CRIMSON PUBLISHERS
Wings to the Research

Archaeology & Anthropology: Open Access

ISSN: 2577-1949

Review Article

Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications

Akhtar R Mir[1]* and Shabber H Alvi[2]

[1]*Department of Geology, Lehcampus, University of Kashmir, India*

[2]*Department of Geology, Aligarh Muslim University, India*

***Corresponding author:** Akhtar R Mir, Department of Geology, Lehcampus, University of Kashmir, Srinagar, India

Submission: July 02, 2017; **Published:** October 15, 2018

Abstract

The Meso- to Neoarchaean Singhbhum Granitoid Complex (SGC), Eastern India has been intruded by NW-SE, NE-SW, N-S and E-W trending Newer dolerite dykes (NDD). A few ultramafic intrusives are spatially associated with NDD. In the studied samples olivine and orthopyroxene makes a major portion. Serpentine as alteration product of olivine is also present in these rocks. On the bases of petrography they are classified as harzburgites. These representative samples have high MgO (>30.0wt.%) and low SiO2 (<45.0wt.%), Al2O3 (<5.0wt.%) and alkalies (<1.0wt.%). On various variation diagrams studied samples follow up normal crystallization trends. Their geochemical characteristics such as SiO2, Na2O+K2O, CaO/Al2O3 (0.85) values and enriched light rare earth element (LREE) patterns suggests that they are picritic in nature rather than komatiitic or komatiites. On Primitive mantle normalized diagrams they show enriched patterns of large ion lithophile elements (LILEs) and LREEs and depletion of high field strength elements (HFSEs) (e.g., Nb,Ta,Zr,Ti). Such characteristics resemble to that of subduction related basaltic rocks. On chondrite-normalized REE diagram studied samples display least to moderate LREE fractionated patterns {(La/Sm)n=2.62-2.97} and almost unfractionated /flat HREE {(Gd/Lu)n=1.12-1.58} with negative Eu anomalies {Eu/Eu*=0.77-0.84}., indicates removal of plagioclase. On tectonic setting diagrams such as Zr/Y vs Ti/Y and Y vs Nb/Thstudied samples plot in plate margin (arc related) tectonic setting. The low values of (La/Yb)n<12.01 and (La/Sm)n<3.39 and high values of Ba/Nb (38 to119) and Sr/P (0.30 to 1.49) parameters in the studied dykes also indicate their arc setting relation.

Keywords: Singhbhumcraton; Petrogenesis; Subduction zone; Ultramafic dykes

Introduction

Precambrian mafic dykes occur in a wide variety of geological and tectonic settings [1,2] and their detailed study through space and time is imperative for understanding of several geological events including the identification of Large Igneous Provinces (LIP) and continental reconstructions. Dykes and dyke swarms, having different orientations, are conspicuous in all the Protocontinents of Indian Shield viz. Aravalli-Bundelkhand Protocontinent, Dharwar Protocontinent, Bastar-Bhandara Protocontinent, and Singhbhum Protocontinent (Srivastava et al., 2008). The genesis of each dyke swarm clearly constitutes a major thermal event affecting the Earth's mantle. Injection of mafic dyke swarms at intervals throughout the Proterozoic provides a window to monitor mantle evolution and changing magmatic style. The SinghbhumCraton in the eastern Indian Shield has a complex history of sedimentation, metamorphism and magmatism because of repeated extensional and compressional tectonics from Paleoarchean to Neoproterozoic [3]. SinghbhumCraton contains several types of granitoids, metasedimentary rocks including banded iron formations (BIF), and mafic volcanic and intrusive rocks. Mafic magmatism in SinghbhumCraton spreads from 3.3Ga old mafic enclaves in Older Metamorphic Group to about approximately 1.0Ga old Newer dolerite dykes (NDD) [4]. However, it is strange that global Neoarchean peak (Condie, 2004) of 2.7Ga is missing in this region [5].

Therefore, it provides a classic region for the study of the different stages of the Precambrian crust-mantle evolution. Proterozoic magmatism in the SinghbhumCraton is manifested mainly as mafic metavolcanic suites and dyke swarms. Several dykes of mafic to acidic compositions are intruding the SinghbhumGranitoid Complex, which are collectively referred to as the Newer Dolerites in the geological literature [6-9]. Some minor ultramafic intrusions are spatially associated with NDD [4-10]. As per available K/Ar age data [9] mafic members of NDD swarm had intruded SGC intermittently during 2200Ma to 950Ma. On the bases of K-Ar ages, Mallick & Sarkar [11] suggested three pulses of mafic intrusive activity, viz. 2100±100, 1500±100 and 1100±200Ma. Recently mafic dykes of Singhbhumcraton are reported as having 1765Ma age by using Pb-Pbbaddeleyite thermal extraction-thermal ionization mass spectrometer method [12]. Whereas, ultramafic members of NDD swarms are dated 2613±177Ma on the bases of Rb-Srisochron method [10]. Thus, the place of NDD swarm in the chronostratigraphy of the SinghbhumCraton is problematic. Since some workers have suggested that the ultramafic, mafic and felsic members of NDD swarms are genetically related representing cumulates, direct crystallization and partial melting products respectively [9]. However, Bose [4] have suggested more investigation related to possible genetic link between the mafic and ultramafic members of NDD swarm. In this regard a preliminary study has been carried out by Mir & Alvi [13], where they concluded that the geochemical characteristics of mafic and ultramafic dykes do not clearly indicate any genetic relationship. It is more likely that these two members of NDD swarms may have originated from different magmatic sources [13]. These findings have encouraged us to pay serious attention towards the nature, petrogenetic and tectonic implications of ultramafic dykes from Singhbhumcratonusing some published and unpublished major and trace element data. Thus this piece of work would add up the existing knowledge and research pertaining to mantle characteristics and evolution of Singhbhumcraton during Precambrian.

Geological Setting

The Eastern Indian Shield is bounded by Mahanadi Graben and Sukinda thrust in the west and in the south by granulite terrain of Eastern Ghats and recent coastal alluvium. In the north and east it is masked by vast Gangetic alluvium and Quaternary sediments of Bengal Basin. Three geological provinces have been recognized in the Eastern Indian Shield: Chotanagpur Granite Gneiss Complex (CGGC), Singhbhum Mobile Belt (SMB) and SinghbhumCraton(SC) (Figure 1A) [14]. CGCC covers an area of about 80,000km^2 (Latitudes 23°00′N to 25°00′N; Longitudes 83°45′E to 87°45′E) in parts of West Bengal and almost entire Jharkhand state, except the Singhbhum region. It is a composite mass consisting mainly of granite-gneisses, migmatites and massive granites with enclaves of para-and ortho-metamorphics, dolerite dykes and innumerable veins of pegmatite, aplite and quartz [15]. The formations occurring in between the SC and CGGC are now collectively recognized either as the SMB. The SC is a roughly triangular-shaped region, bounded by thearcuate Singhbhum Shear Zone in the north and the Sukinda thrust in the south and is surrounded by Tertiarysediments of the Bengal Basin in the east. A major part of the SC is occupied by the Singhbhum Granitoid Complex (SGC) of 3.2-2.8Ga [16]. The SGC comprises at least 12 separate magmatic bodies, emplaced during two major phases of magmatism [9]. The early phase of the Singhbhum Granite is dated as 3.25±0.05Ga [16]. Available ages for the later phase of the Singhbhum Granite are 3.06Ga (Pb/Pb whole rock) and 2.9Ga (Rb/Sr whole rock) compiled by Saha [9]. Older Metamorphic Group (OMG), 3.3Ga old, forms the oldest recognized unit in this craton. Three major banded iron formation belts which surround the SGC are Gorumahisani-Badamphar in the east, Tomka-Daiteri in the south and southwest and Noamundi-Koira in the west.

The Bonaimetavolcanic rocks consist of variable amounts of mafic lavas and tuffs with minor silicic volcaniclasticinterbeds. A remarkably fresh or least metamorphosed rectangular volcanic outcrop "Jagannathpur Suite" is well exposed (Latitudes 22°00′ and 22°15′N: Longitudes 85°30′ and 85°45′E) around Noamundi, extending up to Jagannathpur. These rocks are younger than Noamundi-Koira sequence of BIF. Simlipal complex is a large circular outcrop pattern containing alternate bands of mafic volcanic rocks and ortho-quartzites, overlies the granitoid basement of Archaean age. The Ongarbirametvolcanic suite, lie on western margin of the SSZ, has a general ENE-WSW trend Blackburn & Srivastava [17] pointed out their MORB affinity and suggested their generation in an extensional environment. However, Raza et al. [18] suggested these volcanic rocks as typical arc-tholeiites. The Dhanjorimetavolcanic suite, lie on eastern margin of the SSZ, containing a variety of rocks including ultramafic to mafic and rarely acid lava flows, tuff and agglomerate is inter layered with ortho-quartzite and phyllite, underlain by quartzite conglomerate and forms a group named Dhanjori Group. On the western margin of the SGC, Kolhan Group is preserved in linear belt extending for 80 to 100Km with an average width of 10 to 12Km.

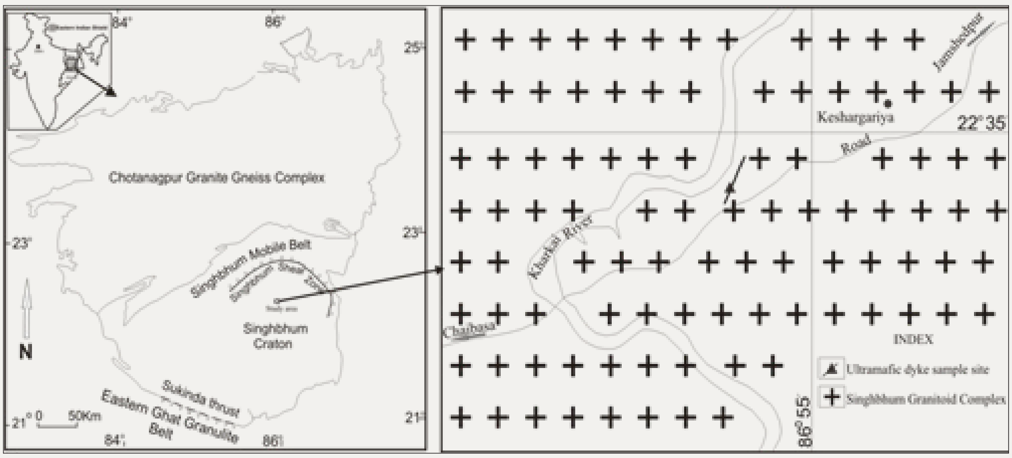

Figure 1A: Map of Easter Indian Shield [14].
Figure 1B: Simplified geological map of Singhbhum Granitoid Complex around Keshargariya, showing ultramafic dyke sample site [13].

How to cite this article: Akhtar R M, Shabber H Al. Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications. Arch & Anthropol Open Acc .3(Suppl - 3). AAOA.000562. 2018. DOI: 10.31031/AAOA.2018.03.000562

A dyke swarm, known as Newer Dolerite traverses within the SinghbhumGranitoid Complex. The dominant trend of the dykes within the SinghbhumGranitoids is NNE-SSW to NE-SW; subsidiary trends are NW-SE and E-W. The dyke swarms, intruding into the SinghbhumGranitoid Complex, form several discontinuous ridges and are few meters to over 20km in length and is up to a km wide. The dyke incidence is estimated to be 1-4per km^2. The most common rock type is quartz dolerite with numerous occurrences of norite. Rarely granophyre, microgranite, syenodiorite are associated with the dolerites. A few ultramafic intrusions are also present. Keshargaria dyke, which is dealt in this present paper, is one of the significant ultramafic intrusion of the region (Figure 1B). Samples were collected from this dyke from central portions at different distances.

Brief Petrography and Analytical Techniques

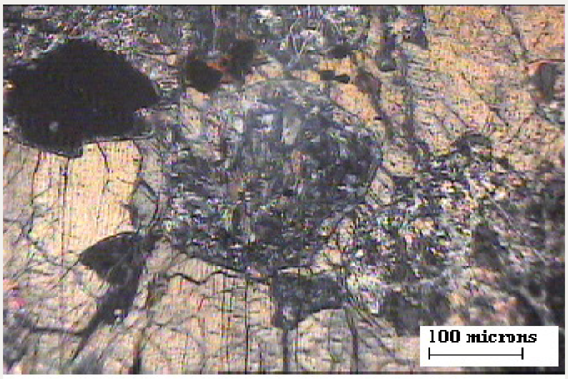

Figure 2A: Microphotograph showing olivine and orthopyroxene in studied samples (crossed nicols x 10).

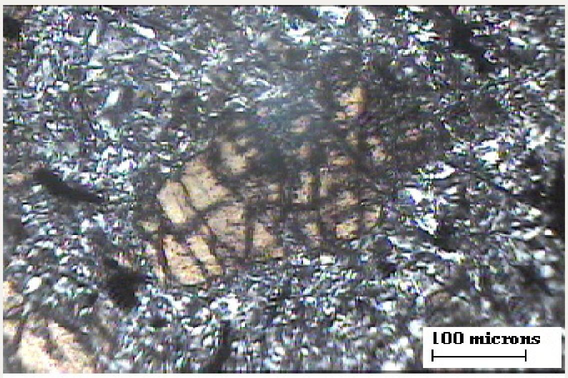

Figure 2B: Microphotograph showing serpentine and orthopyroxene in studied samples (crossed nicols x 10).

Present medium grained ultramafic dykes show NE-SW trend direction. They are mostly composed of olivine and orthopyroxene (Figure 2A). Though, in some cases most of the olivine grains are converted into serpentine (Figure 2B). They show poikilitic texture and are devoid of spinifex texture which may indicate that they are not komatiitic in nature. On the bases of petrography they are classified as harzburgites. After petrography fresh samples were selected for geochemical analysis. Selected samples were crushed to -30 mesh grains. These grains were powdered to -200 mesh size using an agate Tima mill. Major and trace element geochemical analysis of selected samples was done at National Geophysical Research Institute, Hyderabad. Whole rock major elemental analyses were carried out by X-ray fluorescence (Philips Magi X PRO model PW 2540 sequential X-ray spectrometer) techniques. Trace elements including rare earth elements (REE) were determined by inductively coupled plasma–mass spectrometry techniques using Perkin Elmer, Sciex ELAN DRC-II system. The precision of ICP-MS data is <5% RSD for all the trace elements [19].

Geochemistry

Elemental mobility

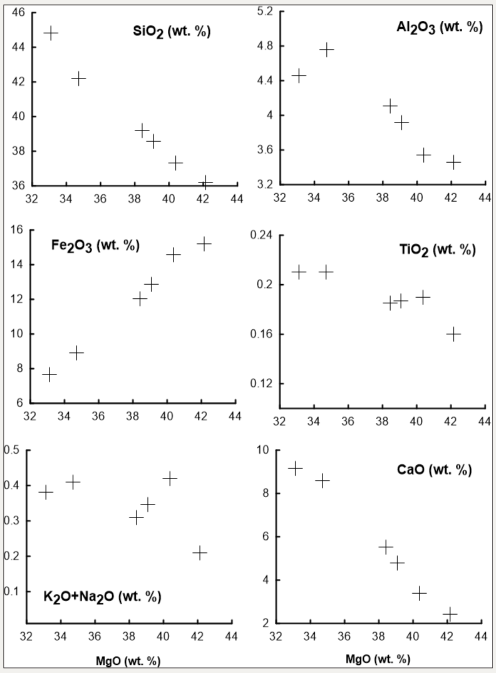

Figure 3: MgO vs. major element oxide plots of ultra-mafic dykes of Singhbhum craton, Eastern India.

Before the interpretation of representative geochemical data of the studied samples we found it necessary to identify the effect of post-igneous alteration processes on the rock chemistry. Binary variation diagrams between MgO and other major oxides (Figure 3) show normal crystallization trends without any scattering of data. Such trends do not favor mobilization of these elements and suggests that these oxides reflect magmatic features. Further, interelemental ratio like Al_2O_3/TiO_2 in studied samples (Table 1) is around chondrite value (=20) such values suggest that these elements were not significantly affected by alterations [20]. During low-grade metamorphism, Zr is considered as a relatively immobile element; hence, plots such as Zr vs Rb, Ba, Nb and Nd are drawn to evaluate the elemental mobility. The positive relationship of these plots (Figure 4) indicates that the trace elements are least disturbed by post-crystallization processes and may represent primary characteristics. Rb/Sr ratio is mostly used to see alteration effects on LILEs, thus, the observed low values of Rb/Sr ratio (0.18 to 0.31) in studied samples implies no effect of post igneous processes on the

How to cite this article: Akhtar R M, Shabber H Al. Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications. Arch & Anthropol Open Acc .3(Suppl - 3). AAOA.000562. 2018. DOI: 10.31031/AAOA.2018.03.000562

primary concentrations of LILE [8]. The light REE are considered to be mobile [21], however, the regularity of REE patterns in the studied samples suggests that the REE were not notably disturbed during alteration, deformation and metamorphism. It is generally agreed that transition metals (e.g. Cr and Ni), HFSEs as well as Th and Ti are relatively immobile during low-temperature alteration. Therefore, in the present study, trace and rare earth elements are used for important petrogenetic interpretations.

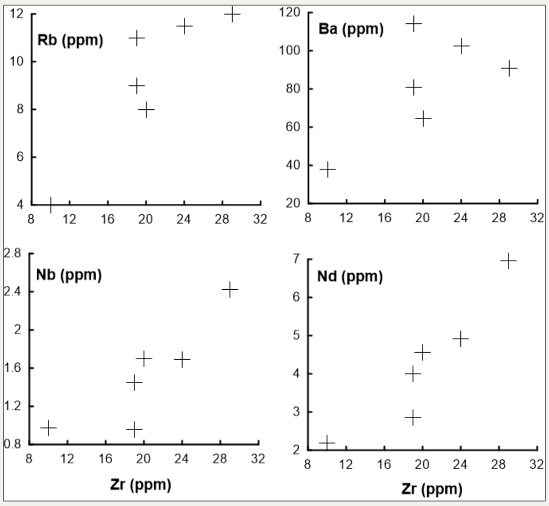

Figure 4: Zr vs. Rb, Nb and Nd plots of ultra-mafic dykes of Singhbhum craton, Eastern India.

Geochemical Characteristics

Geochemical data of representative samples is given in Table 1. These samples show high MgO and low SiO_2, Al_2O_3, TiO_2 and alkalies (Table 1). CaO shows large variation from 2.43 to 8.92wt.% which indicates fractionation of plagioclase. SiO_2 and Na_2O+K_2O values indicate their subalkaline nature. Subalkaline affinity is also supported by their Nb/Y ratio less than 0.7. In Figure 3, studied dykes show negative trend of MgO against SiO_2, Al_2O_3,CaOand TiO_2 and positive relation with Fe_2O_3. Alkalies do not show any clear relation. During plagioclase removal, CaO/Al_2O_3 ratio increases whereas it remains constant during olivine fractionation. Therefore, the high CaO/Al_2O_3 ratio (greater than 0.9) in the studied samples indicates that they may have undergone plagioclase fractionation.

Primitive mantle [22] normalized Multi-Element (ME) diagram (Figure 5A) and chondrite normalized Rare-Earth Element (REE) [23] diagrams (Figure 5B) are drawn for further evaluation of geochemical characteristics of the studied dykes. Most distinguishable feature noted on ME patterns (Figure 5A) is that studied samples show slight depletion of Rb, Ba and Sr; prominent negative anomalies of Nb, P, Ti and shallow Zr negative anomalies and well defined positive Pb anomaly. In (Figure 5B) studied samples display least to moderate LREE fractionated patterns {(La/Sm)n=2.62-2.97} and almost unfractionated/flat HREE {(Gd/Lu) n=1.12–1.58} with negative Eu anomalies {Eu/Eu*=0.77-0.84}.

Table 1: Major element (in wt.%) and trace element (including Rare earth elements) (in ppm) data of ultramafic dykes from Chaibasa district, Singhbhumcraton, Eastern India.

Sample No.	UM 1	UM 2	UM 3	UD1**	UD2**	UD3**
SiO_2	44.82	39.21	38.57	37.3	42.21	36.21
TiO_2	0.21	0.19	0.19	0.19	0.21	0.16
Al_2O_3	4.46	4.11	3.92	3.54	4.76	3.46
Fe_2O_3	7.67	12.04	12.88	14.56	8.89	15.19
MgO	33.11	38.44	39.09	40.39	34.72	42.15
CaO	9.17	5.51	4.8	3.38	8.59	2.43
Na_2O	0.25	0.2	0.2	0.21	0.25	0.15
K_2O	0.13	0.11	0.14	0.21	0.16	0.06
MnO	0.18	0.19	0.2	0.21	0.19	0.19
P_2O_5	0.01	0.01	0.01	0.01	0.01	0.01
Total	100	100	100	100	100	100
Ni	221	227	179	208	150	304
Cr	1596	1509	2115	1772	2458	559
Co	91	89	86	97	75	102
V	57	58	71	56	86	30
Sc	15	16	18	14	22	9
Pb	7	7	8	8	9	5
Zn	100	60	131	180	81	39
Cu	27	25	33	30	35	15
Ga	3	4	4	3	5	2

How to cite this article: Akhtar R M, Shabber H Al. Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications. Arch & Anthropol Open Acc .3(Suppl - 3). AAOA.000562. 2018. DOI: 10.31031/AAOA.2018.03.000562

Rb	9	8	12	11	12	4
Sr	45	39	62	58	65	13
Ba	81	65	103	114	91	38
Zr	19	20	24	19	29	10
Nb	1.45	1.7	1.69	0.96	2.42	0.97
Ta	0.09	0.11	0.11	0.06	0.15	0.06
Y	6.33	7	7.5	5	10	4
U	0.08	0.1	0.09	0.06	0.12	0.07
Th	0.84	0.98	1.06	0.58	1.53	0.42
Hf	0.5	0.5	0.62	0.49	0.74	0.26
Cs	1.17	0.91	1.56	1.69	1.42	0.4
La	3.84	4.4	4.74	2.73	6.75	2.04
Ce	8.34	9.58	10.34	5.87	14.8	4.36
Pr	0.83	0.95	1.02	0.59	1.45	0.44
Nd	4	4.57	4.91	2.86	6.95	2.19
Sm	0.84	0.96	1.02	0.6	1.43	0.49
Eu	0.24	0.27	0.29	0.18	0.4	0.14
Gd	1.04	1.2	1.25	0.72	1.78	0.61
Tb	0.17	0.2	0.21	0.13	0.29	0.1
Dy	0.95	1.07	1.14	0.71	1.56	0.58
Ho	0.2	0.23	0.24	0.15	0.33	0.13
Er	0.67	0.75	0.8	0.53	1.07	0.42
Tm	0.11	0.13	0.14	0.09	0.18	0.07
Yb	0.63	0.69	0.75	0.52	0.97	0.41
Lu	0.09	0.1	0.11	0.08	0.14	0.06
Ratios						
CaO/Al_2O_3	2.06	1.34	1.22	0.95	1.8	0.7
Al_2O/TiO_2	21	22	21	19	23	22
Rb/Sr	0.2	0.21	0.19	0.19	0.18	0.31
Nb/ La	0.38	0.39	0.36	0.35	0.36	0.48
Nb/Ce	0.17	0.18	0.16	0.16	0.16	0.22
Ba/Nb	55.86	38.05	60.65	118.75	37.6	39.18
Sr/P	1.79	1.65	1.67	1.97	1.4	2.92
(La/Yb)n	4.1	4.3	4.3	3.55	4.7	3.36
(La/Sm)n	2.88	2.88	2.94	2.86	2.97	2.62
(Gd/Lu)n	1.38	1.49	1.41	1.12	1.58	1.27
Eu/Eu*	0.79	0.77	0.79	0.84	0.77	0.78

** published data from Mir & Alvi [13]

How to cite this article: Akhtar R M, Shabber H Al. Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications. Arch & Anthropol Open Acc .3(Suppl - 3). AAOA.000562. 2018. DOI: 10.31031/AAOA.2018.03.000562

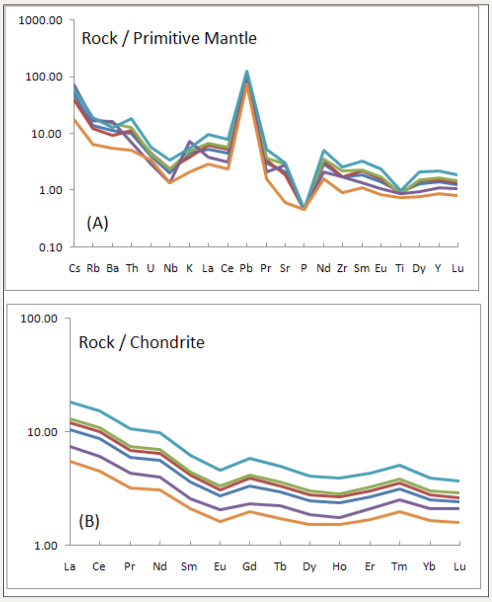

Figure 5A: Primitive mantle (Sun and McDonough, 1983) normalized multi-element diagram.
Figure 5B: Chondrite normalized rare-earth element (REE) [23] diagram for ultra-mafic dykes of Singhbhum craton, Eastern India.

Petrogenesis

Crustal contamination

Fractional crystallization associated with crustal contamination is an important process during magmatic evolution and may modify both elemental and isotopic compositions [24]. Crustal materials are rich in K_2O, Na_2O and LILEs, however, low concentrations of K_2O, Na_2O, Th, and Th/Yb ratio of studied dykes supports that no crustal contamination has occurred in these rocks (Table 1). In the present study, samples with lower MgO contents have higher Ni contents such a character is not possible by crustal contamination. The low values of Nb/La (<0.5) and Nb/Ce (<0.23) of the studied samples are lower than that of primitive mantle (1.04 and 0.40, respectively, Sun and McDonough, 1989), average bulk crust (0.69 and 0.33, respectively) and average lower crust (0.83 and 0.39, respectively, Taylor and McLennan, 1985). Such lower values are not likely to be produced by processes of contamination by an average crustal component. Thus, these trace element characteristics may have been obtained due to LREEs–LILEs-enriched source characteristics with depletion of HFSEs.

Source composition

The Archean and Proterozoic mafic and ultramafic rocks generally show tholeiitic and komatiitic characteristics. Their behavior can be discriminated based on field, textural and chemical characteristics [25]. If textural criteria may not be possible then geochemical characteristics are used for discrimination e.g. REE pattern, values of CaO/Al_2O_3. Studied samples have LREE enriched pattern (Figure 5B) distinct from the majority of the world-wide komatiites which show LREE depletion and their CaO/Al_2O_3 values are greater than 0.85. Thus, these geochemical characteristics in addition to absence of spinifex texture may designate these rocks are notkomatiiticorkomattites.

Tectonic setting

Geochemistry of mafic-ultramafic rocks is normally used to discriminate tectonic settings; this is mainly because basaltic rocks are formed in almost every tectonic environment, and they are believed to be geochemically sensitive to the changes in plate tectonic framework. Various diagrams by many researchers have been given to understand tectonic settings of mafic –ultramafic rocks such as Ti/1,000 vs V diagram by Shervais [26], Zr vs Zr/Y by Pearce & Norry [27], Zr/Y vs Ti/Y by Pearce & Gale [28] etc. In (Figure 6A) studied samples plot in plate margin basalt field and in (Figure 6B) they plot in arc field. Arc related tectonic setting of studied samples is also discriminated by Zr vs Zr/Y and Ti/1,000 vs V plots (Diagrams not shown here). The low values of $(La/Yb)_n<12.01$ and $(La/Sm)_n<3.39$ and high values of Ba/Nb (38 to 119) and Sr/P (0.30 to 1.49) parameters in the studied dykes also indicate the arc setting relation [8,29,30]. Above all, their enriched patterns of LILEs and LREEs and depletion of HFSEs (e.g., Nb, Ta, Zr, Ti) of under study rocks resembles to that of subduction related basaltic rocks [10,26].

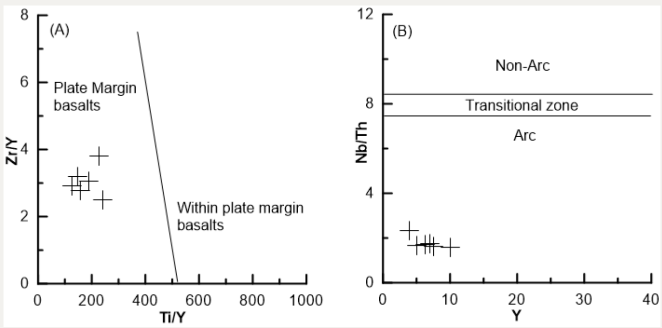

Figure 6A: Zr/Y vs Ti/Y [28].
Figure 6B: Nb/Thvs Y tectonic setting diagrams for ultra-mafic dykes of Singhbhumcraton, Eastern India.

Conclusion

On the bases of petrography and geochemical characteristics studied ultramafic samples are classified as harzburgites and are not komatiiticor komatiitesin nature. They follow plagioclase fractional crystallization trends on various Harker variation type diagrams and show least/ no crustal contamination. On tectonic setting discrimination diagrams it is concluded that present samples show arc related tectonic setting characteristics. Their enriched patterns of LILEs and LREEs and depletion of HFSEs resembles to that of subduction related basaltic rocks. Their source is thought to have been variably enriched in incompatible elements by the addition of melts or fluids or even both.

Acknowledgement

We are thankful to Director NGRI, Hyderabad for grant of permission to analyze these samples. We pay our sincere thanks to Dr. V. Balaram, NGRI, Hyderabad for his valuable suggestions and support. First author is thankful to Dr. K.S.C. Subramanyum, NGRI, Hyderabad and Dr. A. K. Krishna, NGRI, Hyderabad for their sincere support and cooperation during analysis.

References

1. Hall RP, Hughes DJ (1990) Precambrian mafic dykes of southern Greenland. In: Parker AJ, Rickwood DH, Tucker DH (Eds.), Mafic dykes and emplacement mechanisms, Balkema, Rotterdam, Netherlands, pp. 481-495.
2. Subba Rao DV, Khan MWY, Sridhar DN, Naga Raju K (2007) A New find of within basin younger dolerite dykes with Continental Flood Basalt affinity from the Meso- Neoproterozoic Chattisgarh Basin, Bastar Craton, Central India. Journal of the Geological Society of India 69(1): 80-84.
3. Majumdar R, Bose PK, Sarkar S (2000) A commentary on the tectono-sedimentary record of the pre-2.0Ga continental growth of India vis-à-vis a possible pre-Gondwana Afro-Indian supercontinent. Journal of African Earth Sciences 30(2): 201-217.
4. Bose MK (2009) Precambrian mafic magmatism in the SinghbhumCraton, Eastern India. Journal of the Geological Society of India 73(1): 13-35.
5. Naqvi SM (2005) Geology and evolution of the Indian plate. Capital Publishing Company, New Delhi, India, pp. 450.
6. Dunn JA (1940) The Stratigraphy of South Singhbhum. Memoir Geological Survey of India 63(3): 303-369.
7. Mir AR, Alvi SH, Balaram V (2010) Geochemistry of mafic dikes in the Singhbhum Orissa craton: implications for subduction-related metasomatism of the mantle beneath the eastern Indian craton. International Geology Review 52(1): 79-94.
8. Mir AR, Alvi SH, Balaram V (2011) Geochemistry, petrogenesis and tectonic significance of the Newer Dolerites from the Singhbhum Orissa craton, eastern Indian shield. International Geology Review 53(1): 46-60.
9. Saha AK (1994) Crustal evolution of Singhbhum-North Orissa, Eastern India. Memoir Geological Survey of India 27: 305.
10. Roy A, Sarkar A, Jeyakumar S, Aggrawal SK, Ebihara M, et al. (2004) Late Archaean mantle metasomatism below eastern Indian craton: evidence from trace elements, REE geochemistry and Sr-Nd-O isotope systematics of ultramafic dykes. Earth planetary science 113(4): 649-665.
11. Mallik AK, Sarkar A (1994) Geochronology and geochemistry of mafic dykes from the Precambrians of Keonjhar, Orissa. Indian Minerals 48: 13-24.
12. Ravi S, Vijayagopal B, Kumar A (2014) Precise Pb-Pbbaddeleyite ages of 1765Ma for a Singhbhum 'newer dolerite' dyke swarm. Current Science 106(9): 1306-1310.
13. Mir AR, Alvi SH (2015) Mafic and ultramafic dykes of Singhbhumcraton from Chaibasa, Jharkhand, Eastern India: geochemical constraints for their magma sources. Current Science 109(8): 1399-1403.
14. Sarkar AN (1982) Precambrian tectonic evolution of eastern India: A model of converging microplates. Tectonophysics 86(4): 363-397.
15. Naqvi SM, Rogers JJW (1987) Precambrian geology of India, Oxford University Press, Oxford, USA, pp. 233.
16. Moorbath S, Taylor PN, Jones NW (1986) Dating the oldest terrestrial rocks - facts and fiction. Chemical Geology 57(1-2): 63-86.
17. Blackburn WH, DC (1994) Geochemistry and tectonic significance of the Ongarbirametavolcanic rocks, Singhbhum district, India. Precambrian Research 67(3-4): 235-248.
18. Raza M, Alvi SH, Abu Hamatteh ZSH (1995) Geochemistry and tectonic significance of Ongarbiravolcanics, Singhbhumcraton, Eastern India. Journal of the Geological Society of India 45: 643-652.
19. Balaram V, Gnaneshwara Rao T (2003) Rapid determination of REEs and other trace elements in geological samples by microwave acid digestion and ICP-MS. Atomic Spectroscopy 24: 206-212.
20. Sun SS, Nesbitt RW (1978) Geochemical regularities and genetic significance ophiolitic basalts. Geology 6: 689-693.
21. Ludden JN, Thompson G (1979) An evaluation of the behaviour of the rare earth elements during the weathering of sea-floor basalt. Earth Planetary Science Letters 43(1): 85-92.
22. Sun SS, McDonough WF (1989) Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders AD, Norry MJ (Eds.), Magmatism in the ocean basins. Special Publication of Geological Society of London 42: 313-345.
23. Taylor SR, McLennan SM (1985) The continental crust: its composition and evolution. Blackwell, Oxford, USA.
24. De Paolo DJ (1981) Trace element and isotopic effects of combined wall rock assimilation and fractional crystallization. Earth and Planetary Science Letters 53(2): 189-202.
25. Arndt NT, Nisbet EG (1982) What is komatiite? In: Arndt NT, Nisbet EG (Eds.), Komatiites. Allen and Unwin, London, pp.9-27.
26. Shervais JW (1982) Ti-V plots and the petrogenesis of modern and ophiolitic lavas. Earth & Planetary Science Letters 59(1): 101-118.
27. Pearce JA, Norry MJ (1979) Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks. Contribution to Mineralogy & Petrology 69(1): 33-47.
28. Pearce JA, Gale GH (1977) Identification of ore deposition environment from the trace element geochemistry of associated igneous host rocks. In: Volcanic Processes in Ore Genesis. Geological Society of London 7: 14-24.
29. Verma SP (2006) Extension-related origin of magmas from a garnet-bearing source in the Los Tuxtlas volcanic field, Mexico. International Journal of Earth Science 95: 871-901.
30. Kepezhinskas P, McDermott F, Defant M, Hochstaedter A, Drummond MS, et al. (1997) Trace element and Sr-Nd-Pb isotopic constraints on a three-component model of Kamchatka Arc petrogenesis. Geochimicaet Cosmochimica Acta 61(3): 577-600.

How to cite this article: Akhtar R M, Shabber H Al. Geochemistry of Ultramafic Dykes from Chaibasa District, Singhbhumcraton, Eastern India: Petrogenetic and Tectonic Implications. Arch & Anthropol Open Acc .3(Suppl - 3). AAOA.000562. 2018. DOI: 10.31031/AAOA.2018.03.000562