, 2 and 3.

Whole rock major and trace element analyses were carried out at the Chemical laboratory, Geological Survey of India (GSI), Kolkata, 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 <2% 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:4 presents the data of major oxide, trace elements and REE.

Petrography and mineral chemistry:

Petrographic studies show that clinopyroxene and biotite occur as phenocrysts in the present lamprophyre (Fig:5a). Clinopyroxene and biotite are present as phenocrysts in the rock in a groundmass comprising plagioclase feldspar showing the panidiomorphic texture. Clinopyroxene occurs in both elongated and rounded forms (Figs. 4a and 5b). In many places, phenocrysts are replaced by amphibole, chlorite and carbonate. Minor amount of Plagioclase feldspar, K-feldspar, fine-grained biotite, carbonate, amphibole, chlorite and epidote occur in the groundmass (Fig:4b). In this particular lamprophyre spinel are present within the groundmass part along with biotite and clinopyroxene (Fig: 5c & 5d). Compositional variation from core to rim is observed in the clinopyroxene phenocrysts. One the basis of the petrography and modal abundance study, this lamprophyre belongs to the Calc-alkaline group.

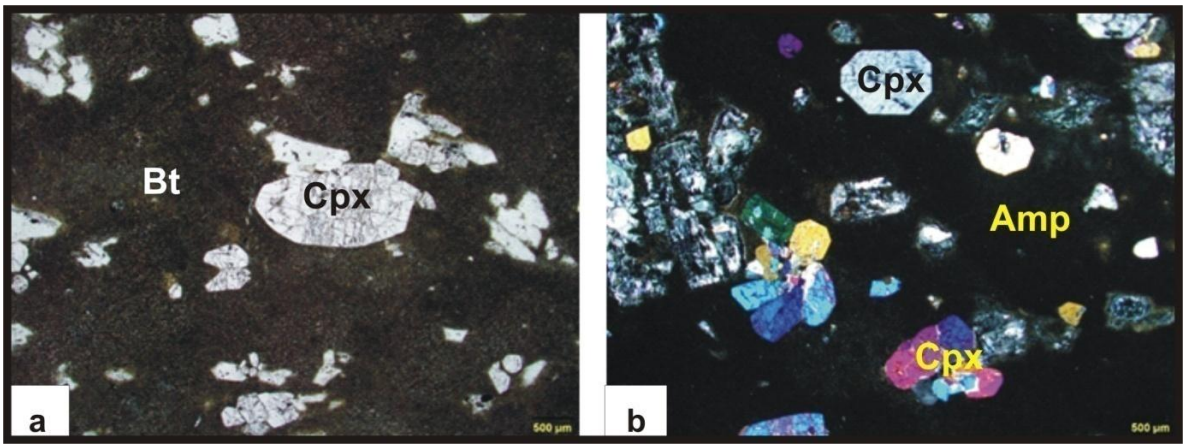


Fig:4aClinopyroxene present as prenocryst within Polshettigudem Lamprophyre (PPL). Fig:4b Elongated Clinopyroxene with amphibole present as prenocryst and groundmass within Polshettigudem Lamprophyre (PPL).

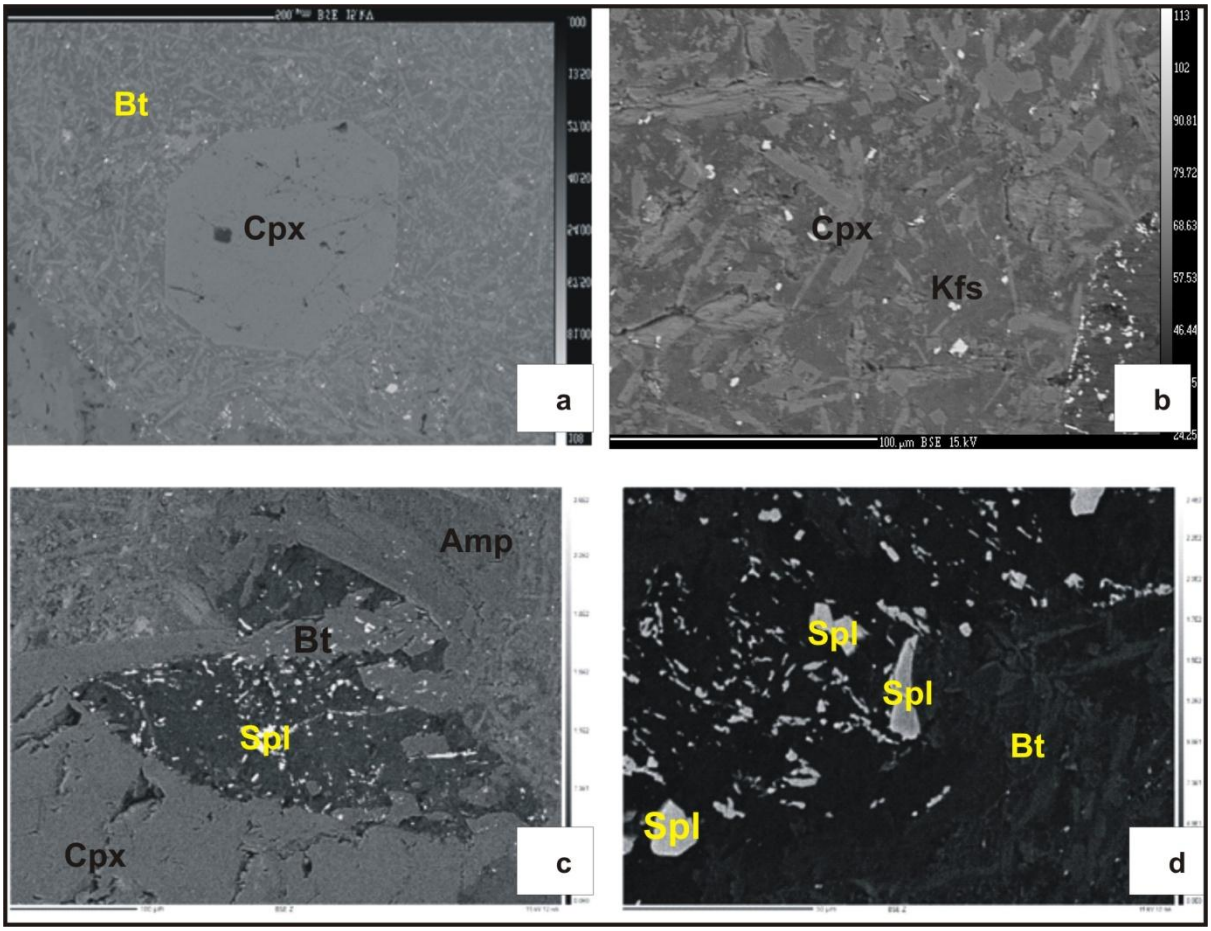


Fig: 5a. BSE image of Clinopyroxene grain as a phenocryst within Polshettigudem Lamprophyre.Fig:5b. BSE image of Clinopyroxene grain as a groundmass within Polshettigudem Lamprophyre.Fig:5c. BSE image of spinel grain within the Polshettigudem Lamprophyre. Fig:5d. BSE image of spinel and biotite grains within the Polshettigudem Lamprophyre.

Clinopyroxene:

In the studied lamprophyre sample (PS-26), clinopyroxenes are mainly diopsidic (Wo42-50 En41-50 Fs2-8) in composition (Fig:6a) (Table:1). When the Al and Ti values of clinopyroxene are plotted on the Ca(a.p.f.u) vs. Ti (a.p.f.u) diagram (Fig:6c), they indicate an orogenic affinity for the lamprophyre.

Amphibole:

Most of the amphiboles are of actinolite variety (Table:4) (Fig:6b). Actinolite is usually absent in the igneous rocks and hence its formation suggests auto metamorphism of existing amphiboles with the hydrous melt (Leake et. al 1997). The amphiboles are depleted in Al2O3, K2O and TiO2 indicating a calc- alkaline nature of the magma (Fig:6d). The TiO2 (wt%) versus SiO2 (wt%) plot (Fig:6d), (after Rock, 1991) for the amphibole also suggests calc-alkaline nature of the studied lamprophyres.

Feldspar:

In the Polshettigudem lamprophyre feldspars are present essentially as groundmass. The feldspars are of albitic composition (Table:5). Some orthoclase composition feldspar also present in the rock.

Biotite:

In the Polshettigudem lamprophyre, biotite occurs both as the phenocryst and in the ground mass. In this rock biotite is Fe rich in nature (Table:2).

Spinel:

In this Polshettigudem lamprophyre spinel occurs in the ground mass. In this rock , spinel is chromite rich in composition (Table:3).

Table 1: EPMA analysis of the clinopyroxene grains of the Polshettigudem lamprophyre

DataSet/Point	1 / 1 .	2 / 1 .	4 / 1 .	5 / 1 .	5 / 2 .	5 / 3 .	5 / 4 .	5 / 5 .
SiO2	52.218	53.865	48.643	53.653	51.632	51.125	51.818	49.811
TiO2	0.499	0.251	1.852	0.532	0.328	0.877	0.655	0.692
Al2O3	2.726	2.188	6.527	1.95	1.947	3.72	2.866	3.717
Cr2O3	0.757	0.433	0.075	0.379	0.725	0.753	0.823	0.311
FeO	4.94	5.354	8.962	5.628	5.246	6.058	5.347	7.162
MnO	0.09	0.149	0.153	0.07	0.095	0.082	0	0.26
MgO	17.537	17.371	13.093	17.143	16.755	16.042	16.077	14.885
CaO	22.336	20.885	20.214	21.653	21.717	21.277	21.972	20.979
Na2O	0.316	0.283	0.461	0.222	0.267	0.352	0.261	0.372
K2O	0.002	0	0.222	0	0.028	0.006	0.008	0.003
Total	101.421	100.779	100.202	101.23	98.74	100.292	99.827	98.192
Formula (corr.)	6(O)	6(O)	6(O)	6(O)	6(O)	6(O)	6(O)	6(O)

Si	1.87661	1.95162	1.805501	1.940369	1.912046	1.870959	1.904443	1.869765
Ti	0.013489	0.006841	0.051707	0.014472	0.009137	0.024141	0.018107	0.019539
Al	0.115461	0.093431	0.285527	0.083115	0.084977	0.160446	0.124142	0.164441
Cr	0.021509	0.012404	0.002201	0.010837	0.021227	0.021787	0.023915	0.00923
Fe3+	0.104942	-0.00288	0.041546	0.011932	0.071923	0.052822	0.025815	0.074939
Fe2+	0.043527	0.165103	0.236642	0.158284	0.090543	0.13258	0.138529	0.14989
Mn	0.00274	0.004573	0.00481	0.002144	0.00298	0.002542	0	0.008266
Mg	0.939545	0.938257	0.724478	0.924242	0.92498	0.875181	0.880848	0.832951
Ca	0.860067	0.810767	0.803901	0.839038	0.861693	0.834285	0.865227	0.843762
Na	0.022018	0.01988	0.033176	0.015566	0.019171	0.024976	0.018598	0.027074
K	9.17E-05	0	0.010512	0	0.001323	0.00028	0.000375	0.000144
Total	4	4	4	4	4	4	4	4
Mg/(Mg+Fe2)	0.955723	0.850364	0.753785	0.853783	0.910841	0.868441	0.864104	0.847493
Fe2/(Fetot)	0.293172	1.017728	0.850656	0.929902	0.557304	0.715093	0.84292	0.666686
Al/(Al+Fe3+Cr)	0.477284	0.907461	0.867142	0.784965	0.477057	0.682588	0.713987	0.661443
Tri. plots								
En	0.509753	0.490175	0.410464	0.480984	0.49274	0.475114	0.467392	0.456011
Fs	0.023616	0.086255	0.134073	0.082373	0.048233	0.071974	0.073506	0.08206
Wo	0.466632	0.42357	0.455463	0.436643	0.459027	0.452912	0.459103	0.46193
augite		augite		augite				
diopside	diopside		diopside		diopside	diopside	Diopside	diopside

Table 2: EPMA analysis of the biotite grains of the Polshettigudem lamprophyre

Biotite						
	36 / 1 .	37 / 1 .	38 / 1 .	39 / 1 .	44 / 1 .	45 / 1 .
SiO2	37.1	35.93	37.46	36.67	36.24	35.88
TiO2	3.93	3.54	3.82	3.11	4.13	3.36
Al2O3	13.33	13.04	13.03	14.04	13.45	13.52
FeO	16.83	17.81	17.56	16.28	17.41	17.81
MnO	0.22	0.18	0.07	0.27	0.23	0.25
MgO	12.57	12.36	12.59	12.58	12	12.28
CaO	0.65	0.74	0.19	0.66	0.07	0.1
Na2O	0.08	0.02	0.07	0.07	0.1	0.04
K2O	9.03	8.95	9.13	8.65	9.21	9.27
Li2O*	1.0957	0.75991	1.19902	0.97229	0.84888	0.74556
H2O*	3.963459	3.863846	3.97181	3.916298	3.894043	3.861851
Subtotal	98.79916	97.19376	99.09083	97.21859	97.58292	97.11741
Total	98.79916	97.19376	99.09083	97.21859	97.58292	97.11741
Si	5.612879	5.57601	5.655428	5.614633	5.580506	5.571127
Al iv	2.37708	2.385316	2.318697	2.385367	2.419494	2.428873
Al vi	0	0	0	0.148474	0.021741	0.045523
Ti	0.447157	0.413166	0.433727	0.358118	0.47829	0.392361
Fe	2.129469	2.311563	2.217163	2.084684	2.242124	2.312757
Mn	0.028193	0.023662	0.008952	0.035018	0.03	0.032881
Mg	2.834891	2.859395	2.833432	2.871313	2.754584	2.842356
Li*	0.666738	0.474329	0.728074	0.598767	0.525755	0.465613
Ca	0.105371	0.123053	0.030736	0.10828	0.01155	0.016637
Na	0.023468	0.006018	0.020492	0.020782	0.029858	0.012043
K	1.742563	1.771652	1.758157	1.689334	1.808982	1.835944
OH*	4	4	4	4	4	4
TOTAL	19.96781	19.94417	20.00486	19.91477	19.90288	19.95611
Y total	6.106448	6.082116	6.221348	6.096374	6.052494	6.09149
X total	1.871402	1.900724	1.809384	1.818397	1.85039	1.864624
Al total	2.37708	2.385316	2.318697	2.533842	2.441235	2.474396
Fe/Fe+Mg	0.428951	0.447028	0.43899	0.420639	0.44872	0.448634
Mn/Mn+Fe	0.013067	0.010133	0.004021	0.01652	0.013204	0.014018
Total Al	2.37708	2.385316	2.318697	2.533842	2.441235	2.474396
Mg-Li	2.168154	2.385066	2.105358	2.272546	2.228829	2.376743
Fe+Mn+Ti-AlVI	2.604819	2.748391	2.659842	2.329345	2.728672	2.692475
Luhr et al. 84	1017.342	980.1617	999.9075	972.254	1021.478	969.8519

Table 3: EPMA analysis of the cromite grains of the Polshettigudem lamprophyre

Spinel	40 / 1 .	54 / 1 .	55 / 1 .	58 / 1 .	63 / 1 .	65 / 1 .	66 / 1 .	6 / 1 .
TiO2	1.03	1.48	1.41	0.89	1.02	0.99	1.11	0.817
Al2O3	12.25	11.35	11.29	13.97	11.71	10.67	10.7	13.584
Cr2O3	40.63	37.92	37.41	42.12	39.57	33.81	34.46	49.39
FeO	39.18	39.51	40.25	34.77	39.16	41.65	40.15	25.181
MnO	3.35	2.52	3.14	1.85	3.32	2.62	2.81	0.235
NiO								
MgO	0.11	1.73	0.28	3.71	0.15	0.09	0.27	10.674
Total	96.55	94.51	93.78	97.31	94.93	89.83	89.5	99.881
Formula (corr.)	4(O)	4(O)	4(O)	4(O)	4(O)	4(O)	4(O)	4(O)
Ti	0.027969	0.040617	0.039436	0.023188	0.028194	0.028925	0.032509	0.019857
Al	0.521191	0.488049	0.494761	0.570296	0.507154	0.488451	0.491005	0.517312
Cr	1.15965	1.093843	1.099786	1.153484	1.149656	1.038296	1.060807	1.261778
Fe3+	0.263222	0.336875	0.326582	0.229843	0.286802	0.415403	0.383171	0.181195
Fe2+	0.919617	0.868647	0.925024	0.777341	0.916641	0.937517	0.924167	0.499258
Mn	0.102432	0.077875	0.098892	0.054276	0.103336	0.086196	0.09267	0.006432
Mg	0.00592	0.094095	0.015521	0.191571	0.008217	0.005211	0.015672	0.514168
Total	3	3	3	3	3	3	3	3
Mg/(Mg+Fe2)	0.006396	0.097737	0.016502	0.197718	0.008885	0.005528	0.016675	0.507356
Fe2/(Fe2+Fe3)	0.777466	0.720557	0.73907	0.771796	0.761682	0.692958	0.706908	0.733714
Al/(Al+Fe3+Cr)	0.268094	0.254356	0.257537	0.291917	0.260934	0.2515	0.253752	0.263896
Tri. plots								
Fe2	0.894596	0.834742	0.889928	0.759724	0.891506	0.911162	0.89507	0.489537
Mg	0.005759	0.090422	0.014932	0.18723	0.007992	0.005065	0.015178	0.504157
Mn+Zn+Ni	0.099645	0.074835	0.09514	0.053046	0.100502	0.083773	0.089752	0.006306
Al	0.268094	0.254356	0.257537	0.291917	0.260934	0.2515	0.253752	0.263896
Fe3	0.135398	0.175568	0.169995	0.11765	0.147562	0.213888	0.198023	0.092433
Cr	0.596508	0.570076	0.572469	0.590433	0.591505	0.534611	0.548226	0.643671
Mole fractions								
XFe2 (A)	0.891648	0.82803	0.885587	0.754153	0.888447	0.908593	0.891659	0.479401
XMg (A)	0.00592	0.094095	0.015521	0.191571	0.008217	0.005211	0.015672	0.514168
XMn (A)	0.102432	0.077875	0.098892	0.054276	0.103336	0.086196	0.09267	0.006432
XAl (B)	0.260595	0.244024	0.24738	0.285148	0.253577	0.244226	0.245502	0.258656
XFe3 (B)	0.131611	0.168437	0.163291	0.114922	0.143401	0.207702	0.191585	0.090598
XCr (B)	0.579825	0.546922	0.549893	0.576742	0.574828	0.519148	0.530404	0.630889
XFe2 (B)	0.013984	0.020308	0.019718	0.011594	0.014097	0.014462	0.016254	0.009929
XTi (B)	0.013984	0.020308	0.019718	0.011594	0.014097	0.014462	0.016254	0.009929
End-members								
Spinel	0.00592	0.094095	0.015521	0.191571	0.008217	0.005211	0.015672	0.514168
Hercynite	0.152244	0.072055	0.132968	0.039301	0.142024	0.152818	0.137161	-0.26194
Galaxite	0.102432	0.077875	0.098892	0.054276	0.103336	0.086196	0.09267	0.006432
Magnetite	0.131611	0.168437	0.163291	0.114922	0.143401	0.207702	0.191585	0.090598
Chromite	0.579825	0.546922	0.549893	0.576742	0.574828	0.519148	0.530404	0.630889
Ulvöspinel	0.027969	0.040617	0.039436	0.023188	0.028194	0.028925	0.032509	0.019857

Table 4: EPMA analysis of the amphibole grains of the Polshettigudem lamprophyre

Amphibole	43 / 1 .	61 / 1 .	62 / 1 .
SiO2	44.43	55.78	56.63
TiO2	3.47	0.03	0
Al2O3	15.65	0.7	0.51
FeO	10.06	9.37	7.44
MnO	0.17	0.23	0.38
MgO	5.34	18.55	18.8
CaO	8.49	12.22	13.25
Na2O	0.33	0.21	0.13
K2O	5	0.07	0.04
Cr2O3	0.02	0	0
No. of oxygens	23	23	23
Structural formulae			
Si	6.772216581	7.855312	7.986836
Al iv	1.227783419	0.116183	0.013164
Al vi	1.583658981	0	0.071609
Ti	0.397844606	0.003178	0
Cr	0.002410238	0	0
Fe3+	0	0.409321	0
Fe2+	1.282355681	0.6942	0.87752
Mn	0.021947709	0.027435	0.045394
Mg	1.213400943	3.894372	3.952707
Ni	0	0	0
Zn	0	0	0
Li* (not implemented)	0	0	0
Ca	1.386499966	1.8438	2.002174
Na	0.09752728	0.057341	0.035549
K	0.972261459	0.012576	0.007197
Ba	0	0	0
Sr	0	0	0
Pb	0	0	0
F	0	0	0
Cl	0	0	0
OH*	2	2	2
Total	16.95790686	16.91372	16.99215
Calculation scheme	∑13	∑13	∑13
Amphibole group	Ca	Ca	Ca
(Ca+Na) (B)	1.484027246	1.90114	2.002174
Na (B)	0.09752728	0.057341	0
(Na+K) (A)	0.972261459	0.012576	0.042746
Mg/(Mg+Fe2)	0.486185604	0.848711	0.818327
Fe3/(Fe3+Alvi)	0	1	0
Sum of S2	12.50161816	13	12.94723
Amphibole names	titanian-potassium-		
	subcalcicalumino-		
	ferro-edenite	actinolite	actinolite

Table 5: EPMA analysis of the feldspar grains of the Polshettigudem lamprophyre

Feldspar									
DataSet/Point	1 / 1 .	3 / 1 .	4 / 1 .	5 / 1 .	6 / 1 .	7 / 1 .	8 / 1 .	9 / 1 .	10 / 1 .
SiO2	63.847	64.482	58.058	62.977	65.188	65.934	63.678	64.673	61.556
TiO2	0.31	0.082	0.828	0.389	0.099	0.388	0.221	0.388	0.5
Al2O3	20.129	21.555	18.504	19.291	19.206	19.981	18.376	17.83	18.611
FeO	0.478	1.004	1.962	0.57	0.299	0.487	0.572	0.891	1.564

MnO	0	0	0.16	0.036	0	0.003	0.07	0.028	0
MgO	0	0	0	0.314	0	0.022	0.125	0.345	0.505
CaO	1.497	3.543	8.772	1.003	0.605	1.131	0.636	0.747	1.005
Na2O	4.554	9.421	6.94	3.036	4.669	6.339	0.874	1.322	0.711
K2O	8.977	1.27	3.176	11.224	8.625	5.56	13.556	12.678	13.567
BaO	0.939	0	0.594	1.414	0.67	0.616	1.056	0.179	0.751
F	0	0	0.676	0.102	0	0.047	0.134	0.012	0
Cl	0.01	0.011	0.028	0.005	0.009	0	0.022	0.025	0.025
Cr2O3	0.001	0	0	0	0	0	0	0.007	0
TOTAL	100.742	101.368	99.698	100.361	99.37	100.508	99.32	99.125	98.795
Oxygens =	8	8	8	8	8	8	8	8	8
Si	2.897541	2.837561	2.69372	2.90078	2.968402	2.938321	2.962613	2.989568	2.903842
Al	1.076736	1.118029	1.011939	1.047335	1.030837	1.049555	1.007708	0.971482	1.034833
Ti	0.010581	0.002714	0.028892	0.013475	0.00339	0.013004	0.007733	0.013489	0.017739
Fe	0.018142	0.03695	0.076132	0.021958	0.011387	0.018151	0.022257	0.034446	0.061704
Mn	0	0	0.006288	0.001405	0	0.000113	0.002759	0.001096	0
Mg	0	0	0	0.02156	0	0.001462	0.008669	0.023774	0.035513
Ca	0.072796	0.16706	0.436097	0.049503	0.029519	0.054007	0.031706	0.037	0.0508
Na	0.40074	0.803867	0.624354	0.271154	0.412249	0.547761	0.078846	0.118494	0.065036
K	0.519648	0.071285	0.187958	0.659431	0.50096	0.316048	0.804463	0.747524	0.816348
Ba	0.016697	0	0.010799	0.02552	0.011954	0.010756	0.01925	0.003242	0.013881
F	0	0	0.099194	0.014859	0	0.006624	0.019717	0.001754	0
Cl	0.000769	0.000821	0.002202	0.00039	0.000695	0	0.001735	0.001959	0.001999
Cr	3.59E-05	0	0	0	0	0	0	0.000256	0
Total	5.013686	5.038287	5.177574	5.027369	4.969394	4.955802	4.967455	4.944084	5.001695
Or	52.32145	6.839799	15.05578	67.28291	53.1394	34.43483	87.91808	82.78062	87.57373
Ab	40.34903	77.13085	50.01196	27.66626	43.72934	59.68092	8.616871	13.12203	6.976717
An	7.329519	16.02935	34.93225	5.050834	3.131252	5.884247	3.465045	4.097355	5.449557

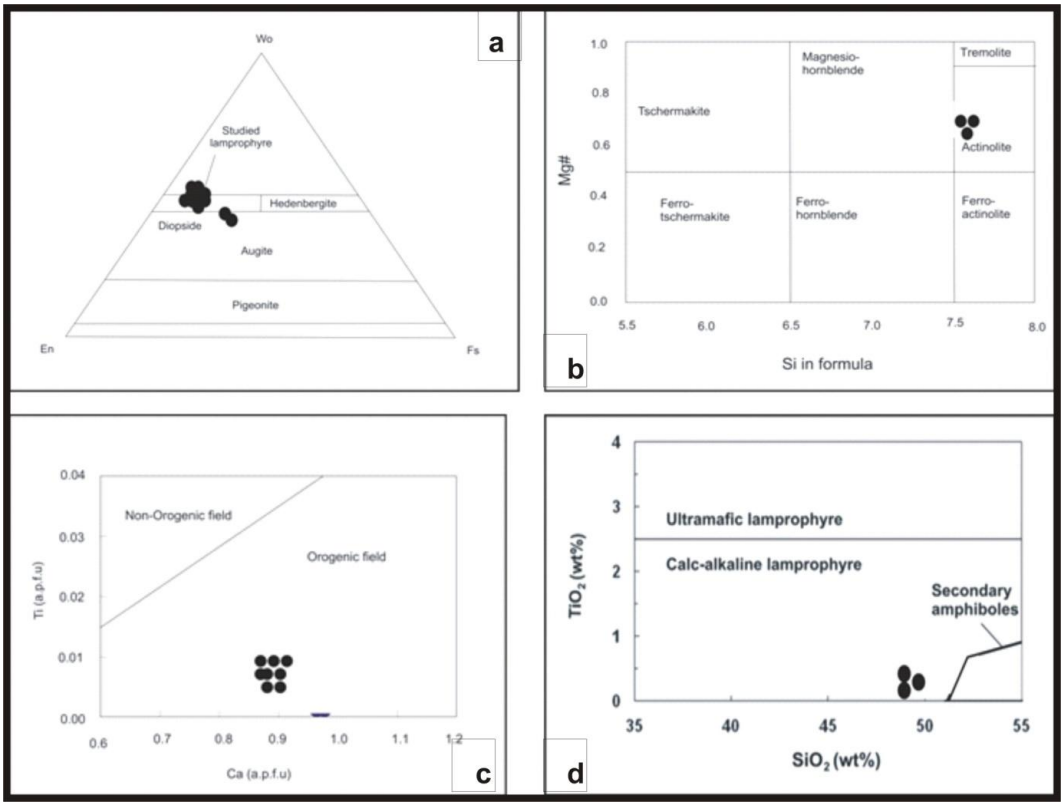


Fig 6a: Pyroxene classification diagram showing diopsidic nature of the clinopyroxenes from the Polshettigudem lamprophyre. Fig:6b: Si vs. Mg# plot for the classification of amphiboles (after Leake et al.,1997) from the Polshettigudem lamprophyre. Fig:6cTi (a.p.f.u) versus Ca (a.p.f.u) plot (after Sun and Bertrad, 1991) of clinopyroxene showing their orogenic affinity.Fig:6d TiO_2 (wt%) versus SiO_2 (wt%) plot (after Rock, 1991) for the amphibole suggesting calc-alkaline nature of the studied Polshettigudem lamprophyre.

Geochemistry:

Whole rock major and trace element analyses were carried out at the Chemical laboratory, Geological Survey of India (GSI), Kolkata, 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 100Xdetection limit. Several standards were run along with the studied samples to check accuracy and precision. Table 6 and 7 presented the data of major oxide, trace elements and REE.

Polshettigudem lamprophyre is characterised (Table 6) by SiO_2 (49.87%-50.62%), Fe_2O_3 (9.46%-9.56%), MgO (10.34%-11.06%), CaO (7.76%-7.93%), K_2O (3.55%-3.62%), TiO_2 (1.28%-1.32%) and Al_2O_3 (11.28%-11.94%) contents. Similarly, trace element analysis (Table 6) of the lamprophyre shows that it contains higher amounts of Ba (1677-3799 ppm), Sr (628-1667 ppm), Ni (230-1056 ppm), Zr (312-498 ppm), V (127-187 ppm) and Cr (610-1374 ppm). REE analysis of the samples indicates that the total REE content (Table 7) of the rock is more than 1000 ppm (1039-1283 ppm). All the samples show this rock is enriched in LREE.

The major oxide data are plotted on the MgO (wt%) versus SiO_2 (wt%) diagram (Lefebvre et al. 2005) (Fig. 7a), and it shows that this lamprophyre belongs to the calc-alkaline group. The SiO_2 vs Na_2O+K_2O diagram (Rock, N.M.S. 1987) (Fig. 7b) and the SiO_2 (wt%) vs TiO_2 (wt%) plot (Rock, N.M.S. 1991) also suggest that this lamprophyre is a calc-alkaline variety (Fig. 7c).

Major oxide data are also used for identifying the source region of the lamprophyre rock. The K_2O vs TiO_2 diagram (Thorpe R.S., 1987) (Fig. 7d) confirmed that this lamprophyre magma has been generated from a subduction-related source. All the samples have been plotted in the overlapping field between the subduction zone and the within-plate field with more affinity towards the subduction zone.

Trace elements and the REE data have been plotted in different diagrams to understand the character of the Polshettigudem lamprophyre. The discrimination diagram (Pearce et al., 1973) based on trace elements Nb/Pb vs V/Cr also supports the calc-alkaline nature (Fig. 7e). This rock is crystallised from the LREE-enriched magma show from the chondrite-normalised REE pattern (Nakamura 1974) (Fig. 7f). Lamprophyre, which is generated from the primary magma, normally has higher values (Rock, N.M.S. 1987) of Sc, Cr, Ni and Co. Polshettigudem lamprophyre samples, given the relatively higher value of Sc, Cr, Ni and Co, also suggest that this lamprophyre magma can be generated from the primary magma source.

Polshettigudem lamprophyre samples contain a higher concentration of LREE and compatible elements (Sun et al. 1989) (i.e., Ni, Cr), which indicates Polshettigudem lamprophyre magma is generated from a small degree of partial melting of peridotite mantle at greater depth in the garnet stability fields (Ferguson et al. 1971, Hirschman et al. 1999).

Table 6: Major oxide and trace element analysis of the Polshettigudem lamprophyre

Sample No	PCS-L 26/1	PCS-L 26/2	PCS-26/3	PCS-26/4
SiO2	50.62	49.91	50.15	49.87
Al2O3	11.28	11.28	11.94	11.85
Fe2O3	9.55	9.46	9.55	9.56
MnO	0.14	0.14	0.14	0.14
CaO	7.76	7.76	7.93	7.76
MgO	10.79	11.06	10.34	10.78
Na2O	1.72	1.84	1.95	1.94
K2O	3.62	3.55	3.58	3.57
TiO2	1.3	1.28	1.32	1.32
P2O5	0.74	0.73	0.83	0.82
LOI	2.16	2.43	2.4	2.22
Ba	1677	1725	3739	3799
Co	69	64	45	40
Cr	1374	835	636	610
Cu	66	68	57	55
Ga	9	8	22	23
Nb	118	112	23	22
Ni	1056	942	230	231
Pb	16	14	79	83
Sc	16	14	27	27
Sr	1667	1489	661	628
V	132	127	187	185
Y	19	17	38	36
Zn	79	75	92	91
Zr	319	312	498	496
Th	12	11	120	123
Rb	55	53	175	181

Table 7: REE analysis of the Polshettigudem lamprophyre

Sample No.	PCS-26/1	PCS-26/2	PCS-26/3	PCS-26/4
La	322.53	343.14	263.30	324.34
Ce	452.98	486.67	452.82	556.82

Pr	55.83	59.12	57.21	70.49
Nd	191.45	202.14	195.18	240.00
Sm	26.77	28.12	26.66	32.62
Eu	5.90	6.16	5.48	6.85
Gd	22.11	23.23	20.85	26.52
Tb	2.09	2.20	2.06	2.69
Dy	8.03	8.41	7.65	10.67
Ho	1.20	1.25	1.27	1.79
Er	3.54	3.67	3.44	5.01
Tm	0.45	0.48	0.47	0.72
Yb	2.68	2.82	2.71	4.25
Lu	0.41	0.43	0.41	0.64
Total	1095.97	1167.83	1039.52	1283.40

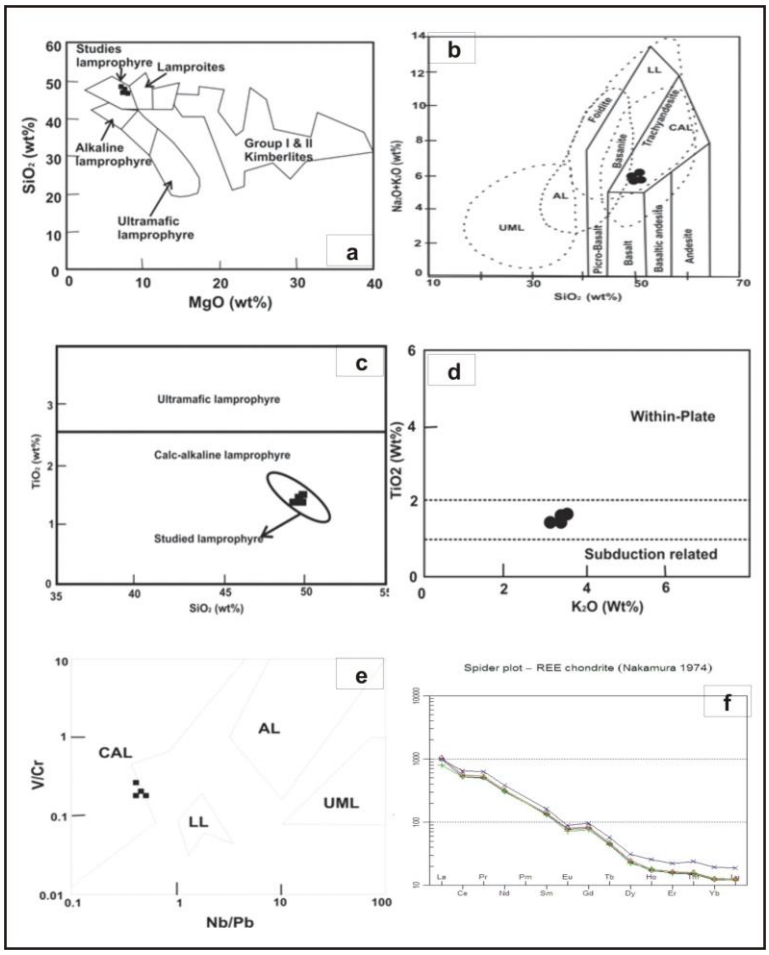


Fig:7aMgO vs SiO_2 discrimination plot for various alkaline mafic potassic ultrapotassic rocks. 7b. Plot of SiO2 versus (Na2O + K2O) for lamprophyres. CAL,Calc-alkaline lamprophyres; AL, Alkaline lamprophyres; UML, Ultrabasic lamprophyres; LL,Lamproites. 7c. TiO_2 vs SiO_2 Plot suggesting calc-alkaline nature of the Polshettigudem lamprophyre. 7d.K_2O vs TiO_2 plot for distinguishing within-plate and subduction related K-rich mafic lavas. . 7e. Simple discrimination between the lamprophyre branches using trace elements ratios of Nb/Pb vs V/Cr. .7f. Chondrite normalized multielement diagrams of Polshettigudem lamprophyre.

The major and trace bulk-rock data for the representative samples of the Polshettigudem lamprophyre are listed in Table 6. The major oxide analysis in Table 6 shows that the Polshettigudem lamprophyre has a limited and low range of SiO2 content, which varies from 49 to 50 wt%. In Table 6, the samples of the Polshettigudem lamprophyre display high levels of K2O (3.55-3.62 wt%), Na2O (1.72-1.95 wt%), and CaO (7.76-7.93 wt%). Due to their elevated K2O levels, these samples fall within the shoshonitic field on the K2O versus SiO2 classification diagram (Fig. 8a, after Peccerillo and Taylor, 1976) and bear resemblance to the co-spatial Udiripi-kondashoshonitic lamprophyres (Pandey et al., 2017b). When compared with global calc–alkaline, ultramafic, alkaline lamprophyres, and the Superior Province Archaean calc–alkaline lamprophyres, the Polshettigudem lamprophyre displays mixed charecteristics (Fig.8b) without confinding to any particular field..

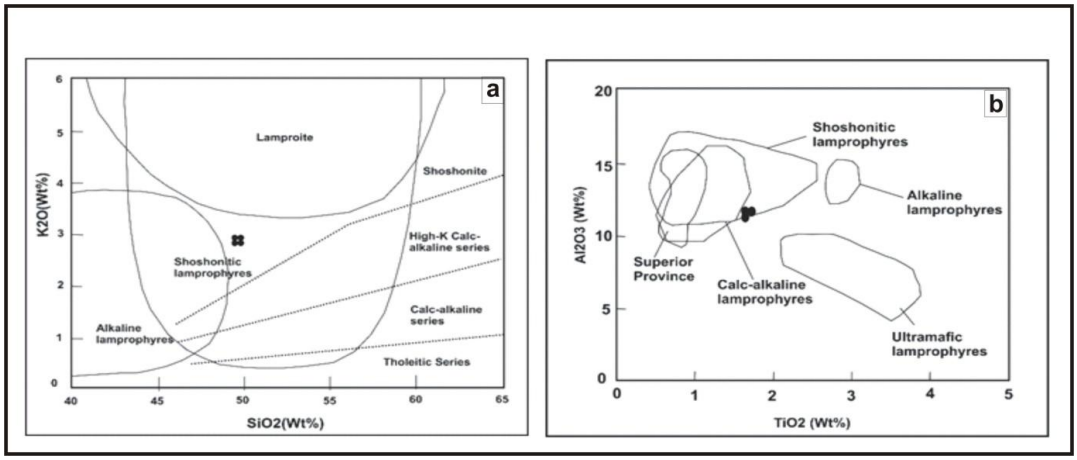


Fig:8a K_2O (wt%) versus SiO_2 (wt%) diagram (Peccerillo and Taylor, 1976) showing shoshonitic character of Polshettigudem lamprophyre, classification scheme is based on Rock (1987). 8b.TiO_2(wt%)versus Al_2O_3(wt%) diagram(afterRock,1987)classifying AN as alkaline lamprophyres (ALs), while other fields are shown for comparison. Data sources: CAL, Calc–alkaline lamprophyres; AL, Alkaline lamprophyres; UML, Ultramafic lamprophyres. Archaean CAL from different cratons are taken from Lefebvre et al. (2005) and references therein. Data for shoshonitic lamprophyres are taken from Rock (1991), Wyman and Kerrich (1993), Jiang et al. (2010), and Taylor et al. (1994). Data Sources for Superior province is from Wyman and Kerrich(1989).

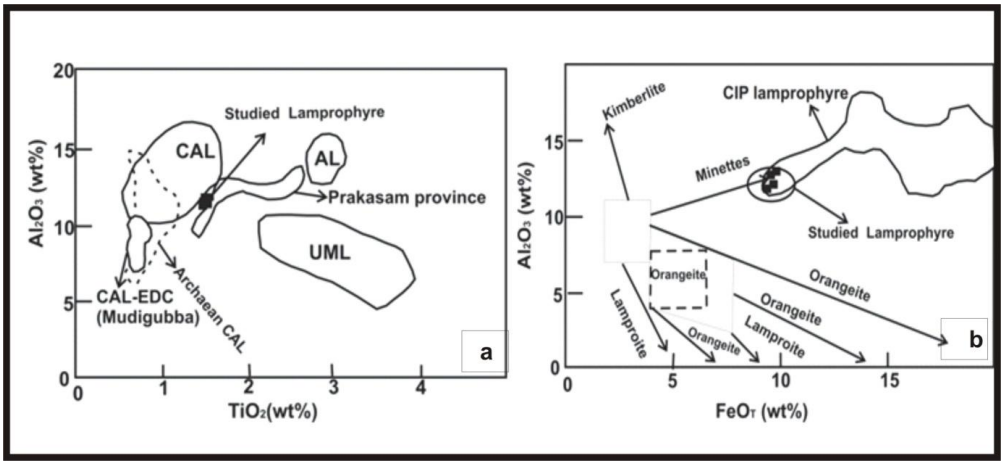


Fig: 9a. .Al_2O_3 vs. TiO_2 classification plots for the Polshettigudem lamprophyre. Fields for CAL (calc-alkaline lamprophyres), AL (alkaline lamprophyres), UML (ultramafic lamprophyres) and Archaean CAL from different cratons are taken from Lefebvre et al. (2005) and references there in. The field taken: Prakasam Province lamprophyres at eastern margin of the Cuddapah basin (Madhavan et al. 1998; Kumar and Rathna2008; Meshram et al. 2015); Eastern Dharwar Craton CAL- Mudigubba (Pandey et al.2017a; Pandey et al.2017b). Fig:9bFeO_T vs Al_2O_3 variation diagram of the Polshettigudem lamprophyre showing fractionation trends of minnett type(shoshonitic varity).

Conclusion:

The FeOT vs Al_2O_3 diagram (Mitchell 1995) shows that this Polshettigudem lamprophyre belongs to the minette group (Fig. 9b). The presence of spinel in the rock indicates the shoshonitic variety. The Al_2O_3 vs TiO_2 diagram shows that the present lamprophyre data plotted well within the calc-alkaline lamprophyre field (Fig. 9a). In this diagram a comparative study was carried out between the Polshettigudem lamprophyre and other CIP/PAP lamprophyres and Mudigubba lamprophyre. This comparison shows that the characteristics of this rock is slightly different from the Prakasam Province field (Madhavan et al. 1998; Kumar et al. 2008; and Meshram et al. 2015) as well as the Mudigubba field (Pandey et al. 2017a; Pandey et al. 2017b). These lamprophyres are quite similar to the Polayapalle lamprophyre of Khammam (Madhavan et al. 1998).

Based on the combined petrographic and geochemical study, it is clear that this lamprophyre belongs to the calc-alkaline group as a shoshonitic variety. This lamprophyre of the Polshettigudem area provides a good opportunity to study one such lamprophyre-granitoid relationships and the evolution of the ancient cratonic lithosphere. In this view, the new finding of calc-alkaline lamprophyre is very crucial for the regional geology and tectonic setting of the EDC.

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