J. Ind. Geophys. Union (September 2017)
v.21, no.5, pp: 384-390

Deep Mantle Plumes and Origin of life on the Earth

U.Raval*
Scientist (Retd), CSIR-NGRI, Hyderabad-500 007, Telangana State
upen0106@gmail.com

ABSTRACT
Origin of the life on the earth remains one of the great mysteries in our scientific exploration of the Nature. The investigations for this naturally require combining the geo- and bio- sciences. The present study outlines the two leading hypotheses for the origin; viz. "The primordial soup" and "ocean floor based alkaline hydrothermal vents", along with search for the antiquity of life on the earth. Further the study discusses volcanism triggered conditions/or the thermo-chemical environment that could lead to the emergence of life. It is proposed here that during the earliest phase of earth's life (i.e. in the Hadean era) the deep mantle plumes (DMP) seem to be the basic (or root) driving source for creating the essential pre-requisites, P.T/ conditions & the chemical/ bio-chemical processes that eventually gave rise to the "Miracle of life".

Key words: Deep mantle plume, Origin of life, The primordial soup, Hydro thermal vents, Hadean era.

INTRODUCTION

Life on earth, in this vast universe, has been quite lonely, since it has not been proved, so far, on any other astro-body (Williams and Russel, 2003, 2007), although conjectures and speculations based on continued astronomical observations do point out some favourable locations (both near and far) where life might exist or evolve (Russel 2006, 2011). In this connection there is an interesting suggestion by Prof. Stephen Hawkins that another celestial body-- a few billion light years away-- may have more evolved civilization than ours, and hence on contacting them, they may behave the same way as Europeans did with native Americans. One wonders that if they are more evolved then why they will necessarily be hostile and use power/strength rather than compassion and be empathetic and helpful.

Among the various hypotheses about the origin of life on the earth (Nisbet 2000) some major ones are

1.Simple beginning 2.Panspermania 3.RNA world 4.Chilly start 5.Deep sea vents 6.Community clay & 7.Electrical spark. From these, the following two ideas gained predominance viz. A) Primordial soup & B) Deep ocean (alkaline) hydro thermal vents (HTV). In the primordial soup scenario complex organic molecules are created by spontaneous chemical reaction. With passing of time these complex molecules, such as amino acids & nucleotides, accumulate in warm little ponds and eventually join together to form proteins and nucleic acids. For many decades the primordial soup hypothesis remained the favourite explanation. As per this hypothesis life begins in warm ponds triggered by energy from lightening spark and/or ultra-violet-light.

However, in the recent times the concept that life emerged near the hydro thermal vents-- formed by the volcanism at the deep ocean floor-- is getting much attention due to increasing significance of HTV. As will be seen later the vent hypothesis supports the thermophylic origin. For example in the July 2016 issue of Nature Microbiology (Service 2016), it has been suggested that the environment within the vents satisfy the conditions so the hydrogen rich scenario feeds the last universal common ancestor (LUCA) of all living beings.

The Hydro Thermal Vents

In its earliest phase the earth plummeted by asteroids, meteors and comets and hence survival of the crust and life (if any) would have been extremely difficult. Hence for the origin, evolution and survival of life one has to look for a 'safer location' and the ocean floor could be one such place. Till 19th century researchers believed that there was no life in the deep. But during the exploration by Challenger in 1872 & 1876 (Rice, 1999) its dredges and trawls brought up living beings from all depths that might be reached. Thus, since more than a century scientists knew that 'bacterium' life exists in the ocean. This gave the clue that life-if possible during the early Archean and Hadean- might originate, evolve and survive on the deep ocean floor. In this context the deep sea expedition during 1977 in the Galapagos region of the Central America, brought out existence of an entire eco-system (Shank & Holden, 2011). It may be noted that this region has been strongly affected by a deep mantle plume. This discovery from the deep sea expedition has been regarded as one of the greatest in the 20th century, as it focused attention on the deep ocean floor for the origin and evolution of life on the earth. Further the regional geology and geodynamics of the Galapagos indicate possible significance of the magmatism on the ocean floor.

During the expulsion of internal heat through large scale volcanism caused primarily by the mantle plumes, there is a continuous steaming out of gases (H2,N2, CO,

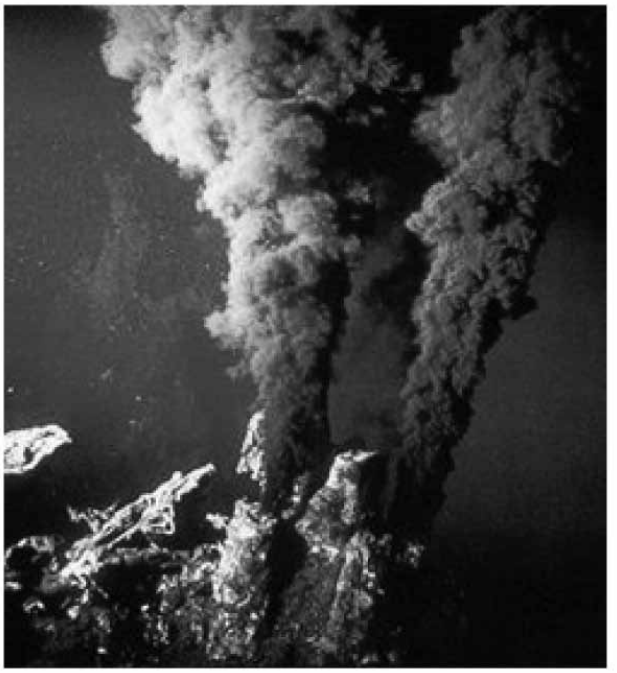

Figure 1. Hydro thermal vents (HTV) consisting of warm, rocky tube like structures formed, due to volcanism on the deep ocean floor. They keep on streaming hot gases and mineral sulphides fed by deep earth processes like mantle plumes (Courtesy: Google, images of HTV).

Figure 2. The hydrothermal vents (HTV) on the ocean floor beneath the Galapagos region in the Central America. (Courtesy: NOAA images of HTV beneath the Galapagos region).

CO2, HCN, H2S, NH3, P4O10 etc), fluids (hotsprings, steam) and minerals from the deep earth ,which led to the formation of hydrothermal vents on the ocean floor (Figure 1 & 2). These vents are rocky, tube-like warm structures, which spew out gases and simultaneous outpouring of minerals form lining in and around the vent surface of metallic sulphides such as nickel and iron sulphides (see Figure 1). The major reservoirs of these metals generally rest in the inner parts of the earth (lower mantle, core-mantle boundary and the core). It may be noted that the deep mantle plumes also upwell from these depths and would bring up materials there. Apparently this scenario favours a thermophylic origin of life.

For nearly two decades the HTV hypothesis did not receive enough support as compared to the predominant 'primordial soup' hypothesis. But the seminal contribution

of the two German scientists Huber & Wachtershauser (1997,1998,2000,2003,2006) and Wachtershauser (1988,1990,2007)-- who carried out the experimental modelling of the volcanism or hydro thermal setting and showed that –

1. life did not arise by assembling pre-existing organic compounds, no matter what the source ; instead it began as 2-D chemical reaction mineral surface pyrites- a compound of Fe, Ni & S. Organic reaction is apparently the key first step in the emergence of life.
2. Activation of amino acid with CO (at 100C abdpH7 to pH10) takes place under anaroxic conditions and due to the catalytic action of (Ni, Fe) S. This leads to the formation of peptides- the building blocks of proteins.
3. Now, for the amino acid, formation of ammonia is a prerequisite. A major source of ammonia (NH3) are the hot springs on the ocean floor, where N2 gets converted into NH3 due to the catalytic actions of the minerals deposited at the vents by upwelling magma.
4. they support the thermophylic origin of life. (The conditions at the ocean floor is understandably like a puritan minister's hell).
5. their result implies that CO and Ni may have much greater role in the primordial metabolism. The latter in due course leads to the DNA formation- which is the blue print of life. Obviously this step is a long leap from mineral surface chemistry to a living cell.
6. high volcanicity and earth's early ocean forms an ideal environment for the origin of life.

Now it has been seen from the study of chemical reactions at the HTV that the conditions at the HTV are similar to those harnessed by modern autotrophs. Sojo et al., (2016) have argued that at the origin of life in alkaline HTV under anorexic conditions of the Hadean time, these vents act as electrochemical flow reactors through the interconnected micro-pores with inorganic walls formed due to difference in pH across the barriers (membranes) and provide the proton-motive force (PMF) required for carbon fixation in extant bacteria and archaea. It would imply that in the earliest stage of the origin of life the chemical reactions in primitive cells were driven by non-biological natural proton gradient form, the core of the needed energy. This makes the HTV hypothesis more suitable than the primordial soup concept (Radzivilavicius 2016). It may be recalled that in the famous Miller-Urey experiment of 1952 for life's production the required energy was provided by a spark (Miller, 1953).

Antiquity of life:

Continued efforts to achieve higher resolution and precision have made it possible to estimate the ages of the beginning of the earth, oldest rocks and the earliest life on the earth. According to one estimate the earth appears to have an age of ~4.53Ga (Dalrymple 1991). These age determinations obviously depend on the availability of suitable samples, which are difficult to find in case of very old rocks. Hence, in some cases minerals like zircon are used. A few old age determinations are outlined below--

1. Study of the Isua supracrustal belt in western Greenland and that of nearby Akilla island gave evidence of life before 3.8 Ga (Mojzsis et al., 1996; Rizo et al., 2012).
2. A tonalite gneiss called Acasta for - being near the river Acasta- east of the Great Bear Lake in the NW territory of Canada seems to have metamorphosed 3.58 Ga back.
3. -4.031 b. y. ago. (Stern and Bleecker, 1998; Izuka et al., 2007). It is also noted from the study of these rocks that earth's early crust was formed from a mafic reservoir similar to the formation of the present day oceanic crust.
4. Another important study is based on zircon mineral from the Jack Hills in Australia. This belongs to the Hadean era (4.0-4.5 Ga). The oldest zircon mineral recognizable (so far) is also from the Jack hills. Coming to the antiquity of life these zircons are from undisturbed graphites, which show ratio of heavy/light carbons to be low–a corroboration of the presence of organic matter (Bell, 2011, 2015). Some earlier studies have shown that life began at 3.8 Ga in form of a single celled prokaryote, such as bacteria. There are also 3.7 Ga. old bio-genic graphites in the metasedimentary rocks of western Greenland (Nutman et al., 2016) and microbial mats fossils found in the 3.48 b.y.old sandstones of Western Australia (Nofke et al 2013). Schoff and Pacher (1987) have recognized early Archean (3.3-3.5 b. y. Old) microfossils from Warwoorna group Australia.
5. The oldest rocks that have been dated, so far, are from the Nuvvuagittuq supracrustal belt in the Quebec province of North Canada, on the eastern coast of Hudson Bay (Figure 3). These have been dated at ~4.28 b.y. (see Figure2). This region contains the oldest sedimentary rocks that formed part of the iron rich deep sea hydrothermal vent system, where these ancient HTVs once spitted lava onto the ocean floor. (Thomassot et al., 2015; O'Neil, 2008 & 2011)

Association with volcanics

An important issue in this discussion is the close connection of these very ancient hydro vents on the ocean floor and fossils with the volcanism (flood basalts, lavas and komatiites etc.)-- see Hezberg (1992). It apparently points out the involvement of deep mantle plumes during the early Archean and the Hadean. This is supported by various evidences, a few are listed below:

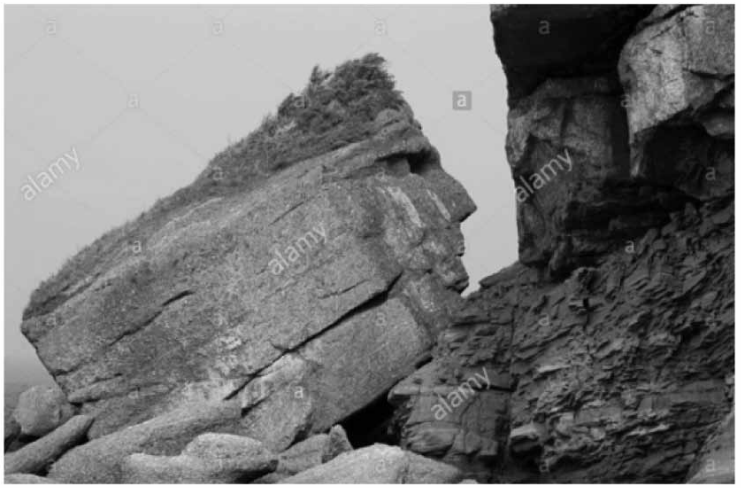

Figure 3. The oldest dated rocks (~4.3 Ga) of the Nuvvuagittuq greenstone belt (NGB) on the east coast of Canada. (Courtesy: Google Images of NGB).

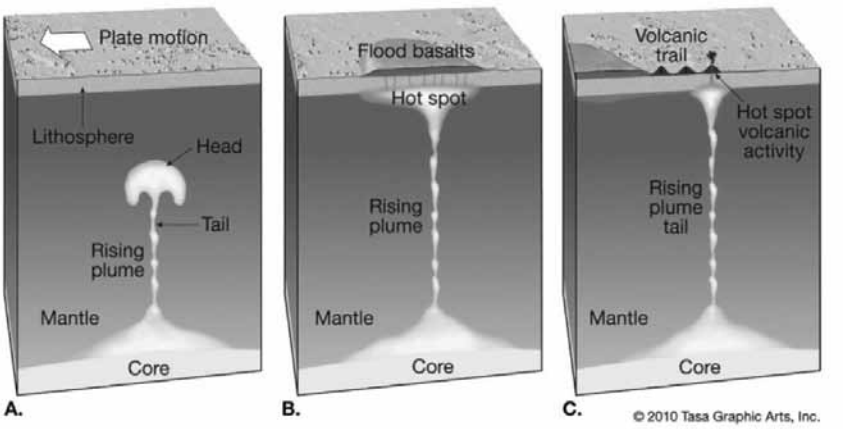

Figure 4. Deep mantle plumes upwelling from near the core-mantle boundary (also termed as the D" –layer). From the geochrnolgical determinations since the antiquity of the origin of life has receded to the Hadean era these deep mantle plumes seem to be the main source of hot spot (2b) volcanism (2c) and alkaline hydrothermal vents (AHTV), which in due course can create the conditions required for the inorganic to organic- to biological reaction sequences and these reactions eventually give rise to 'miracle of life' (Courtesy: Google images of Deep Mantle Plumes).

1. Bateman et al., (2001) found that the nature of the Archean magma is highly mafic. Similar deduction was arrived at by de Ronde and deWitt (1994). Further, in the 3235 m.y. old Archean rocks the setting of filamentous fossil bacteria is part of an old volcanogenic massive sulphide ore. (Rasmussen, 2000; Anvanink et al., 1983)
2. Another study of bio-signatures from the archean Dresser formations of the Pilbara craton in the NW Australia (Djokic et al., 2017) found that these rocks have been deposited within a volcanic caldera affected by voluminous hydrothermal fluids. Two horizons of silicified sedimentary formations exhibit alternating pillow lava and metabasalts.
3. Analysis of the thin section (Dodd et al., 2017) from the sliced rocks of 4.28 Ga old Nuvvugittuq greenstone belt (NGB) discovered fossils, which are tucked into the crystal embedded in the rocks. In view of such an early age of fossils (4.28Ga) Kevin Hand of NASA has commented… "As the froth of geology began to cool, biology established its role as a planetary process" (Kevin Hand, 2009).

Deep Mantle Plumes (DMP)

From the various evidences discussed above discussion, following two significant points emerge-

1. Volcanism at the deep ocean floor produces the hydrothermal vents, which spew out gases, fluids and minerals from inside the earth. As explained earlier these together create the requisite chemical environment for the reactions that eventually led

to emergence of life. It implies that the volcanism appears to be root cause for the scenario required for the origin of life.

2. The antiquity of life has been traced back to the Hadean era (4.1 –4.3 Ga old) –a time when the plate tectonics would have not commenced due to hotter mantle and resulting buoyancy of the asthenosphere that prohibits subduction—the main driving force of plate tectonics. Hence, the sea- floor spreading and associated volcanism will not take place on the ocean floor. In view of this and other evidences it seems that the deep mantle plume (DMP) - which up well from the core mantle boundary (CMB) to the base of the lithosphere (Figure 4) - is the most likely source of major volcanism during the Hadean. Following evidences also corroborate the involvement of the deep mantle plumes--

a. Presence of platinum group elements in Ni, Fe occurrences indicate deep mantle origin (Herzberg et al., 2016).
b. The elusive Hadean rocks in the Isua revealed an enriched reservoir.
c. Another evidence comes from the study of Valley et al., (2014). They used atom-probe tomography of the 4.4 Ga old Hadean zircon, post magma ocean time. One of the results reveal enriched incompatible elements including unusually high 207Pb/206Pb ratio,
d. Williams (2008) has also confirmed that the ultramafic pinnings of the vent system have similar chemical composition as that of lavas that erupted into the primordial ocean on early earth.
e. Study of the oldest NGB (Nuvvuagittuq greenstone belt) rocks (~ 4.3Ga old) also show that large amount of lava was spilled on the ocean floor (Papineu et al., 2008)
f. It is shown (Reminink et al., 2016) that the Hadean Acasta gneiss, Canada was formed from a mafic reservoir.

All these points obviously bring out a direct connection between a major "geodynamic process" and the "life" (Raval, 1999). Recently Schrieber and Mayer (2017) have given a model wherein life originated in the earth's crust and mantle reaching deep faults, that played a key role; which also appears to imply a close magmatic connection.

CONCLUSION

The study and discussion here highlight the hypotheses for the origin of life on the earth viz. the 'primordial soup' and the 'hydrothemal vent. It then dwells on the critical role of volcanism on the ocean floor in the development of the hydrothermal vents on the ocean floor and the attendant outpouring of the crucially required gases and minerals compounds. The volcanic output combining under the high (P,T) conditions on the ocean floor of the hot early earth gives rise, in due course of time, to the various reaction sequences that led to the emergence of the primary elements of life.

Since the age determinations of the rocks and paleo-fossils put their antiquity into deep past i,e. the Hadean era, the deep mantle plume (DMP) seems to be the main cause of the volcanism and the other subsequent chemical mechanisms; as the plate tectonics would have not begun due to the higher thermal state of the mantle of the early earth. It thus seems that the mantle plume tectonics has preceded the now more dominant plate tectonics; various geological features, geochemical signatures and geophysical anomalies observed over the lithosphere, are caused by these plumes (Raval 2003).

Thus from the point of this study the DMP appears to be at the "root" of the eventual emergence of life on the earth. In other words such a scenario obviously shows the close and causal connection of a "Major Geodynamical Process" with the "Origin of Life.

(It might be of some interest that this framework for the origin initiated by a mantle plume upwelling from deep interior of the earth to its surface seems to have a surprising resemblance with the description of 'creation' in some ancient Indian scriptures).

ACKNOWLEDGEMENTS

Author is extremely thankful to Dr. P.R. Reddy a senior seismologist / geophysicist for continuously encouraging me to submit a study based on studies of mantle plumes. He has been exceptionally patient. I am also thankful to him for critical reviewing and painstakingly editing the manuscript, which has enriched the original write up and for this I am grateful. This work is dedicated with deep gratitude to the memory of my teacher and guide Dr. Janaradan G Negi, who inspired us towards out-of-box thinking also. I do wish to profusely thank Dr. A.S.S.S.R.S. Prasad and Mrs.Revathi for their help in preparation of this manuscript.

Compliance with Ethical Standards

The author declares that he has no conflict of interest and adheres to copyright norms.

REFERENCES

Anvanik, S.M., Scoff, J.W., and Walter, M.R., 2016. Filamaentous fossil bacteria from the Archea of Australia Precam. Res., v.20, pp: 357-374.

Batman, R., Costa, S., Swe, T., and Lambert, D., et al., 2001. Archean mafic magmatism in the Karlgoorlie area of yilgran craton western Australia Precam. Res., v.108, pp: 75-112.

Bell Elizabeth, Harrison, T.M., Mcculloch, M.T., and Young, E.D., 2011. Early Archean crustal evolution of the Jack hills zircon source terrane inferred from LU-Hf, 207 Pb/ 206Pb and d18O systematic of Jack hill zircons Geochem. et Cosmochem. Acta., v.7, pp: 4816-4829.

Bell Elizabeth, A., Boehnk, P., Harrison, T.M., and Ma, W.L., 2015. Potentially biogenic carbon preserved in a 4.1 Ga zircon Proc. Nat. Acad. Sci., v.112, pp: 14518-14521.

Dalrymple, G.B., 1991. The age of the earth Stanford Univ. Press, pp: 492.

Djokic, T., Martin, J., Van Kranendonke, Campbell, K.A., Walter, M.R., and Ward, C.R., 2017. Earliest signs of life on land preserved in 3.5Ga hot-spring deposits. Naure Article no.1, May issue, v.8, pp: 755.

Dodd, M.S., Plack, D., Ritter, M., Piranjno, F., O'Neil, J., and Little, C.T.S., 2017. Evidence of early life on earth's oldest crust: hydrothermal precipitate. Nature, v.543, no.7643, pp: 60-64.

Herzberg, C., 1992. Depth and degree of melting of Komatiites, J. G. R., v.97, no.B4, pp: 4521-4540.

Herzberg, C., Vidito, C., and Starkey, N.A., 2016. Ni-Co contents of olivine record origin of mantle peridotite and related rocks Am. Min., v.101, pp: 1952- 1966.

Huber Claudia and Wachtershauser, G., 1997. Activated acitic acid by carbon fixation on (Fe,Ni)S under primordial conditions Science, v.276, no.5310, pp: 245-247.

Huber Claudia and Wachtershauser, G., 1998. Peptides by activation of amino acids with CO on (Ni,Fe)S surfaces: implications for the origin of life. Science, v.281, no.5377, pp: 670-672.

Huber Claudia and Wachtershauser, G., 2000. A possible primordial peptide cycle. Science, v.301, no.5635, pp: 938-940.

Huber Claudia and Wachtershauser, G., 2003. Primordial reductive amination revisited,Tetra hydron letters, v.44, no.8, pp: 1695-1697.

Huber Claudia and Wachtershauser, G., 2006. ά-hydroxyl and ά-amino acids under possible hadean volcanic origin of life conditions. Science, v.314, no.5794, pp: 630-632.

Izuka, T., Komiya, T., Ueno, Y., and Dunkley, D.J., 2007. Geology and Zircon geochronology of the Acasta gneissic complex, N. W. Canada, New constraints on its tectonothermal history Precam. Res., v.153, no.3-4, pp: 179-208.

Kevin Hand, 2009. Is there life on Europa? Nature, v.457, pp: 384.

Miller, S.L., 1953. A production of amnio acids under possible primitive earth conditions. Science, v.117, pp: 528-529.

Mojzsis, S.J., et al., 1996. Evidence for life on earth before 3.8Ga. Nature, v.384, pp: 55-59.

Nisbet, E., 2000. The realms of Archean life. Nature, v.405, pp: 621-626.

Nofke, N., Christian, D., Wacey, D., and Hazen, R.M., 2013. Microbially induced structures recording an ancient system in the Ca. 3.48 b. Y. Old Dresser formation, Pilbara, W. Australia. As. Friend C.L.R., Van Kranenonk., 2016. Rapid emergence of life shownby discovery of 3700 m.y. old microbial structures. Nature, v.537, pp: 535-538.

Nutman, A.P., et al., 2016. Rapid emergence of life shownby discovery of 3700 m.y. old microbial structures. Nature, v.537, pp: 535-538.

O'Neil, J., Carlson, R.W., Paquette, J.L., and Francis, D., 2008. Neodymium-142 evidence for Hadean mafic crust. Science, v.312, pp: 1828-1831.

O'Neil, J., Francis, D., and Carlson R.W., 2011. Implications of the Nuvvugittuq greenstone belt for the formation of Earth's early crust., J. Petro., v.52, no.5, pp: 985-1009.

Papineu, D., De G Regorio, B.T., Cody, G.D., O'Neil, J., Steele, A., Stroud, R.M., and Fogel, M.L., 2011. Yound poorly crystalline graphite in the 3.8Ga old Nuvvuagittuq banded iron formation. Nature Geo Science, v.4, pp: 376-379.

Radzivilavicius, A.L., 2016. We have been wrong about the origin of life for 90 yrs. in Independent Science News 16th Aug. Issue.

Rasmussen, B., 2000. Filamentous microfossils in a 3235 m.y.old volcanologic massive sulphide ore. Nature, pp: 676-679.

Raval, U., 1999. Do mantle plumes contribute to the origin of life and quntum jumps in the evolution, IUGG – 99 xx11 Gen. Assembly UK.

Raval, U., 2003 Interaction of mantle plumes with the Indian continental lithosphere in Mem. Geol. Soc., no.53, pp: 449-479.

Reminink, K., Davies, J.H.F.L., Chacko, T., Stern, R.A., Heaman, L.M., Sarkar, C., Schaltegger, U., Creaser, R.A., and Pearson, R.D., 2016. No evidence of continental crust within earth's evolved rock unit Nature Geosciences, v.9, no.10, pp: 777-780.

Rice, K., 1999. The Challenger expedition: understaning the ocean, marine science in the wake of HMS Challenger Routledge pub., pp: 27-48.

Rizo, H., Boyet, M., Blichest-Toft, J., O'Neil, J., Rosing, M.T., and Paquette, J.L., 2012. The elusive Hadean enriched mreservoir revealed by 142 Nd deficits in Isua Archean rocks, Nature, v.491, pp: 96-100.

Ronde, C.E., and J. de Witt, 1994. Tectonics, v.13, pp: 938-1005.

Russel, M.J., 2006. First Life, American Scientist, v.94, no.1, pp: 32.

Russel, M.J., (ed), 2011. Origin, abiogenics and the search for life in the universe, Published by Cosmology science.

Schreiber, U., and Mayer, C., 2017. Life originated in the earth's crust (Uni. Of Essen) Geology Feb. 17 Issue.

Schoff, J.W., and Pacher, B.M., 1987. Early Archean (3.3-3.5 b.y. old) microfossils from the Warwoorna group Australia. Science, v.237, pp: 70-73.

Service, R.F., 2016. Our last common ancestor in haled hydrogen from underwater volcanoes, Science july 25 issue.

Shank, T., and Holden J., 2011 Exploring Biodiversity along the Galapagos rift : A NOAA ocean explorer; Galapagos Rift.

Sojo, V., Herschy, B., Whicher, A., Camprubi, E., and Lane, N., 2016. The origin of life in the alkaline hydro thermal vents (AHTV), Astro biology Feb16, v.2, pp: 181-297.

Stern, R.A., and Bleeker, W., 1998. Age of world's oldest rock re-find using Canada's SHRIMP : The Acasta gneissic complex NW territory, Canada. Geoscience Canada, v.25, pp: 27-31.

Thomassot, E., O'Neil, J., Francis, D., Cartigny, P., and Wing, B.A., 2015. Atmospheric record in the Hadean eon from multiple sulfuur isotope measurements in Nuvvuagittuq greenstone belt (Nunavik Quebec) Proc. Nat. Acad. Sci., v.112, no.3, pp: 707-717.

Valley, J.W., et al., 2014. Haden age for a post-mafic ocen zirconconfirmed by atom-probe tomography, Nature, v.7, pp: 219-223.

Wachtershauser, G., 1988. Pyrite formation, the first energy source for life: a hypothesis System Appl. Microbilogy, v.10, pp: 207-210.

Wachtershauser, G., 1990. Evolution of the first metabolic cycles. Proc. Acad. Sci., v.87, pp: 200-204.

Wachtershauser, G., 2007. On the chemistry and evolution of the pioneer organism Chem. Biodivers., v.4, no.4, pp: 584-602.

William, M., and Russel, M.J., 2003. On the origin of cells: a hypothesis for the for the evolutionary transition from prokaryotes to nucleated cells: The a biotic geochemistry to chemoautotrophic prokaryotes and from prokaryotes to nucleated cells, Phil. Trans. R. Soc. Ser B., v.358, no.1429, pp: 59-83.

Williams, M., and Russel, M.J., 2007. On the origin of biochemistry of van alkaline hydrothermal VENTS Phil. Trans R. Soc. Lond. Ser B., v.362, no.1486, pp: 1887-1925.

William, M., et al., 2008. Hydrothermal Vents and origin of life. Nature Reviews (Microbiology), v.6, pp: 805-814.

Received on: 21.4.17; Revised on: 12.6.17, Re-revised on: 23.6.17; Accepted on: 27.6.17

Quotes- Origin of life on Earth

"The great age of the earth will appear greater to man when he understands the origin of living organisms and the reasons for the gradual development and improvement of their organization. This antiquity will appear even greater when he realizes the length of time and the particular conditions which were necessary to bring all the living species into existence. This is particularly true since man is the latest result and present climax of this development, the ultimate limit of which, if it is ever reached, cannot be known."

- Jean-Baptiste Lamarck (1744-1829) pioneer French biologist

***

"A wonderful area for speculative academic work is the unknowable. These days religious subjects are in disfavor, but there are still plenty of good topics. The nature of consciousness, the workings of the brain, the origin of aggression, the origin of language, the origin of life on earth, SETI and life on other worlds...this is all great stuff. Wonderful stuff. You can argue it interminably. But it can't be contradicted, because nobody knows the answer to any of these topics."

- Michael Crichton(1942 – 2008) was an American author, screenwriter and film director

***

"Considering the way the prebiotic soup is referred to in so many discussions of the origin of life as an already established reality, it comes as something of a shock to realize that there is absolutely no positive evidence for its existence."

- Michael Denton (1943--) is a British-Australian author and biochemist.

***

"Many investigators feel uneasy stating in public that the origin of life is a mystery, even though behind closed doors they admit they are baffled."

- Paul Davies(1946--) is an English physicist.