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Ring fractures around Sri Lankan Island

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Abstract: *Ring fracture seen around Sri Lankan Island is reported. The geological evidences are basalt, carbonatite and silicate-perovskite volcanic activities in and around Tamil Nadu, Sri Lanka and Central Indian Ocean Basin. The deposition of Mio-Pliocene to Quaternary limestone covering the fracture on the northern portion of the island is one of the evidences defining shape, size and age of ring fracture composed of discrete net-work of fracture system. The deep fractures might have been opened vents for volcanic, magmatic activities and hydrocarbon deposits around periphery of Sri Lanka. More geological studies are required to trace evolution of the ring fracture seen around Sri Lanka.*

Keywords: *Sri Lanka, Ring fractures, Micro-plate margins, Carbonatite lava activities, Hydrocarbon deposits.*

1. INTRODUCTION

During the course of study of offshore structure by using Google Earth Images discrete fracture net-work system forming a ring like circular feature was observed around Sri Lanka (Fig. 1).

Fig 1: *Google Earth Image showing ring fracture around Sri Lankan Island and its boundary with Central Indian Ocean Basin (CIOB) in the South Eastern portion.*

HC- Highland Complex; VC- Vijayan Complex, WC- Wanni Complex, Sedi- Sedimentary rocks

Geological ring-fracture or circular feature is topographic expression that has certain genetic significance. It indicates release of tectonic stress at depth leading to earthquakes, magmatic and volcanic activities. It causes subsidence of land-mass, formation of folds (doublely plunging anticline / syncline), divergent or convergent micro plate margin, volcanic or earthquake prone zone, island arc, geosyncline, dome or basin, annular drainage pattern, ring-dyke, cone-sheet, emplacement of magmatic fluid and cauldron subsidence of volcanic pipe. Meteoritic-impact structure is also produced such fracture. Ring fracture might have been created from unknown tectonic deformation at deep-interior of the Earth. The process that leads to ring-like topographical modifications on surface of the Earth is yet to be studied. The structure that makes possible in a discrete net-work of fault system. The system is composed of concentric normal faults around outside of the ring. Any release of tectonic stress at depth inside the global Earth may be triggered earthquake energy in the form of funnel-like configuration leading to form ring-like or curvilinear fracture on the surface of the Earth. The radius of the funnel and steepness of slope determines the depth of origin of tectonic forces that may be caused earthquakes, magmatic, volcanic or micro-plate tectonic movements. Each micro-plate has both a convergent margin consuming older rocks and a divergent plate margin with a hot-spot underneath. Almost equal proportions of lavas erupted at divergent plate margin cause consumption of older rocks at convergent margin or at oceanic trench. Thus origin of ring fracture is multi-facet and enigmatic. The development of ring fractures depends up on the depth and intensity of tectonic stress released through, rigidity of host-rocks, magnitude, space and time. Detailed field and petrographical studies are warranted to solve the various puzzles encountered with ring fractures.

2. GEOLOGY

The deep submarine canyon encircling east and south of Sri Lanka below -4000m depth and relatively shallow depth in north-west and west appears to be a form of steeply inward dipping ring fracture. The mean depth of the offshore ring-structure -2300m msl encircles Sri Lanka and Peninsular India together. The ring fracture seen around Sri Lanka is slightly elliptical in nature with 450 km length in N-S direction and 440 km width in E-W direction. The approximate depth tectonic stress released varies between 820 and 2515km below the surface of the Sri Lanka. The depth reaches to the position of lower mantle (660-2891km) for inward dipping fracture varying between 75° and 85°. The general feature of the ring fracture reveals that Sri Lankan block has been uplifted and fragmented into several small blocks of different dislocations and orientations. The lineaments expressed by these blocks bounded with faults reveal geological settings of the Sri Lankan Island during younger block tectonic movements [1, 2, 3]. The geology of Tamil Nadu is very similar to that of Sri Lanka. The Geology of the Highland Complex (HC) of Sri Lanka [2] is very similar to that of the rocks lying south of Cauvery lineament between Karur and Cape Comorin-Madurai Block [3]. These rocks are charnockite, garnet-sillimanite gneiss, quartzite, calc-granulite and crystalline limestone. The Precambrian rocks of Vijayan Complex (VC), Wanni Complex (WC), Kadufannawa Complex (KC) and other smaller blocks of rock units in Sri Lanka are comprised of granitic gneisses migmatized by emplacements of younger granite plutons. They show imperceptible gradation to the rocks of HC. Similar variations exist between granitic gneisses and granulitic rocks of Tamil Nadu. The rocks in the HC in Sri Lanka may be correlated to the rocks lying between Karur and Cape Comorin. They are subjected to extensive shearing and silicification of granite gneiss with development of quartzite and sporadic gem and graphite mineralization and hydrocarbon bearing fluid-inclusions in quartz are very similar to the rocks of Tamil Nadu and Sri Lanka. The shape of the terrain is inherited from the trend and character of the initial rift [4, 5, 6], but it also reflects subsequent modification. The present form of many faults and continental slopes results from reactivation over initial tectonic rifts. The configuration and characteristics of sedimentary sequences are controlled by tectonically driven growth fault and subsidence [7, 8].

3. BASALTIC AND CARBONATITE LAVA FLOWS

As Indian plate included with Sri Lanka moved NNE direction, it is possible that the thickness of the Indian plate degenerated further as it passed over Reunion hotspot. Huge volumes of Deccan Trap lava flows associated with release of massive amounts of gases [4-8] during the passage of movements of Indian Plate over the hotspot. Several types of fault-planes, ring fractures might have been developed followed by effusions and escape of volcanic gases from deep-seated sources. Very large volumes of basalts, small volumes of carbonatites, insignificant volumes of silicate-perovskite [9] recent basaltic effusions, warm mud flows and hot-springs are notable incidences in Peninsular India, Tamil Nadu and Sri Lanka. Besides, several rootless basaltic, carbonatitic and silicate-perovskite flow of insignificant volume often less than 1 m^3 are seen. Such insignificant volume of basaltic flow between the years 1996 and 2004 is also notable event. They have particularly taken place in the southern parts of the Peninsular India. The chemical compositions and trace-element signature indicates that they originated from deep mantle source [9-22]. Basaltic flow is widely spread in north and north-western part of Central Indian Ocean Basin (CIOB) exceeding over several thousands of squares kilometers [4-8] and at depths greater than -4000m [10]. On land basaltic rocks were reported near Kudangulam area [11, 12], Karaikal-Dharangambadi coast [13], Mylampatti [14] and in off-shore 3 consequate basalt sub-crops in Cretaceous sandstone at about -4000m depths in borehole sections [10] near Mandapam in Mannar Tamil Nadu. Occurrences of atypical and degassed carbonatitic lava agglomerates, lapillus and pisolites in association with soda-trachyte [11], olivine tephrite [12] apatite-phlogopite sovite [20, 21] were reported from Kudangulam (near Cape Comorin). Grey and pink coloured bi-model volcanic carbonatite lapillus, pisolites, ashes occur in Mio-Pliocene calcareous gritty sandstone [19] near Thiruvalangadu village located at 60 km west of Chennai. Again platelets of carbonatitic lava fragments with olivine-tephrite along the coast of Dharangambadi - Karaikal [13] further indicate similar type of volcanic activities along the coast of Tamil Nadu. Occurrence of carbonatite-lava in crystalline limestone formation of Palayam, Ettimadai (Coimbatore), Walaiyar, Pandalgudi, Maravaperugudi and Vilathikulam [14, 15] in the form of very small rootless diatreme indicates a wide spread carbonatitic lava activities in Tamil Nadu. However, these volcanic carbonatites contain low LREE but high HREE contents with absence of differentiated alkali derivative except minor occurrence of soda-trachyte and tephrite [12]. An imperceptible gradational variation is seen between trachyte and carbonatite lava in some well sections near Kuttam and Kudangulam villages. The characterization of continental rifting and de-gassing of volatiles and direct eruption of mantle carbonatite are well explained by D.K. Bailey [23, 24]. Dolerite dykes of south-western portion of Sri Lanka representing bulk rock composition of basalts with varying ages between153 and143Ma are seen [25]. Dolerites of Sri Lanka and Tamil Nadu have similar petrographical features.

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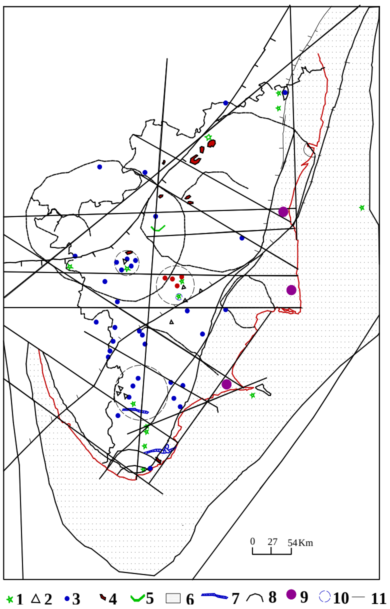

1 Basalt, 2 Silicate perovskite, 3-Carbonatite lavas 4 Alkali syenite carbonatite 5 Anorthosite 6 Sedi-mentary rocks 7 Kankar 8 Arc-shaped fractures 9 Petroleum Deposits 10 Circular Features, 11 lineaments [9].

Fig 2: *shows ring fractures and associated magmatic and volcanic activities in Tamil Nadu*

Many rootless basaltic eruptions [14, 15] near Sirukinaru (Dharapuram); Abisheakapatti, Thrupani-karisalkulam, Nanguneri Anikulam (Thirunelveli); Vadamambakkam, Nagavedu (Arakonam) and Top-slip (Pollachi) are reported [14, 15]. Petrography and detailed geochemical study reveals that they represent true basaltic characteristics and mode of eruptions. The EDAX analyses of bulk composition, individual grains and matrix of recent effusive between 1996 and 2004 (Fig. 4-6) show that they vary between tholeiitic and alkali basaltic composition. The major elements of Si, Al, Fe, Mg. Ca, Na, K and Ti are within the limits chemical composition of basalts. They enriched with significant amount of trace elements of C, F, Cl, P, S, Dy, Y, U, Pb, Sr, Hf, Zr, Ta and Nb. Similar trace element-

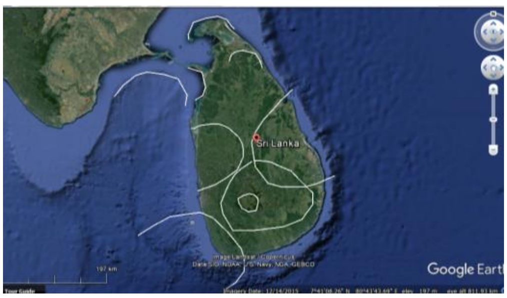

Fig 3: *Based on geomorphological features circular and curvilinear fractures are identified except outer ring fracure shown in Fig.1*

Fig 4: *a) The eruptive lava material clings on the branches of a tree 20 m away from the orifice b) narrowing of orifice / vent downwards hardly extend 50 cm below the surface at Sirukinaru village.*

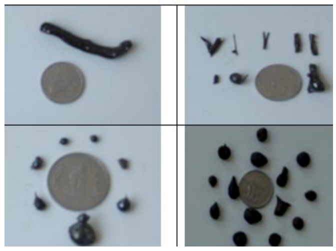

Fig 5: *Glassy shards, pelehairs and globules throwout from the orifice at Sirukinaru*

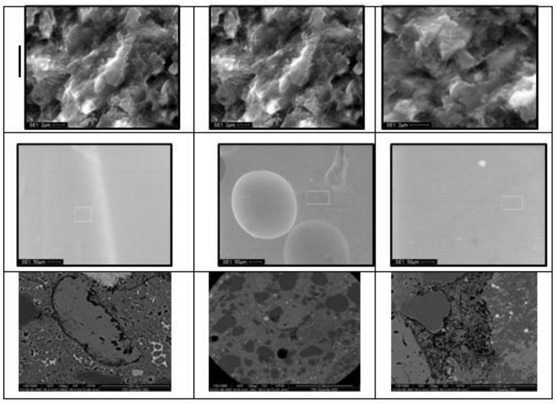

Fig 6: *Scanning Electron Microscopic images of erupted basaltic lava at Sirukinaru (Dharapuram), some grains are 8x2, 4x 3 1x0.5 µm and fine grained glassy matrix, some grains have corroded outlines and some have dark inclusions*

pattern is seen in carbonatite lava and silicate perovskite lava occurring in Tamil Nadu. Such lava effusive derives from very deep-seated source ascending as microplasma-plumes that transformed into lava at near surface conditions just before quenching out into solid on the surface of the Earth [9]. Curvilinear, circular or ring fracture with steep dip, cause vent for such effusion and degassing. The earthquake tremors with intensities of 3 to 4 in Richter's scale followed by warm mud water-flow in the village Mandalawadi located at the foot-hill of Elagiri, Tamil Nadu took place 1998. 12 hot springs were reported [16] on plate margins of Sri Lanka. Similar type of sudden arise of a hot spring with smokes was reported in Panama City [17]. Most carbonatitic lava flows are very small in volume and they are rootless (maximum size of 5 m length 5cm width with a maximum depth of 30 cm for the lava body [15] near Mylampatti). Detailed field studies are required to locate such small exposures of volcanic activities in Sri Lanka too. An occurrence of silicate perovskite (Fe-Nb-Zr-Y-Si-Ti oxide) lava [9] flow (Maximum 200m x 100m x15m on the bank of Hanuman River, Sambavarvadakarai (Thirunelveli District, Tamil Nadu) was reported [9]. Small quantities of lava or oxide flows were reported from several parts of Tamil Nadu [9]. CO_2 liquid CO_2, HCO_3 and CH_4 bearing fluid inclusions are found in quartz in some pegmatites in Karur and Dharmapuri Districts [26, 27]. Structural evolution and mineralization of graphite and semi-precious mineral in Tamil Nadu and Sri Lanka are identical to each other [26, 27]. Geophysical studies also prove this fact [28]. Gulf of Mannar covering over 250000 km^2 has 28 producing wells in Tamil Nadu [29-32] in India. Hydrocarbon deposits are also found in Gulf of Mannar of Sri Lanka below -4000m in sandstone-beds enclosed by shale beds [32] It is quite possible that huge volume of hydrocarbon ascent from deep lower mantle and core of the Earth in the form of plasma-plumes and form as large deposits within the enclosure of shale in sandstone formation, in fractured crystalline rocks or below thick ice-caps in the polar permafrost regions [33]. A global survey of hydrocarbon deposits indicates that, many hydrocarbon deposits were closely localized with carbonatite-lava in the Eastern Hemisphere [34].

4. AGE

The deposition of Mio-Pliocene to Quaternary sediments in the northern portion of Sri Lanka over the ring fracture defines shape, size and age of the structure belonging to just prior to the deposition of sedimentary sequences. The carbonatite lava occurrence belongs to the age of Mio-Pliocene (Kudangulam). The bi-modal grey and pink carbonatitic bombs, lapillus, pisolites and ashes in Early Pleistocene boulder / conglomeritic sandstone in Thiruvalangadu, near Chennai also gives minimum age of Early Pleistocene carbonatitic volcanic activity. Further, outcrop of silicate perovskite flow at Sambavar-vadakarai belongs to nearly 5000 years old. The very recent basaltic effusions in certain parts in some of Tamil Nadu between 1996 and 2004 are also gives important clues on the evolutions of tectono-volcano-magmatic activities in Tamil Nadu and Sri Lanka. The close association of Precambrian rocks along the ring fracture, it is apparently known that the ring fracture developed during Precambrian Period might have been re-opened time to time to a depth of deep interior of the Earth. The determination of age of fracture zone and emplacement of magmatic and volcanic rocks rather a complex problem and many puzzles are to be solved to trace evolution of the fracture.

EVIDENCES

The reviews of geological records of Sri Lanka and Tamil Nadu, India reveal that:-

- Several occurrence of circular ring-feature in Tamil Nadu and Sri Lanka
- Regional lineaments trending NNW-SSE, N-S, NE-SSW and E-W direction
- Ring fractures guide many rivers
- Centrally uplifted land mass in the Island.
- Deep fault and shear zone ranging age from Precambrian to Recent with reactivations in younger period
- Occurrence dolerite and gabbro equivalent to the bulk composition of basalt.
- Volcanic rock: bi-model carbonatite lava, apatite-magnetite rock and silicate-perovskite lava flow in Tamil Nadu
- Occurrence Eppawala carbonatite [22] in Sri Lanka along the boundary of HC and VC.
- Fluid deposited graphite mineralization is inferred by the presence of graphite crystals orient perpendicular to vein walls in granitic gneisses of Sri Lanka and Tamil Nadu [26, 27]. Such graphite crystals show high degree of ordering of sequential crystallization giving rise to rosette, spherulitic aggregate displaying radial array [26, 27].
- Fluid deposited hydrocarbon deposits in Cauvery Basin and Offshore Gulf of Mannar region [28-30] and off-shore region of Sri Lanka.
- Fluids deposited gem minerals in Sri Lanka and Karur Gem Tract of Tamil Nadu are similar.
- Identical geological settings between Tamil Nadu and Sri Lanka with horst-graben and block tectonic movements with extensive silicification leading to form quartzite
- Immediate plate boundary of the Central Indian Ocean Basin (CIOB) spreading with basalts at the south and south east of Sri Lanka

- Age of ring fracture was assumed to be just prior to the deposition of Mio-Pliocene and Quaternary limestone. In Tamil Nadu such rocks are included with lapillus an pisolites of carbonatite lapillus and pisolites in Kudangulam and Thiruvalangadu area
- Indian Plate rapidly moved between Jurassic and Miocene Period which was the peak period continental drift from Madagascar (Africa) and Antarctica pull-apart diverging plate tectonic movements.
- Presence of Jurassic dolerites indicates basaltic volcanisms in Sri Lanka [25]
- Copper-magnetite mineralization in Sri Lanka
- Copper mineralization in the shear zones of Mamandur, near Thiruvannamalai and Mo-Pb-Zn mineralization near the carbonatite Complex of Tirupattur near Enjambakkam
- Presence of several pockets of anorogenic anorthosite bodies
- Mantle derived rocks of pyroxenite and serpentinite in Sri Lanka and in Tamil Nadu
- Occurrences of 12 thermal springs in Sri Lanka; similar springs are reported from Thiruduraipundi, Adhiramapattinum and in Agniyar basin (30-90^{o}C) Tamil Nadu [1].
- Mild earthquake hazard is low in onshore regions while in the Gulf of Mannar experiences M 5.0-6.0; intensities [1]
- Warm mud flow event followed by mild earthquake tremor 3-4 in Mandalavadi village at the foot Elagiri Hill
- Two principal mantle-discontinuities beneath Palk Strait were found at 418 and 678km respectively, which are both deeper than the global averages, suggesting a hotter upper mantle [28]

5. CONCLUSIONS

The maar-like structure or ring fracture associated has a net-work of deeply inward dipping normal faults extend to mantle. The rootless effusion due to rapid ascends of plasma-plume [9]. The boundary between HC and VC is formed by converging plate movements [2, 3] with exposure of mantle derived pyroxenite and serpentinite at one margin, the faulting and uplift of HC by block-tectonic horst and graben movements at other end of diverging micro-plate margin. Sri Lanka might have been composed of a few more micro-plates which are yet to be identified to get a clear picture on the evolution of Sri Lanka and Tamil Nadu and to locate economic mineral and hydrocarbon deposits.

List Item – 1 Article with 6 pages

List Item - 2 Six figures

List Item – 3 34 References

List Item - 4 Author's bibliography with photo

REFERENCES

[1] K. Gopalakrishnan, B. Badrinarayanan, and K.S. Subramanian, *Geological setting of Palk Bay-Gulf of Mannar area between India and Sri Lanka: Their relevance to Sedu Samudram Shipping Canal* Project –Feasibility Rept., Geol. Surv. India, Kolkata 2007.

[2] M.B. Katz, *Sri Lanka-India Intra-plate Tectonics – Precambrian to Recent, Gondwana* Research, **3** (1), 3-5, 2000

[3] Ingo Brown and Leon Kriegsman *Proterozoic crustal evolution of southernmost India and Sri Lanka,* Geol. Soc. London Spl. Publication, v. 206, 169-202 2003

[4] R. Ramasamy, *A possible paleo-rift system of the Eastern Ghats in Peninsular India,* J. Moscow State Univ., Geology, Ser 4(2),pp 32-37 (Russian) 1982.

[5] R. Ramasamy *A submarine trench along the eastern coast of Peninsular India,* Current Science, v. 93 (12) 2007, pp.1650-51 2007.

[6] A.D. Mukherjee, S.D. Iyer, *Synthesis of morpho-tectonics and volcanic of the Central Indian Ocean Basin,* Current Science, v. 76, pp.296-304, 1999.

[7] Christine Deplus *Indian Ocean activity deforms, Science, v.292* (5523). 1850-51 2001.

[8] Kumar Prakash, Y. Xiaohui, M.R. Kumar, K. Rainer, Li. Xueqina, R.K. Chadha, *The rapid drift of the Indian tectonic plate,* Nature, v.449 (7164), pp.894-897, 2007.

[9] R. Ramasamy, *Silicate perovskite (Si-Fe-Nb-Ca-Ti) lava flows in Tamil Nadu,* IJISSET, v. 2 (11), pp.8-15, 2016.

[10] 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.

[11] R. Ramasamy, *A note on the occurrence of soda-trachyte from Kudangulam area near Cape Comorin, Tamil Nadu, Current Science,* **v.**61, 401-403, 1991.

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

[13] R. Ramasamy, *Carbonate-tephrite and bi-model carbonatite lava occurrences in Dharangambadi-Karaikal coast, Tamil Nadu, India,* IJMSET, v. 1. (6) pp. 15-30, 2014.

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

[15] R. Ramasamy, *Petrographic observations on lava-tube injections and eruptions and spray of volcanic beads in Tamil Nadu and evolution of plume tectonics of Indian Plate Workshop on Plume Tectonics,* NGRI, Hyderabad, Abst. pp.32-33, 2000

[16] www.srilankatrekking.com/hot.springs.in.sri.lanka.htm

[17] Cr, L.LB. Pierce, *Hot smoke baffles Geologists, Panama City News Herald* p 1B Sept, 5, 1992.

[18] R. Ramasamy, *Occurrence of carbonatite dykes in Kudangulam area, Near Cape Comorin, Tamil Nadu, Journ. Geol. Soc. India, v. 48*,pp. 221-228, 1996

[19] 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.

[20] R. Ramasamy, R. *Evidences of Neocene-carbonatitic volcano-tectonic deformations in Kudangulam area, Cape Comorin, Tamil Nadu, Tamil Civilization*, v14 pp.167-179, 1996.

[21] 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..

[22] M.A.G.M. Manthilaka, Y. Sawada, and S. Sekai, (2008) *Genesis and evolution of Eppawala carbonatites, Sri Lanka, Journal of Asian Earth Sci.,v.*32, pp. 66-75, 2008.

[23] D.K. Bailey, *Continental rifting and mantle degassing,* in Neuman, ER and Ramberg, IB (edrs) *Petrology and Geochemistry of Continental Rifts* D. Reidal Publishing Company, Holland, pp 1-13, 1978

[24] D.K. Bailey, *Mantle carbonatite eruption: Crustal context and implications, Lithos v. 26, pp.* 37-42, 1990

[25] M. Yoshida, M. Funaki, and P.W. Vitanage, A Jurassic-Cretaceous dolerite dyke from Sri Lanka, Journ. Geol. Soc. India, v. 33(1) Jan 1989.

[26] R.C. Newton and C.E. Manning, Role of saline fluids in deep crustal and upper mantle metasomatism: insights from experimental studies, " Frontiers in Geofluids" Edrs B. W,D Yardley and C. Manning, Geofluids, v. 10, pp. 58-72, 2010

[27] F.J. Luque, J. D. Pasteris, B. Wopenka, M Rodas,. and J.F. Barrenechea,. *Natural fluid deposited graphite: mineralogical characteristics and mechanisms of formation, American J. Sci.,* v. 298 June, 471-498, 1998,

[28] F.Pathak, Arundhati, M. Ravi Kumar, and D. Sarkar, *Crustal structure and Tectonic Evolution of the Southern Granulite Terrain India, Seismic structure of Sri Lanka using receiver function analysis: A comparison with other high grade Gondwana terrains,* Gondwana Research, v.10 (1-2), pp.198-202, 2006.

[29] N. Gunaratne, Oil exploration soon in the Mannar Basin, The Sunday Times, Financial Times, ISSN: 1391-0531, 15th June 2008.

[30] https://www.oxfordbusinessgroup.com/.../tapping-offshore-deposits-mean-country-co

[31] www-prde-srilanka.com/exploration/mannar

[32] *Offshore South East Asia Show Geology and hydrocarbon Prospects of East Coast Basins if India and their relationship to evolution of the Bay of Bengal* 12th Feb 1982, Singapore, 1982

[33] R. Ramasamy, SP. Subramanian, R. Sundara-vadivelu, *Formation of gas hydrates at deep interior of the Earth and their dissipation to near surface horizon,* Journal of Geological Research, v 2013, 11p. 2013.

[34] R. Ramasamy, SP. Subramanian and R. Sundara-vadivelu, *Carbonatite emplacement and localization of gas hydrates in the ocean floors of Eastern Hemisphere,* 8th ISOPE, Ocean Mining Symposium, NIOT, Chennai, India, Gas hydrates, pp.88-95 2009,

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