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

ISSN 2455-4863 (Online) www.ijisset.org Volume: 3 Issue: 2 | February 2017

Geochemical studies on carbonatite lava flows occurring in and Kudangulam area, Tamil Nadu, India

R. Ramasamy

Retired Project Adviser, Department of Civil Engineering, Indian Institute of Technology, Madras, Chennai-600036

Abstract: *Very fine-grained black coloured low-density silica-undersaturated carbonate lapillus and pisolites admixed with unfossiliferous tufaceous limestone or Mio-Pliocene shell-limestone found in association with soda-trachyte, olivine-tephrite, pockets of phlogopite-apatite and sovite dykes are termed as carbonatite lava. Surface-exposures as well as tuff like yellowish-pink banded unfossiliferous pisolites showing spherulitic textures are included as carbonatite lava. They occur 20 km NE of Cape Comorin and 2 km south of Kudangulam village (08°11′N-77°43′E}. Volcano-tectonic structures hosted with sediments indicate that they took place in the form of series of circular features with cauldron subsidence during Early Pleistocene Period in a NW-SE trending graben near Kudangulam. It also occurs as black thin-films along intergranular boundaries of calcites in crystalline limestone occurring in some parts of Tamil Nadu. Sovite essentially composed of calcite, apatite, sanidine and intergrowth of leucite-phlogopite occurs. Wet gravimetric analyzes show high degree of oxidation. The SiO_2 content varies from 1.29 to 10.22 and the mean value is 2.87% while Al_2O_3 0.85 to 3.46 and the mean value is 1.53%. The EDAX analyzes of some samples show that they are composed of continuous linear variations in normative proportions of sodium and potassium carbonates, gypsum, alkali-sulphates, alkali-fluorites, fluorites and phosphates. The desilicated minerals such as olivine, nepheline and kalsilite are commonly found. In special cases, quartz occurs as xenocryst with corroded outline. The pore fluids remained after normative calculations are acidic and enriched with CO_3, SO_4, and PO_4 ions. They react with Na, K, Ca, Mg, Fe, Al, and Si ions. The excessive anions in bulk compositions and in pore fluids react with refractory elements including with Al^{+3} and Si^{+4} forming their respective components. The linear positive correlation of V, Ni, Pb, Sr, U, Zr, Hf, Nb, Ta, Y and REE in bi-model carbonatite-lava indicates that it rapidly differentiated by degassing of volatiles on its way to the surface from mantle source. The host rocks of granite gneisses are kaolinized and epidotitized with release of transparent granular quartz.*

Keywords: *Carbonatite-lava, Kudangulam, Tamil Nadu, Kaolization, Sovite-dykelets in Mio-Pliocene shell limestone,*

1. INTRODUCTION

Magmatic origin of carbonatites was widely accepted after outflows of sodium carbonate lava from Oldoinyo Lengai, Northern Tanganyika in the year 1960 [1]. Subsequently many carbonatite lava occurrences were reported as carbonatite-lavas and tuffs throughout the world [2]. In India, carbonatite lava lapillus, aggregates of pisolites and lava flows were recognized just before the year 1983 from Kudangulam area, but not enough studies were made to report them as carbonatites. With available field and petrographical data, carbonatite volcanic activities were reported in IGS [3, 4]. Carbonatite occurrences in the form of black and pink coloured bi-model bombs, lapillus, pisolites and ash in coarse-grained conglomeratic sandstone of Early Pleistocene boulder-bed in Thiruvalangadu near Chennai were reported [5]. Similarly, black and pink coloured lava floats occur in the form of very flat lapillus and pisolites along Dharangambadi beach [6]. In Kudangulam area tuff-like flow-banded yellowish-pink unfossiliferous carbonate rock admixed with very fresh dark carbonatite lapillus and pisolites are reported [4].

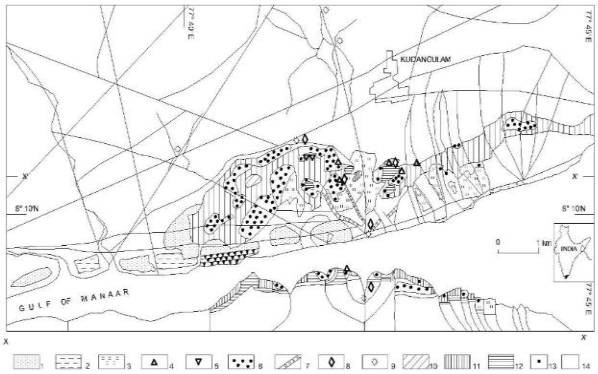
2. FIELD STUDIES & GEOLOGICAL STRUCTURES

One of the ONGC drill hole MI 1A in the Gulf of Mannar near Mandapam met 3 consequent subcrops of Deccan Trap basaltic effusive flows at 2262, 3280, 3685m depths are reported as intrappean marine Lower Cretaceous shale and sandstone formations [7]. In Kudangulam area, volcanic rocks of soda-trachyte, basalt, carbonate-tephrite and carbonatite lavas [8, 9,10] are reported. Occurrences of very fresh fine-grained dark carbonatite lapillus and pisolites and yellowish pink flow-banded massive tuff-like carbonate rock composed of aggregates of pisolites are known as two different facies of carbonatite lavas in Kudangulam area. However, the latter has wringled irregular weathered surface appearing to be furnace clinker. The broken interior surface is massive often finely laminated. Strewn carbonatite lava floats are seen here and there in the neighbourhood of the limestone. In the study area ten types of carbonate rocks were observed: a) black lapillus / pisolites b) thin laminated and banded yellowish pink tuff with pisolites, c) pale-green carbonatite lava porphyries, d) black thin film at intergranular boundaries of calcites in crystalline limestone e) some dark black thin films occurring at contact between granite-gneiss and crystalline limestone, f) coarse-grained sovite, beforsite, pockets of apatite-phlogopite and fine-grained ferro-carbonatites, g) calc-granulites at contact between igneous intrusions and carbonate rocks, h) tufaceous limestone formed by evaporated encrustation [11], i) older shell limestone with inverted gastropods or lamellibranches and j) younger shell limestone with gastropods or lamellibranches in living positions are found. Among them types a) to f) are known as carbonatites.

The petrography and mode of occurrences tufaceous limestone type g) [11] were not yet clearly understood. It is cavernous with varying dimensions between >0.1 and >50 cm about 2 km west of Uvari. Some cavities are filled with transparent calcites of icelandspars. In places along the coast, they are covered dunes made by teri-sands. Some places they occur between >0.1 and >10m widths in curvilinear-fractures and their axes plunging towards NW or NE directions. The thickness of tufaceous limestone varies between >0.1 and >3m. In the north, they exposed at several places near the villages of Pannamparai, Nazareth-Sattankulam, Ittamoli, Kayattar-Uttumalai, Sankarankoil, Surendai and Sendamaram. There is no evidence that they are evoporite deposits. They are not appeared to be formed by any alteration of basement rocks. No gradational alteration is seen. But they have imperceptle gradation into yellowish-white massive tuff. It is admixed with one or two shells or black carbonatite lapillus / pisolites here and there. The wide-spread massive caliches materials occur in southern parts of Thirunelveli District.

The curvilinear and circular features, cauldron subsidence and slicing of faulted blocks (Fig. 1, 2 and3) belonging to Late Cenozoic period were identified [4]. Their cross sections represent staratigraphic horizon(Table-1). The different lineaments trending NW-SE directions appear to be deeply dissected faulted blocks. A graben structure was formed in between two high lands due to cauldron subsidence by disposition of different rock units and shallow curvilinear fractures dipping inwards. Many circular features are seen overlapping one over other. Using pitting, trenching and drill-hole data, constructed cross section shows that carbonatite lava outflows over shell limestone. It also conformably interlaid between shell limestone along its bedding or weak planes. Fresh banded yellowish pink carbonatite-lavas with patches of coalesced aggregates of pisolites of 20-50 mm on the southern and northern slopes of the ridge are seen as a blanket.

During reserve estimation of shell limestone for India Cements Ltd., the Tamil Nadu State Department of Geology and Mining made systematic trenching and pitting and drilling works between 1980 and 1983 [12] on a ridge elevated to 50m above msl. During investigation some pits have revealed exposures of soda-trachyte, sovite, pocket of apatite-phlogopite and yellowish pink carbonatite lava. The yellowish pink tuff shows fine lamellae flow-bandings. Aggregates of coalesced pisolites are seen on erosion surface of the rock. Geological, structural and cross-section of the maps (Fig.. 1,2 and 3) have revealed that the volcanic lava was younger to deposition of Mio-Pliocene shell limestone. The lava conformably emplaced along bedding or weak planes of the shell limestones. Black and pink carbonatite-lava floats are strewn along the beach. Black-carbonatite lapillus and pisolites are admixed as inclusions in yellowish-pink-carbonatite, indicating bimodal carbonatitic volcanic activities as in Thiruvalangadu [5] and in Dharangambadi [6]. The black carbonatitic activity was older to pink ones.



1 Dune sand, 2 Tidal clay. 3 Quarternary Sand stone,, 4 ignimbriye, 5 Icelandspapar bqaring limestobe, 6 carbonatite lava, 7 Sovite complex 8 Trachyte 9 Tephrite, 10 Fenite 11 Mio Pliocene sgell limestone 12 Noarse grained sanf stone 13 u;itramafics 14 Charnockite

Fig 1: *Geological map of Kudangulam and its cross-section. Unfossiliferous yellowish-pink carbonatite-lava is inter-bedded conformably along bedding planes and other weak planes and on the erosion-surface of Mio-Pliocene shell limestone.*

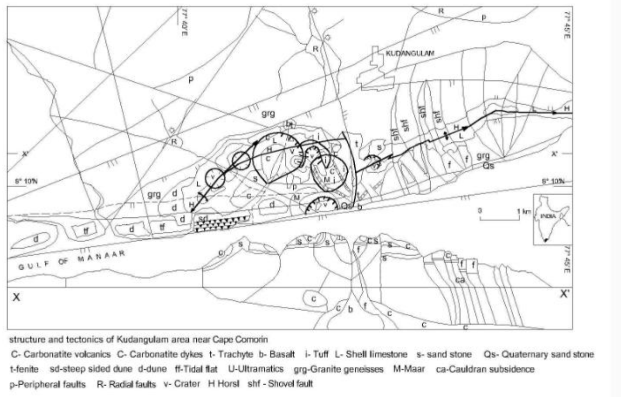


Fig 2: *Simplified volcano-tectonic map of Kudangulam sedimentary map*

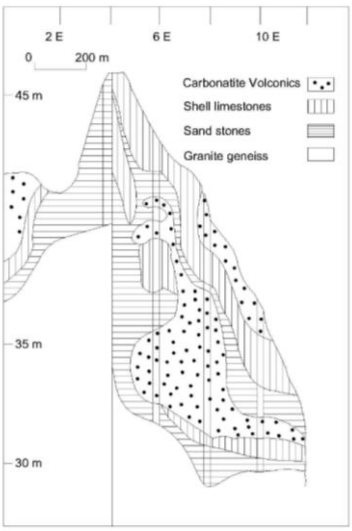


Fig 3: *A cross-section constructed shows that yellowish-pink pisolites carbonatite-lava is exposed both on the erosion-surface as well as inter-bedded conformable bands parallel to bedding or weak planes. A fault-plane vertically dissects the elevated ridge.*

The basaltic, trachytic and carbonatite activities are seen in some well-sections at Kudangulam, Sanganeri, Thiruvambalapuram and Kadakulam. The host rocks granitic gnisses are extensively kaolinized and epidtitized at some places in Idinthakarai and Vijayapathy over 10m thickness from ground surface. Kaolinization is found at varying thicknesses in Kanakkankulam and Tisaiyanvilai and other places. South of Tisaiyanvilai transparent granular quartz is released by this process from granite gneisses.

Dykelet (10-20mm) of carbonatite lava in granite gneiss is seen at 1 km west of the road from the road Vilathikulam-Ettaiyapuram branching out to Periloan-patti. It is found associated with crystalline gypsum deposits just 2 km west of the carbonatite lava dykelet.

3. STRATIGRAPHY

The geological investigation and staratigraphic correlation in this area [4, 11-15] in this area is shown the Table 1.

Table 1: *Staratigraphic succession in Kudangulam area [4, 11-15]*

Rock type/form	Thickness (m)	Age
Teri sands-dune	15	Recent to Holocene
Tidal flat Clayey-sand	10	
Shell limestone gastropods and lamellibranches at living positions	0.5	Holocene to E. Pleistocene
Carbonatite flows & eruption Tufaceous limestone Sovite, beforsite, ankerite Eruption of basalts, trachytes	3.7	E to M Pleistocene
Shell limestone carrying inverted gastropods and lamellibranches. Compact Calcareous Sand stone	6.7 5.7	Mio-Pliocene Mio-Pliocene
Charnockite granite gneiss		Precambrian

Unconformities are recognized between successive staratigraphic units.

4. METHODOLOGY

Samples of black-coloured lapillus and pisolites from tufaceous or shell limestone occurring in Kudangylam, Radhapuram, Uvari, Putthan-tharuvaikulam Tisaiyanvilai, Sattankulam, Nazareth, Pannamparai, Manapadu, Uttumalai, Surendai Sambavarvadakarai, Sendamaeam, Pasuvandanai and Singikulam were collected. High-resolution SEM and EDAX analyzes were made in Metallurgical Engineering and Material Science Laboratory, Indian Institute of Technology. Madras. The elements determined were re-calculated into oxides (Table 2-7). The chemical compositions of samples vary according to the feed-back of elements. The Table 7 gives almost satisfactory results. Using their oxides Rittmann's norms [16] were calculated for the samples. Geochemical variation diagrams were constructed to evaluate their genetic implications. Sizes of mineral grains were measured and textures of the rocks were studied.

5. TEXTURAL DESCRIPTION

Under thin sections both black and yellowish-pink carbonatite lava exhibit spherulitic textures. They are composed of homogeneous calcite crystals of 2 μm with intergranular cavities of heterogeneous shapes and sizes. Large vesicles are also present. Under higher magnification x10000 the micro grains are tabular prismatic euhedral in form amidst fine-grained matrix of size <1µm or vesicles. Porphyry of pale-green carbonatite lava occurs as floats in Podupatti-Pasuvandanai area near Eppodumvendran. It exhibits growth of large phenocrysts of calcite crystals of <15 x3 mm. Interpenetration and intersertal twins of calcites exhibit with ophitic texture amidst fine-grained matrix composed of inequigranular grains <10µm. Intriguing carbonate veins in pink pegmatites are seen. The black carbonatite films occurring at some intergranular boundaries of calcites are composed of microlites <2x1 µm amidst very fine-grained matrix enriched of U and REE in crystalline limestone of Pasuvandanai and Pandalgudi. Further, thin dark film occurs at contact of granite gneiss and crystalline limestone 2 km south of Singikulam village. It shows vitrophyritic texture with skeletal microlites of <2x1µm and matrix also are enriched with U and REE. The coated film-like materials in cavities too enriched with U and Zr bearing pyrochlore and with high K/ Na, Pb/Sr, U/Pb, Hf/Zr and Ta/Nb. They might have been formed by vapour-deposition along peripheral portions of cavities.

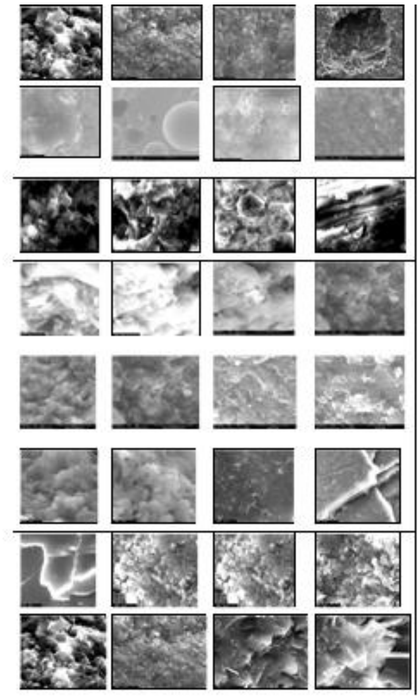


Fig 4: *EDAX images of carbonatites and their mineral assemblages.*

Rhombohedral skeletal crystals of calcites (4x3x3µm) with tubular cavities of 20x4µm are seen. Some cavities are partially filled with secondary minerals. An ellipsoidal cavity with a dimension of 100x60x40 µm contains platelets (4x2 µm) of pyrochlore composed of oxides of Ca, Nb, Y and Zr. Globular calcite <90x60µm is seen in a carbonate-tephrite associated with carbonatite-lava. An older shell limestone carrying inverted gastropod shells is admixed with yellowish carbonatite-lava. Corroded quartz (4x2x2µm) admixed on the surface of carbonatite pisolites is seen. Flow bands <1µm thickness are seen as thin lamellae. Chains of circular (globular) spherulites (5 to 0.5 µm) and lihophyses (10 to 200µm) carrying fine needles projecting towards common centers are seen. Thin veins, fissures as well as fractures carry recrystallized coarser-grained calcites at peripheral portions with central cavities are found. Besides, pockets of 10-50 µm of myrolitic cavities carry fine-grained calcite crystals at peripheral portions and heterogeneous coarser tabular calcites towards inner portion. Alkali and REE minerals are deposited inner portions from vapour phases with central cavities. The heterogeneous sizes and abundance of vesicles and the nature of filling and growth within the vesicles as platelets are widely varied but indicating volcanic nature. Very low-density reddish brown floats od carbonatitic scoria are seen along the beach. The grain size calcite, dolomite, apatite and phlogopite respectively occurring in sovite, beforsite and apatite-phlogopite exceeds over 10x8cm. However, co-existing fine-grained ferro-carbonatite shows aphanetic fine-grained texture. Irregular shaped voids exceed over 30% in volume. Rhombohedral crystals of calcites (4xx4µm) are seen in between fine lamellae (6 µm) of yellowish pink carbonatite lava. The rock also exhibits spherulitic needles of calcites (6x1.5µm) towards central cavity X-ray diffraction on of calcite in sovite accommodates 17% of $MgCO_3$ in its lattice indicating that the mineral was formed at 770^{o} C [17].

6. GEOCHEMICAL STUDIES

Wet-gravimetric analyzes show that the mean chemical composition for 21 samples is SiO_2 4.02, Al_2O_3 1.00, $Fe_2\,O_3$ 1.00, FeO 0.77, MgO 2.53, CaO 36.50, Na_2O 0.97, K_2O 0.43, TiO_2 0.13, P_2O_5 0.00, SO_3 0.00, CO_2 30.65 and moisture 1.13%. The minimum degree oxidation most of carbonatite lavas exceeds over 0.5 and the mean value is 1.17. The compositions of the rocks vary depending up on the input of characteristic elements controlling composition of rocks or minerals. Thus a slight compositional variation is seen from Table 2 to 6. The mean EDAX analyzes for 10 samples (Table-7) indicate that, SiO_2, 2.87, $Al_2\,O_3$,1.53, FeO 0.29, MgO 3.28, CaO 43..96, Na_2O 1.18, K_2O 0.49, TiO_2, 0.16 ZrO_2 1.64, Nb_2O_5 1.90, $Y_2\,O_3$ 1.37, F 1.24, P_2O_5 1.48, $SO_3$1.20, Cl 0.36 and CO_2 37.04%. The EDAX analyzes show enrichment of volatile components, ZrO_2, Nb_2O_5 Y_2O_3 and other characteristic trace elements for carbonatites. Rittmann's norms were calculated and listed along with Table-2 to 7.

Some samples listed in the Table-2 to 7 are enriched with SO_3 to form of normative gypsum >48% and alkali sulphates <9.3%. Silicon sulphate exceeds over 41%. Fluorite occurs up to 29.20%, alkali fluoride <6.16%, apatite <33.21%, silicon phosphate <31.82% and alkali carbonate <8.3%. A very large apatite crystal composed of F and CO_2 is reported from this area [18]. Alkali-carbonates present in some samples related to sodium or potassium carbonatites. The enrichment of K over Na may reflect high degree of degassing of volatiles from the magma. The alkali carbonates easily removed by meteoritic water and it is difficult to trace distinguish it from tufaceous limestone [11] in the field. Some are silica undersaturated with development of olivine (ol), nepheline (ne) and kalsilite (ks). *The pore fluids interlocked in cavities and intergranular boundaries are acidic and enriched with CO_3, SO_4, and PO_4 ions. They react with Na, K, Ca, Mg, Fe, Al, and Si ions. The pore-fluids necessarily react with refractory elements including with Al^{+3} and Si^{+4}forming their respective components.* The characteristic chemical components were plotted in the Figure.5 to study their variation trends (Table-7).

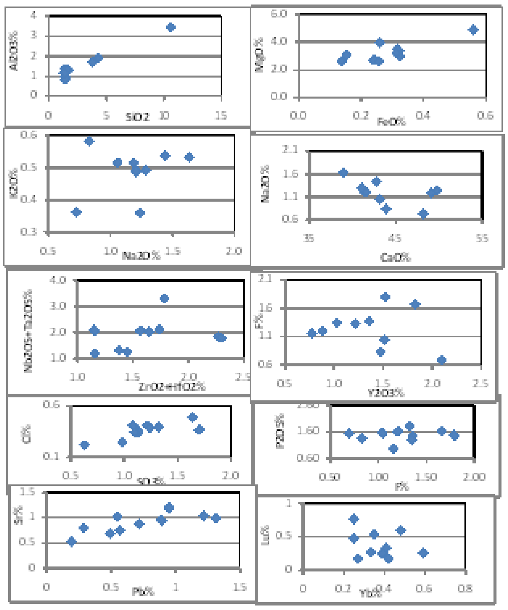


Fig 5: *shows the trends of variation of binary chemical components. All of them show positive linear correlation. However, Na_2O against CaO show different trends of both positive and negative variation indicate formation of Na-rich carbonatite magma / lava.*

Al_2O_3 against SiO_2, MgO vs FeO, K_2O vs Na_2O, Na_2O vs CaO, Nb_2O_5+Ta_2O_5 vs ZrO_2+HfO_2,, F against Y_2O_3 Cl vs SO_3 P_2O_5 vs Pb; Sr against Pb and Lu vs Yb are all show positive linear variations during the course of rapid ascending of low viscous carbonatite lava from depth and relative interlocking of volatiles within lava.

The EDAX analyzes of black carbonatite lapillus are very similar to the EDAX composition of yellowish-pink carbonatite lava (Table 2). However, not determinations of Hf affect the value of total ZrO_2 + HfO_2 and Ta affects the value of Nb_2O_5+Ta_2O_5. Sr correlation against Pb was not possible. Table-3 Zr was not determined showing lower content of ZrO_2+HfO_2 contents and Zr is one of the characteristic elements in carbonatite. F is another volatile element causing vapour deposition (Table 4). In all the samples of black carbonatite lapillus the fluoride content was not estimated. Similarly without determination on Zr and Cl caused by slightly increasing weight percent of other elements (Table-5). The EDAX composition between carbonatite lava and coarse-grained carbonatites occurring in this area are similar. However, coarse-grained intrusives have higher contents of volatiles. Nb is one of the characteristic elements occurring as pyrochlore and other Nb-minerals in carbonatites. Presence or absence of Nb, significantly changes the EDAX composition (Table-6).

Though, under thin section, the coarse-grained carbonatites exhibits silica-undersaturated minerals such as leucite-intergrowth with phlogopite or sanidine intergrowth with phlogopite, nepheline, calcite, apatite mineral assemblages enriched with volatiles do not show normative silica undersaturated minerals due to interlocking of volatile constituents at grain boundaries obliterating normative nepheline and leucite. On the other hand volatiles degassed from fine-grained rocks show normative proportions of nepheline (ne) and kalsilite (ks), due to escape of volatiles during ascending low-viscous lava from depth. Sudden cooling of lava with interlocking of volatiles at grain-boundaries also obliterates normative silica undersaturated minerals. The presence or absence of volatile constituents plays critical role on normative proportions of nepheline and kalsilite. The emplacement of carbonatite lava kaolinizes the host rocks of granite gneisses. The mafic minerals like pyroxene, hornblende and chlorite were epidotized. The ferric minerals like magnetite and garnet were altered to limonite coating red colour staining on the kaolin clay in some places. Transparent granular quartz is released out.

7. CONCLUSIONS

The geological structure, texture, mineralogy and geochemical composition of 6 types of carbonatites from Kudangulam and adjoining areas analyzed show similar enrichments of volatiles and Nb, Ta, Zr, Hf, U, Pb, Sr,Y, Yb and REE. An imperceptible gradation exists between laminated yellowish-pink carbonatite lava and massive wide-spread tufaceous limestone. They occur in curvilinear fractures. More studies are required to distinguish yellowish-pink carbonatite lava from tufaceous limestone. In the present investigation no EDAX analyzes on tufaceous limestone was made. More studies are required to evaluate petrology and mode of occurrence of tufaceous limestone admixed with black lapillus, shells of inverted or living positions. Such studies are important to prove wide-spread carbonatitic volcanic activities in Tamil Nadu.

Table 2: *EDAX analyzes of carbonatite-lavas without Hf, Ta and Pb*

VI	48	49	50	51	52	53
SiO2	6.51	6.16	37.05	10.87	46.61	49.55
Al2O3	1.52	1.49	8.75	4.08	9.05	21.94
FeO	0.32	0.39	12.40	2.95	10.15	4.81
MgO	0.91	1.04	3.57	1.24	9.98	2.74
CaO	38.60	31.32	9.78	3.41	8.04	6.84
Na2O	0.45	0.76	1.41	1.87	1.67	4.36
K2O	0.32	0.64	0.72	0.27	0.49	0.48
TiO2	0.06	1.40	1.04	0.67	0.94	0.63
ZrO2	1.64	0.53	1.38	0.74	1.08	0.94
Nb2O5	2.23	0.89	1.53	0.93	1.19	2.01
Y2O3	1.36	0.00	0.83	0.64	0.80	0.50
F	0.00	0.46	0.98	0.88	2.79	1.16
P2O5	0.78	1.33	0.55	0.18	0.56	0.14
SO3	0.77	1.98	2.65	1.29	0.68	0.37
Cl	0.18	0.75	0.00	0.30	0.22	0.18
CO2	44.38	50.93	18.35	69.68	5.73	3.35
SUM	100	100	100	100	100	100
gy	1.03	2.36	4.15	2.68	0.96	0.54
nak2s						6.60
hl	0.51	2.07		0.61	0.64	0.54
fl		1.77	4.78		7.11	
nakfl				1.83	6.16	
xeno	1.13		0.88	0.37	0.74	0.22
si2y2	0.10			0.97		0.22
ap		2.58	0.19			
nb	1.28	0.49	1.13	1.40	0.74	1.24
zr	1.33	0.39	1.38	1.46	0.96	0.87
ol					14.17	11.58
cpx					33.33	21.43
il	0.10	1.77	1.63	1.34	1.27	0.87
mt			1.26	0.30	0.80	0.65
cc	69.50	48.20	13.45	1.58	9.24	8.23
mc	1.85	0.98	11.19	2.56	4.56	
fec			14.33	3.05		
al2c3	1.79	1.48		7.92		
sic2	11.99	12.10		26.07		
ks	1.08	2.07	0.94	0.73		
ne	1.38	0.44	8.49	2.01		
or						2.71
ab						20.29
an						11.09
qz						
porefl	6.92	23.36	36.20	45.13	19.32	12.93
	100	100	100	100	100	100
Cr	0.00	1.15	0.00	0.02	0.17	0.13
Sc	0.00	0.23	0.00	0.02	0.21	0.19
v	0.14	0.57	0.76	0.36	0.64	0.75
Ni	0.11	0.23	0.04	0.08	0.04	0.25
Sr	0.79	0.00	0.83	0.55	0.83	0.58
Ba	0.00	0.39	0.00	0.08	0.56	0.31
La	0.00	0.75	0.00	0.08	0.73	0.43
Ce	0.00	0.21	0.00	0.00	0.35	0.22
Nd	0.00	0.64	0.00	0.10	0.23	0.30
Eu	0.00	0.00	0.00	0.08	0.40	0.46
Dy	0.14	0.57	0.76	0.36	0.64	0.75
yb	0.30	0.30	0.00	0.00	0.59	0.00
Lu	0.44	0.56	0.00	0.11	0.59	0.24

The sample Numbers (S.No.) 48 and 49 represent Yellowish-pink carbonatite lavas, others are black carbonatite lapillus.

Table 3: *EDAX analyzes without determination of Zr*

V	38	39	40	41	42	43	44	45	46	47
SiO2	60.58	51.64	60.21	32.99	40.77	13.44	21.71	8.39	17.10	22.79
Al2O3	1.36	5.25	0.31	0.00	7.74	0.43	5.07	0.86	5.94	5.58
FeO	6.96	9.16	7.49	4.82	7.24	1.05	1.70	1.68	1.71	3.33
MgO	18.30	16.96	16.25	10.84	18.10	0.00	4.26	0.00	7.43	2.14
CaO	0.12	0.06	0.15	0.18	0.04	0.39	0.33	0.40	0.35	0.45
Na2O	0.58	0.00	1.03	0.00	0.00	1.20	3.59	0.49	5.57	2.03
K2O	0.34	5.10	0.48	0.88	4.48	0.21	1.36	1.15	1.47	1.77
TiO2	0.00	0.57	0.00	0.12	0.40	0.00	0.26	0.36	0.35	0.64
ZrO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nb2O5	1.21	0.63	2.01	2.03	1.13	1.71	2.16	3.34	2.20	2.90
Y2O3	0.50	0.63	2.14	1.16	0.37	0.62	2.99	3.73	1.66	2.75
F	3.57	4.93	1.93	2.80	7.94	2.20	4.27	2.39	7.01	2.49
P2O5	0.00	0.00	0.00	0.10	0.00	13.61	26.06	13.95	10.58	15.17
SO3	4.06	2.40	0.00	34.62	3.11	48.47	10.09	49.23	11.41	15.13
Cl	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.66	1.06	0.97
CO2	2.42	2.66	8.00	9.46	8.68	16.69	15.12	13.37	26.17	21.88
SUM	100	100	100	100	100	100	100	100	100	100
gy	5.31	3.01		41.17	3.63		2.45		12.57	0.00
sis2				4.77		41.79	16.79		0.56	15.69
nak2s							9.28			
al2s3							4.00			
hl							3.09	1.50		
sicl4									1.77	1.71
fl	14.68	19.54	8.14		29.20	11.44	18.02	11.69	11.03	2.32
nakfl									19.64	11.38
sif4				10.64						
xeno				0.12		0.75	2.77	4.31	1.40	2.65
si2y2	0.42	0.60	2.07		0.28					
si3p4							31.82	18.75	10.94	18.40
ap										
nb	0.73	0.40	1.22	1.44	0.56	0.81	1.01	1.89	0.98	1.82
zr										
cpx	34.98	28.43								
il		0.70			0.47					0.88
mt	0.62	1.81	0.69		1.35					0.22
cc										
mc	5.73	6.03	19.36		18.35					5.19
fec										2.54
nc										
kc				1.67						
al2c3							8.96	2.68	13.55	14.99
sic2				37.09				2.16	24.25	21.99
or		27.12			22.12					
ab	6.77									
qz	30.77	12.36	52.29	3.11	18.21					
porefl			16.22		5.82	45.21	1.81	57.02	3.31	0.22
	100	100	100	100	100	100	100	100	100	100
Cu	0.01	0.00	0.06	0.09	0.00	0.00	0.05	0.00	0.00	0.10
Cr	0.00	0.07	0.04	0.06	0.00	0.00	0.19	0.27	0.15	0.24
Sc	0.00	0.18	0.00	0.06	0.00	0.00	0.45	0.28	0.19	0.60
v	0.00	0.09	0.00	0.09	0.00	0.00	0.11	0.13	0.11	0.14
Co	0.00	0.12	0.15	0.07	0.00	0.00	0.33	0.35	0.09	0.29
Ni	0.02	0.08	0.11	0.07	0.04	0.00	0.23	0.08	0.07	0.00
Pb	0.32	0.41	1.32	0.60	0.23	0.26	1.23	1.87	0.57	1.12
Sr	0.69	0.36	1.10	0.93	0.62	0.63	0.79	1.49	0.67	1.05
Ba	0.00	0.18	0.16	0.00	0.08	0.00	0.31	0.00	0.24	0.06
La	0.00	0.20	0.13	0.13	0.00	0.00	0.56	0.40	0.56	0.79
Ce	0.00	0.25	0.00	0.23	0.04	0.00	0.50	0.33	0.24	0.71
Nd	0.00	0.27	0.15	0.12	0.00	0.00	0.57	0.42	0.27	0.46
Eu	0.00	0.23	0.15	0.29	0.00	0.00	0.73	0.93	0.62	1.05
yb	0.04	0.13	0.00	0.21	0.00	0.00	0.15	0.83	0.29	1.12
Lu	0.00	0.30	0.34	0.26	0.00	0.00	0.66	0.66	0.42	0.77

S. No. 43, 44, 45, 46 and 47 represent coarse-grained Ca-poor carbonatite, beforsite, ferro-carbonatite and alkali-carbonatite enriched with volatiles of SO_3, $P_{2=}O_5$, F, Cl and CO_2 formed by vapour depositions in voids in course-grained sovite, beforsite, apatite-phlogopite rocks.

Table 4: *EDAX analyzes without determination of F*

IV	28	29	30	31	32	33	34	35	36	37
SiO2	1.03	0.77	0.93	1.42	0.81	0.58	1.15	1.00	0.00	0.81
Al2O3	0.80	0.68	0.44	0.70	0.36	0.39	0.91	0.84	0.00	0.94
FeO	0.07	0.00	0.00	0.11	0.00	0.22	0.09	0.11	0.00	0.17
MgO	2.03	1.78	1.69	2.38	1.85	1.11	1.86	1.28	0.00	2.14
CaO	58.25	52.28	52.84	46.12	56.41	61.01	52.26	49.72	64.89	51.05
Na2O	0.00	0.49	0.00	0.41	0.00	0.00	0.73	0.44	0.00	0.45
K2O	0.52	0.18	0.18	0.46	0.27	0.60	0.47	0.56	0.00	0.57
TiO2	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00
ZrO2	1.85	2.08	1.60	0.48	2.27	2.01	1.75	2.23	10.12	1.42
Nb2O5	2.95	1.87	1.81	1.09	2.26	1.05	3.35	3.46	15.41	1.35
Y2O3	0.96	1.97	0.88	1.28	1.65	2.02	1.00	0.92	9.58	1.62
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P2O5	0.23	0.21	0.23	0.48	0.00	0.81	0.27	0.49	0.00	0.62
SO3	1.09	0.44	0.70	0.77	0.58	1.02	0.99	1.06	0.00	1.09
Cl	0.27	0.00	0.11	0.29	0.14	0.27	0.34	0.31	0.00	0.32
CO2	29.95	37.25	38.57	43.86	33.40	28.92	34.84	37.57	0.00	37.45
SUM	100	100	100	100	100	100	100	100	100	100
gy	1.49	0.93	1.05	0.74	1.38	1.29	1.36		1.44	5.31
hl	0.85	0.31	0.84	0.42	0.85	1.04	0.94		0.93	
fl										14.68
xeno	0.32	0.31	0.73		1.17	0.42	0.73		0.93	
si2y2		0.52	0.42	1.58	0.74	0.52	0.10			0.42
nb	1.75	1.08	0.63	1.37	0.64	1.98	2.04 ca.8nb.08y.		0.77	0.73
zr	1.59	1.13	0.42		0.32	1.46	1.67		0.82	
badl				0.95	0.69		0.10		0.71	
cpx										34.98
il			0.21							
mt										0.62
cc	72.15	90.36	85.11	79.98	69.89	82.72	89.14		87.69	
mc			5.76							5.73
nc			0.42							
kc			0.79							
al2c3			1.10							
sic2			2.52							
ks	0.42									
ab										6.77
qz										30.77
porefl	21.43	5.26		14.96	24.31	10.60	3.91		6.70	
	100	100	100	100	100	100	100	0	100	100
Cr	0.00	0.00	0.00	0.03	0.00	0.14	0.00	0.05	0.00	0.10
Sc	0.16	0.00	0.00	0.18	0.05	0.00	0.12	0.08	0.00	0.00
v										
Co	0.00	0.00	0.00	0.13	0.11	0.14	0.11	0.06	0.00	0.09
Ni	0.05	0.00	0.00	0.14	0.20	0.25	0.09	0.12	0.00	0.16
Pb	0.24	0.24	0.00	1.02	1.47	1.53	0.32	0.54	2.53	0.53
Sr	0.68	1.33	0.62	0.82	1.17	1.48	0.67	0.65	7.16	1.08
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.26	0.00	0.00
La	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.18	0.00	0.11
Ce	0.00	0.00	0.00	0.20	0.00	0.42	0.00	0.00	0.00	0.22
Nd	0.07	0.00	0.00	0.40	0.00	0.00	0.00	0.24	0.00	0.00
Eu	0.05	0.00	0.00	0.07	0.00	0.16	0.06	0.08	0.00	0.11
Dy	0.00	0.00	0.00	0.43	0.17	0.20	0.00	0.11	0.00	0.10
yb	0.00	0.14	0.00	0.33	0.00	0.00	0.10	0.00	0.00	0.14
Lu	0.00	0.00	0.00	0.45	0.20	0.59	0.00	0.27	0.00	0.20
U	0.41	1.17	0.47	0.36	0.80	0.95	0.64	0.54	4.83	0.29

S.No. 28-37 belongs to analyzes of black carbonatite lapillus

Table 5: *EDAX analyzes without determination of Zr and Cl*

III	18	19	20	21	22	23	24	25	26	27
SiO2	51.25	47.30	48.97	26.01	38.41	8.67	14.56	5.41	11.35	13.84
Al2O3	1.15	4.81	0.26	0.00	7.29	0.28	3.40	0.55	3.95	3.39
FeO	5.89	8.39	6.09	3.80	6.82	0.68	1.14	1.08	1.14	2.02
MgO	15.48	15.54	13.21	8.55	17.06	0.00	2.85	0.00	4.93	1.30
CaO	14.61	8.30	17.04	19.86	4.66	34.95	31.27	35.83	32.71	38.27
Na2O	0.49	0.00	0.84	0.00	0.00	0.77	2.41	0.31	3.70	1.23
K2O	0.29	4.67	0.39	0.69	4.22	0.13	0.91	0.74	0.97	1.07
TiO2	0.00	0.58	0.00	0.10	0.42	0.00	0.19	0.25	0.25	0.43
ZrO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nb2O5	1.55	0.96	2.95	2.13	1.44	1.43	3.51	2.78	2.66	3.00
Y2O3	0.81	0.30	2.18	1.82	1.10	0.88	1.83	1.77	1.01	1.65
F	3.02	4.51	1.57	2.21	7.48	1.42	2.86	1.54	4.65	1.51
P2O5	0.00	0.00	0.00	0.08	0.00	8.78	17.48	8.99	7.02	9.21
SO3	3.43	2.20	0.00	27.27	2.93	31.24	6.76	31.70	7.57	9.18
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.42	0.70	0.59
CO2	2.05	2.44	6.50	7.46	8.18	10.76	10.14	8.62	17.38	13.29
SUM	100	100	100	100	100	100	100	100	100	100
gy	4.58	2.74		39.47	3.63	46.46	9.09	48.44	9.34	12.86
hl								1.47	1.97	1.90
fl	12.73	18.14	6.88	10.82	22.35	6.73	2.16	7.52	18.09	6.71
nakfl					8.82		12.28			
xeno				0.12		0.95	1.73	1.96	0.88	1.68
si2y2	0.75	0.30	2.09	1.74	0.98					
ap						18.46	33.21	18.10	11.80	17.17
nb	0.96	0.56	1.82	1.39	0.83	1.01	2.11	1.28	1.47	1.96
cpx	45.69	42.58	43.04	4.05	19.71					4.47
il		0.71		0.12	0.49		0.22	0.37	0.29	0.56
mt	0.59	1.02	0.61	0.46	0.69	0.06	0.11	0.12	0.10	0.17
cc	4.90	0.20	16.29			0.12	1.51	1.96	21.14	33.78
mc		5.39		19.68	18.24		7.57		12.00	
fec						0.24			0.10	
nc						2.20	6.33	0.92	6.78	
kc						0.48	1.57	1.47	1.57	
al2c3						0.77	8.92	1.71		
sic2						7.74		13.76		
or	5.86	23.88	1.38						5.16	6.43
ab									1.77	6.43
an										2.80
qz	18.67	4.22	21.46	22.16	24.26	5.48	13.20	0.92		
porefl	5.27	0.25	6.44			9.29			7.54	3.08
	100	100	100	100	100	100	100	100	100	100
Cu	0.01	0.00	0.06	0.09	0.00	0.00	0.05	0.00	0.00	0.10
Cr	0.00	0.07	0.04	0.06	0.00	0.00	0.19	0.27	0.15	0.24
Sc	0.00	0.18	0.00	0.06	0.00	0.00	0.45	0.28	0.19	0.60
v	0.00	0.09	0.00	0.09	0.00	0.00	0.11	0.13	0.11	0.14
Co	0.00	0.12	0.15	0.07	0.00	0.00	0.33	0.35	0.09	0.29
Ni	0.04	0.13	0.00	0.21	0.00	0.00	0.15	0.83	0.29	1.12
Pb	0.32	0.41	1.32	0.60	0.23	0.26	1.23	1.87		1.12
Sr	0.69	0.36	1.10	0.93	0.62	0.63	0.79	1.49	0.67	1.05
Ba	0.12	0.13	0.00	0.12	0.07	0.04	0.10	0.00	0.11	0.09
La	0.00	0.20	0.13	0.13	0.00	0.00	0.56	0.40	0.56	0.79
Ce	0.00	0.25	0.00	0.23	0.04	0.00	0.50	0.33	0.24	0.71
Nd	0.00	0.27	0.15	0.12	0.00	0.00	0.57	0.42	0.27	0.46
Eu	0.00	0.23	0.15	0.29	0.00	0.00	0.73	0.93	0.62	1.05
yb	0.00	0.12	0.15	0.07	0.00	0.00	0.33	0.35	0.09	0.29
Lu	0.02	0.08	0.11	0.07	0.04	0.00	0.23	0.08	0.07	0.00

S. No. 23-27 are coarse-grained sovite, beforsite, ferro-carbonatite and alkali-carbonatite enriched with volatiles of SO_3, $P_{2=}O_5$, F, and CO_2.

Table 6: *EDAX analyzes determined without Nb*

II	11	12	13	14	15	16	17
SiO2	4.51	3.46	3.03	5.72	24.26	4.83	2.54
Al2O3	2.69	2.30	1.62	3.10	7.83	2.00	1.39
FeO	0.63	0.43	0.15	0.65	0.91	0.84	1.02
MgO	1.75	1.64	1.32	1.28	3.17	11.77	3.46
CaO	53.60	50.85	57.11	49.93	28.49	48.17	57.23
Na2O	0.58	0.76	0.16	0.12	0.63	0.32	0.87
K2O	0.64	0.68	0.34	0.33	8.16	1.33	0.99
TiO2	0.20	0.33	0.00	0.00	0.45	0.26	0.43
ZrO2	0.90	1.57	2.16	2.06	1.87	2.13	3.71
Nb2O5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y2O3	0.53	0.91	1.67	1.59	0.66	1.88	2.10
F	0.56	0.53	0.00	0.19	0.62	0.00	0.74
P2O5	1.60	1.57	1.05	0.80	1.21	1.13	1.48
SO3	1.59	1.48	0.92	0.87	1.71	1.62	1.72
Cl	0.45	0.44	0.07	0.09	0.50	0.27	0.60
CO2	29.76	33.03	30.39	33.27	19.53	23.45	21.72
SUM	100	100	100	100	100	100	100
gy	2.08	1.95	1.26	1.15	2.20	2.07	2.33
hl	1.35	1.23	0.21	0.21	1.47	0.83	1.80
fl	2.34	2.15		0.78	2.62		3.13
xeno	0.52	0.82	1.58	1.15	0.63	1.66	2.01
si2y2				0.31		0.10	
ap	2.50	1.89			1.52		0.27
zr	0.73	1.33	1.79	1.77	1.57	1.76	3.18
cpx		2.76	0.37		18.51	3.88	
il	0.21	0.41			0.63	0.31	0.53
mt	0.05			0.05	0.05	0.05	0.05
cc	70.38	76.91	72.67	78.79	46.57	55.15	52.39
ks		2.15	1.11		24.23	2.79	1.91
ne		2.00	0.47			0.31	
or	3.64			1.82			
ab	1.56			0.52			
an			2.90	0.78		2.33	
porefl	14.63	6.40	17.64	12.66		28.76	32.40
	100	100	100	100	100	100	100
Cr	0.09	0.11	0.00	0.00	0.29	0.05	0.22
v	0.05	0.10	0.00	0.00	0.25	0.03	0.20
Co	0.11	0.18	0.00	0.00	0.43	0.11	0.37
Ni	0.04	0.14	0.00	0.00	0.21	0.00	0.17
Pb	0.20	0.25	0.47	0.00	1.38	0.34	1.52
Sr	0.36	0.47	0.71	0.53	1.16	0.78	1.15
Ba	0.05	0.10	0.00	0.00	0.25	0.03	0.20
La	0.40	0.47	0.00	0.00	0.92	0.17	0.72
Ce	0.21	0.18	0.00	0.00	0.57	0.36	0.48
Nd	0.23	0.31	0.00	0.00	0.66	0.22	0.64
Eu	0.27	0.26	0.00	0.00	0.88	0.29	0.66
Dy	0.12	0.21	0.00	0.00	0.53	0.17	0.40
yb	0.39	0.26	0.00	0.00	0.53	0.57	0.69
Lu	0.28	0.25	0.00	0.00	0.81	0.22	0.89

S. No. 11, 12, 13 and 14, represent very fine-grained laminated yellowish pink carbonatite lava. Others are black coloured carbonatite lava. S.No. 12 and 13 are composed of normative nepheline and kalsilite. S.No. 15, 16, 17 represent pale-green carbonatite lava porphyries.

Table 7: *EDAX analyzes of black lapillus carbonatites*

I	1	2	3	4	5	6	7	8	9	10
SiO2	4.27	1.29	3.79	1.40	10.62	1.63	1.59	1.38	1.40	1.36
Al2O3	1.91	1.16	1.70	1.36	3.46	1.33	1.34	1.01	0.85	1.16
FeO	0.32	0.24	0.32	0.26	0.56	0.32	0.26	0.15	0.14	0.31
MgO	3.37	2.72	2.94	2.61	4.85	3.50	3.96	3.05	2.63	3.22
CaO	49.08	41.34	48.17	41.09	43.86	42.74	38.96	49.74	41.54	43.12
Na2O	1.19	1.21	0.73	1.29	0.83	1.44	1.63	1.24	1.20	1.06
K2O	0.52	0.49	0.36	0.49	0.58	0.54	0.53	0.36	0.49	0.52
TiO2	0.24	0.25	0.00	0.25	0.14	0.08	0.21	0.00	0.22	0.17
ZrO2	1.16	1.57	1.37	1.64	1.16	2.26	1.74	1.45	1.79	2.30
Nb2O5	1.21	2.06	1.30	2.02	2.09	1.84	2.11	1.25	3.31	1.80
Y2O3	0.88	1.36	0.78	1.83	1.22	1.52	1.52	1.47	1.03	2.10
F	1.20	1.36	1.16	1.66	1.33	1.04	1.79	0.83	1.35	0.69
P2O5	1.63	1.46	0.99	1.65	1.79	1.56	1.47	1.37	1.31	1.56
SO3	1.22	1.13	0.63	1.24	1.08	1.64	1.32	0.98	1.10	1.70
Cl	0.40	0.35	0.22	0.38	0.41	0.49	0.39	0.25	0.35	0.37
CO2	31.41	42.00	35.56	40.84	26.03	38.08	41.16	35.47	41.31	38.56
SUM	100	100	100	100	100	100	100	100	100	100
gy	1.52	1.39	0.81	1.51	1.42	2.01	1.69	1.22	1.40	2.15
hl	1.11	0.99	0.61	1.10	1.22	1.41	1.09	0.71	1.00	1.02
fl	4.81	5.35	4.73	6.57	5.37	4.12	7.00	3.36	5.35	2.82
xeno	0.81	1.19	0.71	1.61	1.12	1.31	1.29	1.32	0.90	1.95
ap	2.28	1.19	0.97	0.95	1.88	1.20	1.04	0.92	1.20	0.41
nb	0.66	1.19	0.76	1.15	1.22	1.41	1.04	0.46	1.90	1.08
zr	0.91	1.29	1.12	1.30	0.91	1.81	1.39	1.22	1.50	1.95
il	0.30	0.30		0.30	0.20	0.10	0.30		0.30	0.20
mt	0.00	0.00			0.05					
cc	72.23	66.53	81.34	66.43	59.91	70.28	61.37	81.95	67.56	74.24
mc		6.14	0.81	5.82		8.33	9.04		5.10	7.68
nc		2.18		2.06		2.41	3.13		2.20	1.84
kc						0.85	0.84		0.75	0.87
al2c3		1.63		1.30		3.26	2.93		2.15	1.79
sic2						1.36	1.94		1.00	0.61
ol	0.15		3.41		5.78					
ks	2.78	1.49	1.22	1.51	1.82			1.22		
ne			2.59		2.28			0.46		
an					5.27					
ns	4.10									
porefl	8.35	9.16	0.91	8.38	2.08	0.15	5.91	7.17	7.70	1.38
	100	100	100	100	91	100	100	100	100	100
Sc	0.25	0.23	0.00	0.35	0.29	0.11	0.32	0.20	0.17	0.17
V	0.10	0.08	0.00	0.08	0.20	0.18	0.12	0.00	0.10	0.15
Co	0.12	0.15	0.00	0.12	0.25	0.17	0.17	0.00	0.12	0.20
Ni	0.00	0.07	0.00	0.12	0.25	0.13	0.13	0.07	0.08	0.13
Pb	0.19	0.57	1.31	0.29	1.22	0.72	0.55	0.89	0.49	0.95
Sr	0.53	0.76	0.99	0.80	1.04	0.88	1.03	0.95	0.69	1.20
Ba	0.00	0.00	0.24	0.00	0.21	0.45	0.12	0.00	0.00	0.29
La	0.33	0.38	0.00	0.35	0.24	0.45	0.34	0.00	0.31	0.38
Ce	0.21	0.38	0.00	0.44	0.30	0.15	0.28	0.00	0.27	0.25
Nd	0.28	0.22	0.00	0.19	0.59	0.44	0.31	0.00	0.21	0.39
Eu	0.30	0.28	0.00	0.49	0.35	0.54	0.37	0.00	0.37	0.24
Dy	0.12	0.24	0.28	0.00	0.66	0.18	0.15	0.00	0.17	0.20
yb	0.39	0.33	0.59	0.25	0.25	0.48	0.42	0.27	0.41	0.35
Lu	0.25	0.27	0.25	0.47	0.76	0.59	0.18	0.17	0.33	0.53

S.No. 1-10 represent EDAX analyzes of black lapillus

ACKNOWLEDGEMENT

The author sincerely thanks to Mr. T. Ragavaiya , the Senior Technician in Dept, of Metallurgical Engineering and Material Science Laboratory, IITM, Chennai, 600036 for his help during SEM and EDAX analyzes of rock samples. He express thanks to Mr. C. Ramalingam and Mr. K. Balasubramanium, Assistant Geologists. Tamil Nadu State Department of Geology and Mining for their help during field investigations.

List Item – 1 Figures-5

List Item - 2 Tables -7

List Item – 3 Pages 1-10

List Item - 4 References-18

REFERENCES

[1] O.F. Tuttle and J. Gittins *Introduction*- in Carbonatites pp. xi-xiii J. Wiley, New York, 1966

[2] R. Dawsons, *Carbobatitic tuff comes in Northern Tanganyika,* Geo Mag. v. 102, pp129-1371,964.

[3] R. Ramasamy, *Carbonatite volcanism related to mineralization in Kudangulam area, near Cape Comorin, Tamil Nadu,* WBO3, Mineralization and alkali magmatism in the Deccan Igneous Province and in other parts of the world, 30th I.G.C, Beijing, 1996 abst 1, p13.

[4] R. Ramasamy, *Evidences of Neocene carbonatitic volcano-tectonic deformations in Kudangulam area, Cape Comorin, Tamil Nadu,* Tamil Civilization, v. 14-18, pp.167-179, 1996-2000

[5] 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.

[6] 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.

[7] V.V. Sastry, *Observations on the age of Deccan Trap and related trap activity in India,* Geol. Soc. India, Mem. No. 3 pp 296-299, 1981.

[8] R. Ramasamy *Occurrences of soda-trachyte near Kudangulam village, Tamil Nadu, South India,* Curr, Sci. v 61, pp. 401-402, 1991.

[9] R. Ramasamy *Occurrences of olivine-tephrite and carbonate-tephrite in Kudangulam area, near Cape Comorin, Tamil Nadu, India,* J. Geol. Soc. of India, v 45 (3) pp.331-333, 1995

[10] R. Ramasamy, *Carbonatite dykes from Kudangulam area, near Cape Comorin, Tamil Nadu,* J. Geol. Soc. of India, v. 48 (2), pp. 221-226, 1996.

[11] N.K.N. Aiyengar, *Minerals of Madras State*, Dept. of Geology and Mining, 1966.

[12] S.V. Vaikundam, C. Ramalingam, and K. Balasubramaniam, *A Report on the detailed Investigation for shell limestone in Kudangulam village, Radhapuram Taluka, Thirunelveli District, Tamil Nadu,* Department of Geology and Mining, 1983

[13] P.K. Muralidharan *Geological and Geomorpho-lohical mapping of Quaternary sediments around Thiruchendur area, V.O.C District and Kanyakumari area, Kanyakumari District, Tamil Nadu,* Geol. Surv. India Prog. Rept. 1986-87.

[14] E.W. Verdenburg *Considerations regarding the age of Cuddalore Series*, Geol. Surv. India, Rec. 36, pp. 321-323, 1908

[15] S. Narayanaswamy *Geology and mineral resources of the Tiruchendur and southern and eastern portions of Nanguneri Taluk, Thiunelveli District, Tamilnadu,* Geol. Surv. India unpub. Rept. 1946-7

[16] A. Rittmann *Stable Mineral Assemblages of Igneous Rocks,* Spinger Verlag, Berlin, 264p 1974

[17] J R. Goldsmith and R.C. Newton *P-T-X relations in the system $CaCO_3$-$MgCO_3$ at high temperatures and pressures.* J. Amer. Sci. v. 267, pp.160-190, 1969.

[18] R. Ramasamy *Carbonate-apatite from carbonatites of Kudangulam near Cape Comorin Tamil Nadu,* Indian Minerals, v. 46 (1), pp91-94, 1992.

AUTHOR'S BIOGRAPHY

Awarded Ph.D. Geol Univ. Madras. 1974. Served as Field Geologist DGM PDF 1977-80 MSU. Project. Advisor DOE & DCE IITM