International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org *Volume: 3 Issue: 12 | December 2017*

Carbonatite-lava extrusions along ring-fractures south of Sivamalai Alkaline Complex, Tamil, Nadu, India

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Abstract: *A dark-grey, fine-grained, low dense and vesicular carbonatite lava adjacent to Sivamalai alkaline complex is reported. The lava occurs along ring fractures. The SiO_2 content varies from 1.59 to 4630%. Al_2O_3 varies from 0.98 to 14.30. BaO reaches up to 40.40% at some sites. Most cases K_2O exceeds over Na_2O. Rittmann's norm indicates that excessive CO_2 reacted with alumina and silica and produced their carbonates. Significant amount of apatite and fluorite are present. Rarely, larnite, sillimanite and corundum are present indicating extreme de-gassing of volatiles (H_2O CO_2, and SO_3) during pre-eruptive state. Calcite is the essential mineral. The rock is Fe and Ti poor, Mg is relatively enriched over FeO but maximum dolomite content reaches only up to 29%. Barite, witherite, alkali carbonates and salts of alkali aluminates are present in this lava apart from fluorites, alkali-chlorites and alkali carbonates. Scattered occurrences of gypsum in the western parts of investigated were reported. Semi-precious stones of moonstone, sunstone, emerald, aquamarine, amethyst and transparent euhedral quartz are mineralized in fluidized pink granite associated with carbonatite-lava. There appears to be genetic links between carbonatitic lava, miaskitic alkaline complex of Sivamalai and basaltic extrusion in the year 1996 irrespective of space and time. The age of Sivamalai carbonatite-lava is not yet studied. However bi-model carbonatite volcanism along coastal tracts of Tamil Nadu ranges between Mio-Pliocene to Pleistocene. It is presumed that carbonatite volcanism might have been took place in Tamil Nadu during the late stages of Deccan Trap volcanism in Tamil Nadu during NE movement of Indian Plate towards Himalaya.*

Keywords: *Sivamalai alkaline complex, Carbonatite-lava, Barite, Larnite, Apatite, Degassing of volatiles.*

1. INTRODUCTION

Sivamalai alkaline complex, Tamil Nadu is famous for zonal arrangement of silica under-saturated differentiated igneous rocks [1, 2]. Subsequently, several petrologists [3-8] investigated the alkaline complex and published a number of papers. The notable differentiated syenite units are ferrosyenite, nepheline syenite, leucosyenite, zircon syenite and corundum syenite. They are all belonging to miaskitic syenites with molar enrichment of Al over Na+K [9]. The excessive alumina in silica undersaturated rocks leads to form corundum in differentiated alkaline series [1]. The association of miaskitic syenites with carbonatite lava reveals their mantle origin with distinct tectonic settings [10-13].

2. FIELD STUDY

During examination of a basaltic extrusion in 1996 the author investigated the area. Two rings of separate discontinuous fluidized pink-granite bands carrying carbonatite-lava, pisolites, agglomerates and breccias are identified in inner Vattamalai and outer Sivamalai ring fractures (Fig. 1) located just south of Sivamalai alkaline complex. The fluidized pink granite is mineralized with semi-precious stones and carbonatite lavas. The mineralized semi-precious stones include moonstone (K-Na feldspar), spangled reddish (albite) topaz, euhedral amethyst, emerald and aquamarine beryl. The fluidization of pink granite appears to be formed by emplacement and metasomatism of carbonatite lava into the granite. Feebly foliated pink-granite is found as remnants just west of Udiyur village. Sivamalai alkaline complex is elliptical in shape and slightly foliated in ENE-WSW direction. Geological setting and close field association indicates that they have genetic relationship with each others. The charnockite present in this area is highly migmatized with multiple injections of grey coloured granitic juices since Precambrian Period and it is highly foliated. The ring fractures and other lineaments present in the area indicate that the magmatic rocks belong to mantle source. Pisolites (>1 - >5 cm) bearing carbonatite-lava is composed of rounded or elliptical fragments surrounded by carbonate matrix. In places accretionary-tuffs showing concretionary aggregates of pisolites or lapillus are seen. Carbonatite-breccias are composed of broken angular fragments similar sized carbonatite lava materials orienting in different directions. Reddish-brown rims are surrounded around these fragments. Lenticular bodies of clast supported agglomerates are seen. They exhibit laminations and subjected to extreme weathering to kankar. A regional study of the area shows that at many places NE of Vattamalai, kankar floats are strewn. In fact it is very difficult to distinguish carbonatite-lava from kankar. In the field, by breaking and examining the broken surface finding out its fresh dark grey, fine-grained nature, presence of vesicular feature, lightness, and conchoidal fracture carbonatite-lava are identified after laboratory studies. However, origin of kankar of 2 to 3 m thick over granite gneiss in this area still remains as problem.

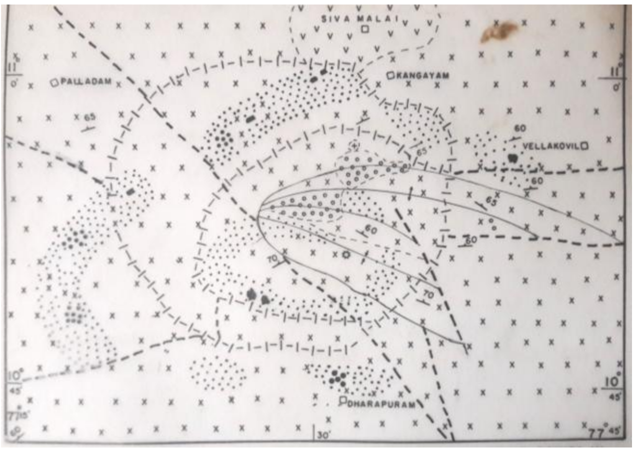

Fig 1: *Simplified Geological map of Sivanmalai Alkaline Complex including ring-fractures of carbonatite lavas. 1* * *Basalt extrusion in 1996, 2* x *Carbonatite lava, 3* · *Pisolites of carbonatite lava 4* /---- *Carbonatite breccias 5* v *Sivanmalai Alkali syenite Complex, 6* o *Pink-granite, 7* x *Charnockite, 8* + *Fluidized pink-granite rocks 9* –I-I-I- *Carbonatite lava ring-dykes 10* -- *Lineaments*

3. PETROGRAPHY AND GEOCHEMISTRY

Thin section of carbonatite lava was examined under polarizing microscope exhibits euhedral calcite crystal and the grains were so fine-grained no valuable information collected. Under high resolution scanning electron microscope attached with EDAS analyzer, the size and shape of mineral grains were studied. Inter-penetrating calcite crystals of 30x5μm 20x4μm abundantly in fine-grained carbonate matrix showing ophitic texture are seen. Gas cavities range around 10x10μm and rarely 25x10μm are seen. This feature indicates that rapid growth of mineral grains from the lava. Globular crystal of 8 μm dimension is also found. Coalesced pits of 3- 2μm are seen on the surface of a linear calcite crystal surrounded with numerous gas-cavities ranging from 1 to 3 μm are seen. This may be due skeletal growth of calcite crystal. Most grains are interpenetrated and euhedral slender prisms with length and breadth ratio exceeding over 4. Calcite plate-lets are very flat and they are less than 2 μm thick. Some calcite plates exceeding over 50 μm lengths steeply dip perpendicular their lengths or foliation directions forming thread-like feature under lower magnification. This feature indicates that carbonatite-lava has magmatic flow-bandings during its emplacement. It has sub-parallel stratification.

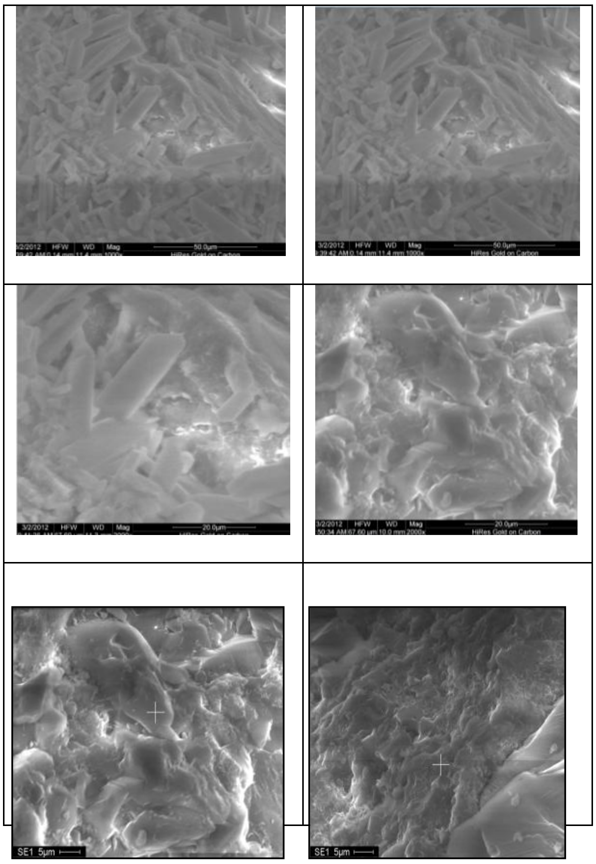

Fig 2: *High-resolution scanning electron images of carbonatite- lava from Sivamalai alkaline complex.*

The silica content of carbonatite lava ranges between 1.59 and 46.30% and alumina varies from 0.83 to 13.31%. The high CaO accompany with high content of CO_2 with low values of SiO_2 and Al_2O_3%. This is characteristic feature on nil-silicate carbonatites. MgO level is higher than total FeO. TiO_2 is very low. P_2O_5 is significantly high. Alkali carbonates $(NaK)_2CO_3$ present up to 14.94%. Aluminum carbonates (<27.72%), silicon carbonates (<19.23%) and aluminum salts of NaK and Ba are present indicating alkaline affinity of the carbonatite-lava similar to the eruption of Oldoinyo L'engai East Africa [13]. The analysis 2 represents Sr bearing barite.

ISSN 2455-4863 (Online) www.ijisset.org *Volume: 3 Issue: 12 | December 2017*

Table 1: *EDAX Chemical compositions of carbonatite-lava sample. Trace elements were determined at magnified levels of 2 to 3 orders.*

SiO2	20.64	9.13	1.74	1.72	1.59	4.36	43.11	34.38	4.07	9.01	16.71	9.43	5.45
Al2O3	10.31	4.16	0.83	0.95	1.01	1.50	13.31	11.14	1.71	4.10	6.21	3.56	1.90
FeO	0.58	0.16	0.24	0.24	0.20	0.28	0.25	0.55	0.80	0.78	6.27	1.00	0.66
MgO	1.37	0.00	1.14	1.44	1.34	0.33	0.45	0.74	0.95	2.83	2.58	1.59	1.37
CaO	5.09	4.53	48.97	41.76	37.94	44.95	10.20	9.12	37.26	35.80	43.16	21.32	19.10
Na2O	2.63	0.72	0.19	0.20	0.42	0.00	0.78	1.07	0.29	0.70	0.00	0.80	1.16
K2O	0.57	0.17	0.53	0.51	0.51	0.55	7.81	6.19	0.48	0.47	1.69	0.58	0.48
TiO2	0.19	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
P2O5	1.39	0.78	1.27	0.86	1.04	0.57	0.30	0.43	0.55	0.85	0.23	0.87	0.99
F	1.52	0.00	0.00	0.42	0.45	0.00	0.00	0.54	0.58	1.46	0.00	1.18	1.55
Cl	0.25	0.00	0.27	0.17	0.20	0.11	0.09	0.05	0.07	0.08	0.00	0.23	0.23
SO3	14.49	28.36	1.04	0.66	0.80	0.18	0.28	0.20	0.44	0.38	0.20	12.39	13.86
CO2	13.69	0.00	41.84	49.48	52.62	46.42	22.02	33.96	52.11	42.82	20.81	25.16	26.96
BaO	25.38	48.84	1.06	1.11	1.05	0.00	0.69	1.02	0.00	0.00	0.82	19.12	22.33
SrO	1.90	3.00	0.86	0.49	0.84	0.75	0.72	0.63	0.70	0.72	1.33	2.74	3.94
	100	100	100	100	100	100	100	100	100	100	100	100	100
Sc	0.37	0.24	0.25	0.43	0.13	0	0.14	0	0.06	0	0	0.21	0.2
Cr	0	0	0.07	0.17	0.04	0	0.09	0	0	0	0	0.19	0.1
Co	0.09	0	0.12	0.28	0.22	0.15	0.15	0	0	0	0.16	0.12	0.1
Ni	0.1	0	0.2	0.2	0	0.16	0.18	0.04	0.05	0	0	0.11	0.14
Cu	0.03	0.16	0.09	0.34	0.04	0.15	0.15	0.11	0	0	0	0.13	0.13
Zn	0	0	0.24	0.13	0.11	0.1	0.19	0.11	0.05	0	0.15	0.29	0.14
Y	0.87	2.03	0.61	0.37	1.17	0.92	0.74	0.61	1.16	0.56	1.02	0.72	1.29
Pb	0	0	0.34	1.62	0.67	1.53	1.16	0.52	0.56	0	0	0.95	0.95
La	0.77	0.68	0.27	0.56	0.25	0	0.25	0	0	0	0	0.3	0.47
Nd	1.92	1.61	0.31	0.49	0.28	0	0.25	0	0	0	0	0.41	0.27
Eu	0	0	0.31	0.52	0.38	0	0.4	0.07	0	0.15	1.62	1.08	0.74
Dy	0.31	0	0.17	0.61	0	0	0.21	0.26	0	0	0	0	0
Lu	0.08	0.22	0.22	0.87	0.22	0.39	0.17	0.11	0	0	0.2	0.43	0.28
Hf	0.1	0	0.21	0.94	0.4	0	0.28	0.33	0	0	0.34	0.34	0.18
Zr	1.14	2.76	1.36	0	1.29	1.03	1.16	0.66	0.86	1.06	0.68	1.74	2.66
Ta	0	0	0.33	0.69	0.39	0.15	0.52	0.14	0	0	0.44	0.47	0.43
Nb	1.04	3.3	0.57	0.61	1.24	1.08	1.17	1	0.36	1.13	3.19	1.53	3.38
Yb	0	0	0	0.74	0.69	0.18	0	0	0.19	0	1.24	0.54	0.32
	1	2	3	4	5	6	7	8	9	10	11	12	13
ap	3.40	2.74	2.46	2.46	2.47	1.12	0.58	0.81	0.81	0.43	0.43	1.93	2.44
il	0.26	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mt	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.59	0.59	0.12	0.07
caf2	7.70	0.00		3.87	2.16	0.00	0.00	2.14	2.14			5.61	8.11
nacl	0.90	0.00	0.82	0.59	1.79	0.32	0.32	0.20	0.20	0.00		0.84	0.79
anh		11.92				0.21		0.20	0.20			0.48	
bar	23.22	55.06	1.33	0.94	1.24		0.32			0.22	0.22	18.23	22.81
cc	6.93		89.66	84.36	83.61	85.88	20.14	16.28	16.28	47.38	47.38	45.38	42.06
basrc				0.47	0.62		0.85	1.32	1.32	1.73	1.73		1.45
nak2c	8.66		0.72	1.05	1.79	0.75	14.94	12.46	12.46	2.91	2.91	2.84	4.09
al2c3	22.64		2.05	2.87	3.09	3.94	18.39	27.72	27.72			10.56	6.20
sic			2.97	3.40	3.22	7.78		19.23	19.23			9.05	12.00
nakal		5.11											
baal2		7.66											
basrsi2		8.23											
lar										37.72	37.72		
sil	5.90						9.70			7.29	7.29		
qz	20.01	8.89					34.76	19.48	19.48			4.95	
cor										1.73	1.73		

Rittmann's norm [14] indicates presence of alkali, aluminum and silicon carbonates, larnite and corundum. Quartz normative sites and silica under saturated sites are seen together in a single sample at different places. Similar feature was observed in the basaltic rock extrusion in this area [15-17].

Al ions against Si ions in this lava exhibit a linear positive variation (Fig. 3) increasing reaction of CO_2 with host rocks. This activity also appears to be increasing the viscosity of the carbonatite melt. Similar variation between Ca and Mg is seen. $CaCO_3$ varies ranges between 81 and 99% and the lava belongs to calcitic. The maximum temperature state of carbonatite melt was 800°C [18]. The dolomite content reaches only up to 29%. A negative correlation is seen between Na and Ca. Almost equal proportions of K and Na ions are present. A negative correlation is present CO_2 against SO_4. Concentration of two separate fields of CO_2 against SO_4 and Sr against Ba ions indicate immiscible separations between carbonates and sulphates and or strontium and Barium. Similar trend is possible between silicate carbonates and divalent carbonates. A smooth positive correlation exists between Sr and Ba indicates accommodation of Sr with increasing Ba in the carbonatitic melt. Ni against Co; Zn against Cu and Nb against Zr are showed smooth positive variations. However, Y against Pb shows limited differential variation.

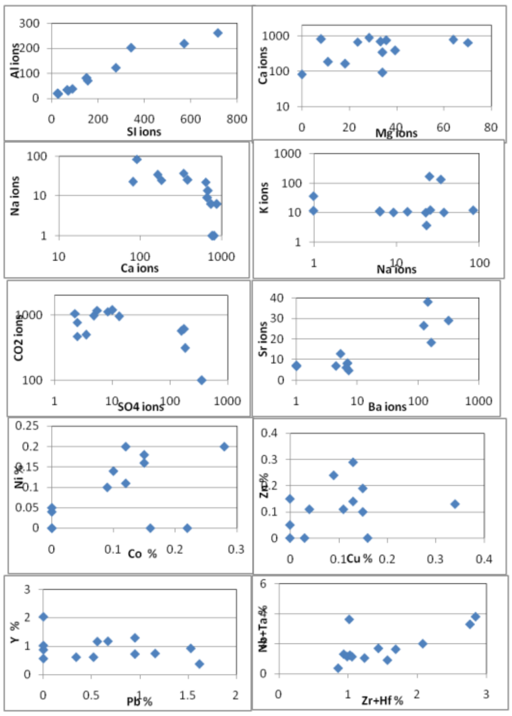

Fig 3: *EDAX chemical variation diagrams of carbonatite-lava in Sivamalai alkaline complex.*

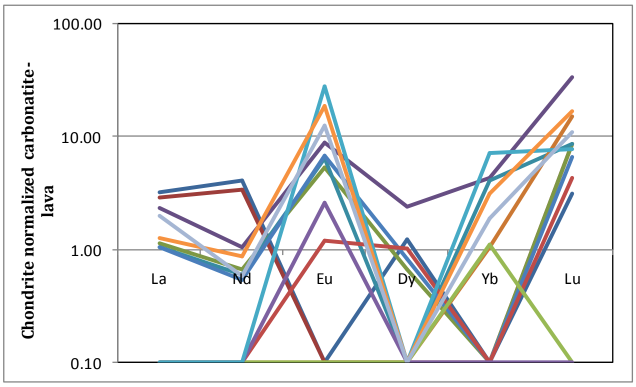

Fig 4: *Chondrite normalized REE in carbonatite-lava show enrichment of Eu and Lu. REE% are magnified.*

A narrow variation of REE in all analyzes confirms that they are co-magmatic and co-genetic (Fig. 4). The high contents of Eu in the melt may be due the pre-solidification state of plagioclase phase in the melt. Yb has similar physicochemical properties of Lu. Positive Yb+Lu anomaly takes place under pre-solidification state of monazite which is a carbonatite mineral.

4. DISCUSSION

Carbonatite generally associates with differentiated alkaline rocks [9]. It has distinct trace element enrichment of Sr, Ba, Nb, REE, Pb, Zn and V [10-13]. However, the concentrations of these elements distinctly vary according to their tectonic settings [10-13, 19]. Volatiles can be dissolved and or exsolved gas-phases in melts and occur as bubbles of at interstitial spaces between melt and growing crystals. The melts are reported from diverse tectonic settings such as intra-plate continental rifts, deep subduction zones, MORB, island arcs, oceanic islands, orogenic belts, ophiolites and shear zones. The trace elements of melts vary depending up on their tectonic settings. Carbonatite have highest melt capacities for dissolving H_2O and other CO_2, SO_3, P_2O_5, CaF_2 and (NaK)Cl [20}. These volatiles form as bubbles of varying sizes from >1µm to >1m depending up on chemical composition, temperature, pressure, viscosity, kinetics of ascending melt, rate of cooling, rate of degassing of volatiles, time-duration and eruption style of emplacement of the melt. All these factors vary from one tectonic setting to other. They are directly related to viscosity of the melt [17]. The maximum $MgCO_3$ entering in calcite-dolomite solves is 19% indicating maximum temperature of the carbonatite melt is 800^oC [18]. Under low viscosity condition dissolved and exsolved volatiles released out as bubbles more rapidly and dissipate into their host rocks converting into fenites or fluidized rocks. On the other hand rapidly ascending carbonatite melts from deeper mantle source attain limited degassing and preserve characteristic trace elements by increasing viscosity at near surface conditions [17]. The increasing concentration of froth-bubbles per unit volume decreases viscosity and changes chemical composition of a melt by dissolved or exsolved volatile phases. Solubility of C, S, P, Ti, Na, K, Ba, Sr, Cr, Ni, V, Zn, Y, REE, Hf, Zr, Nb, Ta, Y varies in water bearing bubble phases. Thus de-gassed or quenched bubbles in melt at various tectonic settings characteristically change their chemical compositions of melts. The analytical error in percent encountered by using different methods of investigations may be better correlated with following chemo-tectonic ratios K_2O vs H_2O, Ba/Sr, P/Ti, Nb/Y, Zr/Y, Zr/Ti, LREE/HREE, and La/Yb [10-13, 19, 20]. Carbonatite melts belonging to intra-plate volcanic settings have high ratios than from other tectonic settings [19, 20]. The EDAX chemical composition of basaltic extrusion during the year1996 varies from alkali basaltic to trachy-andesite [17] is an example for variation in such chemo-tectonic settings.

5. CONCLUSIONS

The present report is a documentation of carbonatite-lava adjacent to Sivamalai alkaline complex.The lava has genetic relationship irrespective of space and time. The lava is enriched with high ratios of characteristic trace elements [19] of carbonatites of intra-plate volcanism. The deep lineaments present in this area show that these rocks were derived from mantle source. The recent basaltic extrusion in the year 1996 appears to be mantle source [17] and parentage for the Neoproterozoic Sivamalai alkaline complex [21] associated with carbonatite-lava irrespective of space and time. Carbonatite lavas occurring along the coastal tracts of Tamil Nadu belong to Mio-Pliocene to Pleistocene Period and determination of age of carbonatite-lava in Sivamalai area is to be studied to trace wide-spread carbonatite volcanism in Tamil Nadu [22, 23, 24]. Movement of Indian Plate towards NE direction might have been caused at late stages of Deccan Trap Volcanism leading to residual carbonatitic melts. The fluidization of pink granites might have been due to metasomatic effect during emplacement of carbonatite lava. Mineral explorations of barite, gypsum, semi-precious minerals, kankar, alkali-feldspar, quartz, and nepheline-syenites and pink-granites for cutting and polishing of dimensional stones are to be made.

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ACKNOWLEDGEMENT

The author expresses his sincere thanks to Mr. T. Ragavaiya, Senior Technician in Material Science Laboratory, IITM, Chennai-36 for his help during EDAX analyses

REFERENCES

[1] T. H. Holland, *The Sivamalai series of elaeolite syenites and corundum syenites in Coimbatore District, Madras,* Geol. Surv. India, Memoir, 30, Pt III, pp. 169-217, 1901

[2] A.P. Subramaniam, *A petrogtaphic study of the alkaline rocks at Sivamalai, Coimbatore, Madras*, Proc. Ind. Acad. Sci. v. 30,, Sec. B, pp. 69-94

[3] G.W. Tyrell, *The Principles of Petrology,* J. Wiley & Sons 349p, 1973

[4] M.K. Bose, *On the Leucocratic syenites of Sivamalai, Coimbatore, Madras,* Bull Geochim. Soc, India, v. 3, pp. 17-23, 1968

[5] B. Bhaskar Rao, *Petrology of the alkaline rocks around Sivamalai, Coimbatore District, Tamil Nadu, India,* Geol. Rundsch, v. 71, pp.263-279, 1982

[6] C. Leelanandam, *Eulitic and ferrosilitic ortho-pyroxenes from ferrosyenites of South India: evidences for a high temperature crystallization and tholeiitic parentage,* Curr. Sci. v. 64, pp. 729-735, 1993.

[7] *https://www.researchgate.net/...Sivamalai.../Neoproterozoic-alkaline-magmatism-at-Si*

[8] M.L. Rangth, M. Santhosh, M. Sathyanarayana, D.V. Subba Rao and Li Tang, *Multiple rifting and alkaline magmatism in Southern India during paleoproterozoic and Neoproterozoic,* Tectonophysics, v.680, pp.233-25312 June, 2016,

[9] E. Wm, Heinrich *The Geology of Carbonatite*s, Chicago University Press, Chicago

[10] S. Samoilov, *The main geochemical features of carbonatites,* J. Geochem Exploration v. 40, (1-3) pp. 251-262, 1991.

[11] W. T. Verwoerd *South African carbonatites and their probable mode of origin,* Ph.D. Thesis Universitette van. Stellenbosch. Annale, vol. 41, Ser. A, No. 2, 1966

[12] D.K. Bailey, *Mantle carbonatite eruptions: crustal context and implications,* Lithos, vol. 26, pp.37-42 1990

[13] C.G.B. Dubois, J. Furst, N.J. Guest and D.J. Jennings, *Fresh Natro-carbonatite lava from Oldoinyo L'engai,* Nature, v.197, pp445-446,02 Feb 1963.

[14] A. Rittmann, *Stable mineral assemblages of igneous rocks,* Springer Verlag, Berlin, 262p 1973.

[15] R. Ramasamy, *Petrographic observations of lava tube injections and eruptions and spray of volcanic beads in Tamil Nadu and evolution of plume tectonics of Indian Plate* National Institute of Geophysical Research Institute, Hyderabad, National Seminar on Plume Tectonics Abst. vol, pp,32-33 13-14th June 2000.

[16] R. Ramasamy) *Molten rock extrusions, Journ. Geol. Soc. India*, v. **55**, pp. 337-338, 2000

[17] R. Ramasamy, *Basaltic-lava extrusions between the years 1996 and 2004 in some parts of Tamil Nadu, India* , ijisset, 2017 in press

[18] J.P. Goldsmith and R.C. Newton *A Portion of calcite limb of calcite-dolomite solvus,* Amer. J. Sci v0167 A pp.160-190, 1969

[19] Yang Xueming, Yang Xiaoyong and M.J. Le Bas, *Geological and geochemical characyteristics of carbonatites and their implications for tectonic settings,* Advances in Earth Sciences, v. 13 (5), pp, 457-466, 1998

[20] A.P. Jones, M Genge and L. Garmody, *Carbonate melts and Carbonatites,* Reviews in Mineralogy & Geochemistry, v. 75, pp. 289-322, 2013

[21] D. Upadhyay, S. Jhan Awe, C. Pin , J. L. Paquette, and I. Braun, *Neoproterozoic alkaline magmatism at Sivamalai Southern India,* Gondwana Research, v. 10, pp. 156-166, 2006.

[22] R. Ramasamy *Carbonatite bombs, lapillus, pisolites and ashes in semi-unconsolidated conglomerate of Early Pleistocene from Thiruvalangadu, Tamil Nadu, India* IJERA, v 4 (8), pp.112-19, 2014.

[23] R. Ramasamy *Geochemical studies on carbonatite lava flows in and around Kudangulam area Tamil Nadu India,* IJISSET, v. 3 (2), pp.23-30, Feb. 2017..

[24] R. Ramasamy, Carbonate-tephrite and bi-model carbonatite-lava occurrences in the Dharangambadi-Karaikal Coast, Tamil Nadu, *India,* IJMSET, v. 1 (6), pp.15-29, 2014.

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