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CORAL BLEACHING IS A TOOL FOR EARTHQUAKE PREDICTION

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ABSTRACT

Coral reefs are referred as a rainforest in the marine environment because of their high productivity and diversity of different fauna and flora even though it is noticed in nutrient poor waters. Recently, the major concern about these coral reefs are bleaching i.e. the corals are dying due to the raise of temperature with climatic change, considered as one of the major hazard in the marine environment. Similarly, the earthquake is another major hazard happening in terrestrial as well as marine environments, however, the human loss happening mainly in the terrestrial environment. So, people are working hard to understand and try to predict the earthquake occurrence early enough to mitigate its hazard and save the human community. To date scientist are not successful in this task. Now, an attempt has been made to predict earthquake through the coral bleaching process. From 1983 to 2015 were correlated with nearest time period earthquakes and a systematic pattern with earthquake occurrences along with the coral bleaching were established. This coral bleaching might have occurred due to the radon gas exhalation from the nearest earth surface which was triggered due to the stress or strain of the nearest period earthquake. Based on this concept, it may be predicted that if earthquake scientist monitor the coral bleaching, the earthquake occurrence between 100 and 3000 km in the surrounding areas may be predicted within 15 to 30 days. This was once again confirmed, in the 10th April 2016 Afghanistan earthquake, as a precursor during 14th March 2016 coral bleach was noticed in Andaman and Nicobar Islands. So, monitoring of coral bleaching may be the best possible, closet predication tool or precursor available till date. Further, it may also suggest from this study that the coral bleaching is not due to climate change but because of earthquakes.

Keywords: coral bleach, earthquake, prediction, seismology, radon gas, coral reef environment.

1. INTRODUCTION

A single coral is an animal; the tube shaped body called a polyp has a mouth and tentacles. These single corals secrete calcium carbonate and connect to one another and form colonies and latter develop a reef system in geologic time. This reef system mainly occurs within 100 m depth from the shore due to symbiotic nature with a microalga called zooxanthellae. These microalgae lives within the tissues of the coral (fauna) provide food to these corals. If these microalgae leave the polyp of the coral the activities of the corals stop and the variety of colour becomes white. This process is called coral bleaching (Open and Lough, 2009). In the past bleaching was observed in patches due to local stresses like low salinity, pollution or low or high water temperature. Now, these bleaching frequencies have increased and large scale mass bleaching events are to be considered a rise in temperature in marine waters (Open and Lough, 2009; Barker *et al.* 2008).Corals are distributed from tropic to Polar Regions. However, the reef building corals are mainly exhibited between 30°N to 30°S Latitudes. Generally, corals are found from surface to 6000 m depth, but reef building corals mainly occurred in between Low Water Mark (LWM) to 50 m depth. Corals most preferred to grow in hard substrate.

Earthquakes are natural phenomenon of earth and release its stress. The released energy moves around the world in the form of waves and it vibrates the earth. This leads to destruction on the earth surface and damages, property and lives. The damages mainly on buildings which can collapse and landslides and fire may occur and tsunamis may be triggered.

Even though large number of workers working on the aspects of trigger of an earthquake but till date it has not develop any precursory phenomenon for earthquake. As reported by Vere-Jones (1995) that last forty years nature brought a salutary reminder that it does not reveal here secretes easily. International Union of Geodesy and Geophysics (IUGG, 1984) recommends “that predictions should be formulated in terms of probability, i.e. the expectation in the time-space-magnitude domain of the occurrence of an earthquake”. Further, Vere-Jones (1995) also proposed that a breakthrough is needed to identify the precursory phenomenon which will provide a high level of confidence and precision alerts.

In this process an attempt had been made to understand the bizarre incidence of temperature rise and coral reef bleaching which may be coincidence with the earthquakes. This inferences lead to a hypothesis is that coral bleaching may be a tool to predict earthquakes.

2. MATERIAL AND METHODS

The data available from the year 1983 onwards on coral bleaching and earthquakes were collected from the published literature (Harriot, 1985; Goreau and Hayes, 1994; Wilkinson, 1998; Wilkinson and Hodgson, 1999; Science Daily, 2007; APA citation, 2007; NOAA, 2010; Chavanich *et al.* 2012; Monaco *et al.* 2012; Mohanthy *et*

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al. 2013; Mondal *et al*. 2014; Kovousi *et al*. 2014; Authors personal observation, 2015) and internet (SEW 1983, 1987, 1998, 2005, 2010, 2012; EMSC 2015). Based on these details a pattern was identified. This pattern was correlated with the identified coral bleaching location and the nearest time period of and the earthquake locations. The distances between these two locations were calculated from the world map. Over and above, different probabilities related to these events were worked out. Then the final conclusion was derived.

3. RESULTS AND DISCUSSIONS

The data collected from the different sources were pooled and presented in Table 1 for the coral bleaching date and nearest time (within a month) period occurred earthquake data. It was found that whenever coral bleaching was reported, immediately after that within 100 to 7000 km surrounding distance few major earthquakes were occurred. The direction may not be a consideration; however, distance noticed fell within the above mentioned range in these entire observed seven incidences from May1983 to April 2015 (Figure1-8).

Based on the above correlation, it may be inferred that the coral bleaching occurred (within a month) before the major earthquake occurrences in a far away places. Based on the senior author's observation for 2010, 2012 and 2015 coral bleaching incidence at Andaman and Nicobar region suggested that within few days of this event, a major earth quake was happened within surrounding of 7000 km. This information forced us to conclude this event was not due to temperature rise but the radon gas emission which might have destroyed these corals. Moreover, this interpretation is further strengthened by another factor that the coral bleaching not happen to the full depth of the water column during 2010 and it was only up LWM to the 5 m depth (Mohan et al. 2010) and in 2015 it was like a ribbon in selective patch.

Radon is an inert gas chemically and also radioactive and constantly generated and normally emitted in a minute amount from the earth crust (Tanner, 1964; Mogro-Camper and Fleicher, 1977; Tanner 1980). The radon gas may be released at larger distance from the earthquake epicenter (Imme and Morelli, 2012) where the stress or strain of rupture zone influences the base rocks of corals ground by the way of developing a new crack(s) or widening or closing of old crack(s) or redistribution of open and closed crack(s) (Scholz*et al*. 1973; Planinic*et al*. 2001) which in turn exhalation to the water column close to the coral bleach location. The diffusive transport of radon might have taken place as reported by Fick's Law (Sabol and Weng,1995) opposite to that of the increasing concentration gradient. Further, it was also reported that the radon gas has a positive correlation with temperature and wind speed as well as negatively correlated with pressure. Moreover, the radon gas is the only gas has radioactive isotopes in normal condition (Wikipedia-2015). Based on the above factors, the radon gas not only is released earthquake sites it also is released wherever there land deformation due to the particular earthquake. In that way, if that particular deformation area has coral reef it is affected by the released radon gas near the coral reef environment and the emitted radon gas may be causing (radioactivity or increase of temperature) the elimination of zooxanthella from coral polyp and in turn the coral bleaching. This might have happened within a short duration only because the half-life of radon is of 3.82 days.

Over and above, as reported by Friedman (1991), Dobrovlsky *et al*. (1979), Virk and Singh (1994) the release of radon gas noticed around 142 km to 600 km away from the earthquake location that also occurred around 15 to 25 days earlier than the reported earthquake dates of the particular locations. The distance would vary depend upon the magnitude of the earthquake. Further, Freund and Stolc (2013) reported that pre-earthquake phenomenon such as radon gas exhalation may be affecting the animals up to 1000 km radius of the epicenter of an earthquake.

Moreover, based on the above hypothesis, it was identified that each coral bleaching location and consequent earthquake locations were present in the same plate, so the impact of the earthquake may trigger the ground surface near to the corals and emit the radon gas. 1983 events placed in the Indo-Australian plate with one earthquake location on the borders of Indo-Australian - Pacific Plates. The year 1987-A event located in South American Plate and 1987-B event located in Indo-Australian Plate. The events occurred in the years 1998, 2005, 2010, 2012 and 2015 were noticed in Eurasian Plate. Here, it has been clarified that the SEW data had more number of earthquake information. The present study considered only the close dated earthquake instead of the all the data because the concept of radon gas release was that within 40 to 45 days priorof the earthquake occurrence. Further, it may also be suggested that the effect of earthquakes on coral bleaching was not found in other earthquakesbecause there is no systematic data on this aspect or that particular earthquake was not have nearby coral reef environment.

A bizarre temperature rise was also noticed for short duration at these locations. Since, it had not any constant temperature information available in literature this factor cannot be authenticated. However, the inference was made based on the Senior Author's experience in 2010 and 2015 coral bleaching i.e. the temperature rose a sudden to 33°C and 38°C, respectively, within a day and reduced to normal in subsequent days. Over and above, before temperature rise, the coral bleaching was started. Based on this information it may be inferred that rise of temperature may also be caused due to the radon emanation fraction which is due to the reduced adsorption of radon (Imme and Morelli, 2012). It is evinced on Port Blair i.e. 13 of April in 2015 when the coral was bleached and the temperature raised to 38°C on 26 of April in 2015 only i.e. the day after the Nepal Major earthquake occurrence.

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So, this hypothesis may be tested in future by the way of constant monitoring of coral bleaching incidence occurrence, in worldwide by the earthquake scientist. Once coral bleaching occurs, from the bleach location, within 3000 km, a warning may be provided to all the earthquake prone areas, which may be expected within 30 days.

Table-1. Date and location of coral bleaching and earthquake occurrence details.
(SEW - Significant Earthquake of the World; EMSC - Euro-Med Seismological Centre; NOAA - National Oceanic and Atmospheric Administration; APA - American Psychological Association)

S. No.	Coral bleaching date	Earthquake date	Location	Distance from thecoral bleaching location - km	Direction from thecoralbleaching location	Intensity of the identified earthquake	Reference
I	May 1983	---	Great Barrier Reef - Australia	---	---	---	Harriot(1985); Goreau and Hayes (1994)
I.1	---	15 May 1983	Tonga Island	3,768	South East	6.4	SEW (1983)
I.2	---	26 May 1983	Honshu , Japan	5,886	North West	7.7	SEW (1983)
I.3	---	01 June 1983	Tonga Island	3,768	South East	6.3	SEW (1983)
I.4	---	01 June 1983	Samoa Island	4,604	East	6.5	SEW (1983)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
II.A	September 1987	---	Caribbean Sea	---	---	---	Goreau and Hayes (1994)
II.A.1	---	22 September 1987	Ecuador	1,853	South	6.1	SEW (1987)
II.B	September 1987	---	Samoa	---	---	---	Goreau and Hayes (1994)
II.B.1	---	28 September 1987	Vanatu Island	2,258	West	6.7	SEW (1987)
II.B.2	---	06 October 1987	Tonga Island	887	South West	7.3	SEW (1987)
II.B.3	---	12 October 1987	Solomon Island	3,051	North West	6.7	SEW (1987)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
III.A	August 1998	---	Bahrain, HayrSahutaya, Arabian Sea	---	---	---	Wilkinson (1998)
III.A	August 1998	---	Saudi Arabia, Arabian Sea	---	---	---	Wilkinson (1998); Wilkinson and Hodgson(1999)
III.A.1	---	28 September 1998	Java, Indonesia	7,499 7,939	South East South East	6.6	SEW (1998)
III.A.2	---	15 September 1998	Eastern Honsu Japan	8,123 8,717	North East North East	5.1	SEW (1998)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
III.B	May 1998	---	Oman, Mirbat Arabian Sea	---	---	---	Wilkinson (1998); Wilkinson and Hodgson(1999)
III.B		---	Lakshadweep, Gujarat, India	---	---	---	Wilkinson (1998); Wilkinson and Hodgson(1999)
III.B.1	---	20 August 1998	Bonin Island	8,586 7,382 7,098	North West North East North East	7.1	SEW (1998)

III.B.2	---	15 September 1998	Eastern Honsu Japan	7.932 7,048 6,538	North West North East North East	5.1	SEW (1998)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
III.C	May 1998	---	Kenya, Indian Ocean	---	---	---	Wilkinson (1998); Wilkinson and Hodgson(1999)
III.C.1	---	28 September 1998	Java, Indonesia	8,122	South East	6.6	SEW (1998)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
IV.A	April-May 2005	---	Andaman Sea	---	---	---	Mohanthy, et al. (2013)
IV.A.1	---	14 May 2005	Nias Region, Indonesia	1,147	South East	6.7	SEW (2005)
IV.A.2	---	19 May 2005	Nias Region, Indonesia	1,147	South East	6.9	SEW (2005)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
IV.B	April 2005	---	Sumatra and Indonesia Islands	---	---	---	Science Daily (2007); APA citation (2007)
IV.B.1	---	14 May 2005	Kermadec Island	9,072	South East	6.6	SEW (2005)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
V.A	May 2010	---	Indian Ocean, Andaman Sea, Gulf of Thailand,Cambodia,Indonesia, Philippines and Maldives	---	---	---	NOAA (2010); Chavanich et al. (2012); Monaco et al.(2012); Mondal et al.(2014).
V.A.1	---	16 May 2010	Papua, Indonesia	2,709	East	7.0	SEW (2010)
V.A.2	---	26 May 2010	Ryukyu Island, Japan	3,387	North East	6.5	SEW (2010)
V.A.3	---	27 May 2010	Vanuatu Island	6,036	South East	7.2	SEW (2010)
V.A.4	---	31 May 2010	Andaman Islands	2,763	North West	6.5	SEW (2010)
V.A.5	---	12 June 2010	Nicobar Islands	2,396	North West	7.5	SEW (2010)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
VI.A	August, September 2012	---	Persian Gulf	---	---	---	Kovousi et al. (2014)
VI.A.1	---	07 September 2012	China	5,027	North East	5.5	SEW (2012)
///////////	///////////	///////////	///////////	///////////	///////////	///////////	///////////
VII.A	13 April 2015	---	Port Blair, Andaman Sea	---	---	---	Authors Observation
VII.A.1	---	25 April 2015	Nepal	2,252	North West	7.8	EMSC (2015)
VII.A.2	---	01 May 2015	Andaman Islands	351	---	5.4	EMSC (2015)
VII.A.3	---	12 May 2015	Nepal	2,252	North West	7.3	EMSC (2015)
VII.A.4	---	30 May 2015	Japan	5,075	North East	7.8	EMSC (2015)

4. CONCLUSIONS

Wherever, coral bleach may occur, from that location, 100 to 3000 km surrounding earthquake prone areas may be provided a warning for occurrence of earthquake within 30 days from the date of coral bleach. Once again, it was witnessed recently that 14th March 2016, the coral bleach was noticed in off Alexandria Island - a part of Andaman Nicobar Groups of Island, within the month period i.e.10th April 2016 earthquake

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occurred in Northern part of Afghanistan at the scale of 6.6.

At this stage this tool looks a fruitful one within close proximity, when comparing all the other predication models existed till date. Further, refinement may be needed based on the future, more detailed data base on coral bleaching and its subsequent earthquake.

Based on the present inferences, it may be considered that the coral bleach has been occurring due to impact of earthquake instead of climatic change.

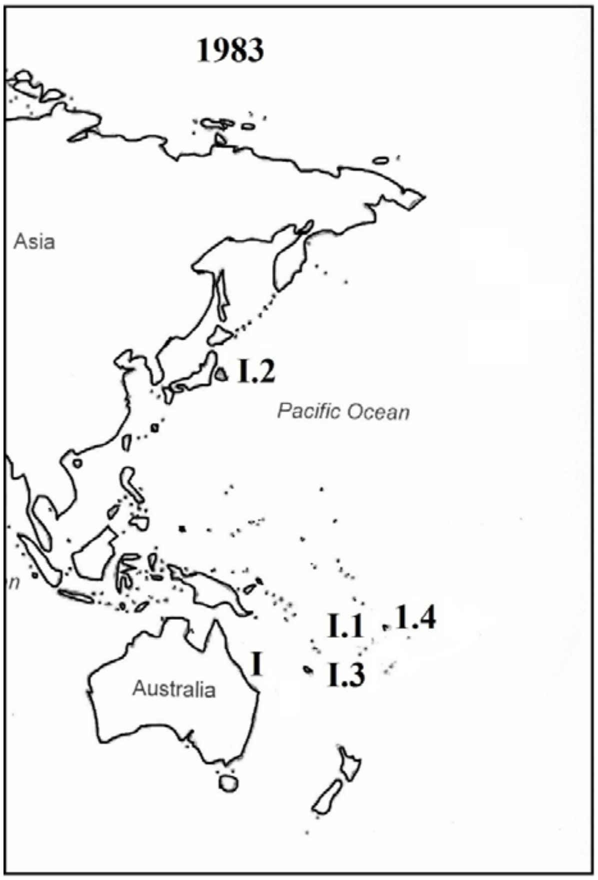

Figure-1. Coral bleaching and earthquake occurrence locations in 1983.

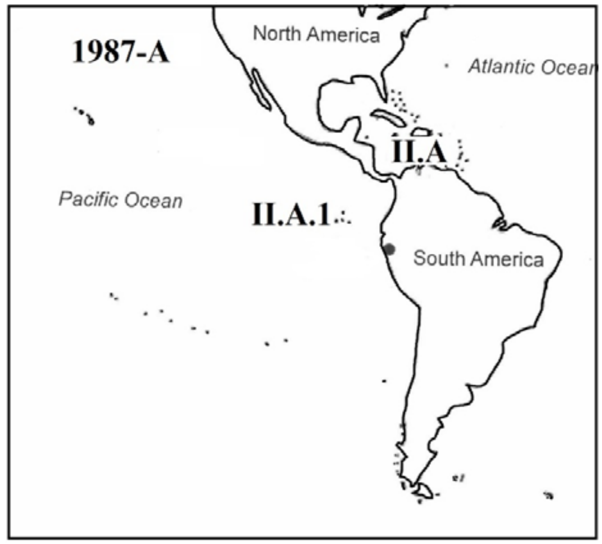

Figure-2. Coral bleaching and earthquake occurrence locations in 1987-A.

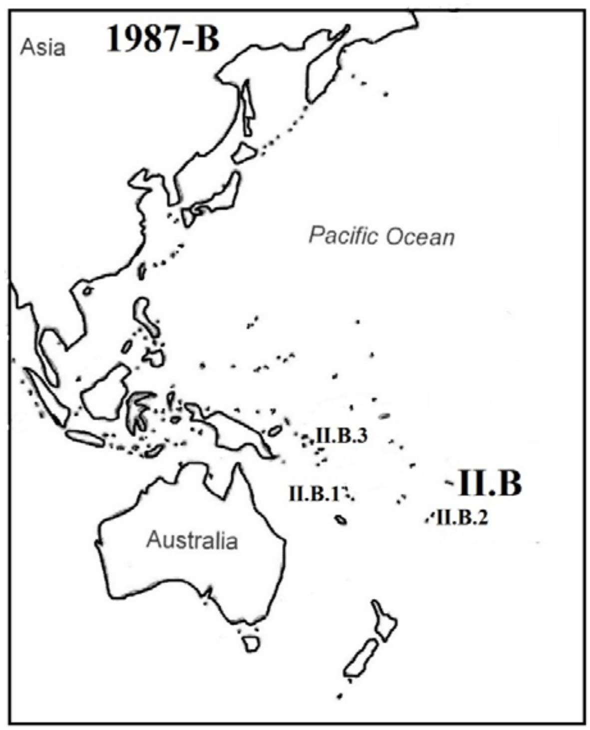

Figure-3. Coral bleaching and earthquake occurrence locations in 1987-B.

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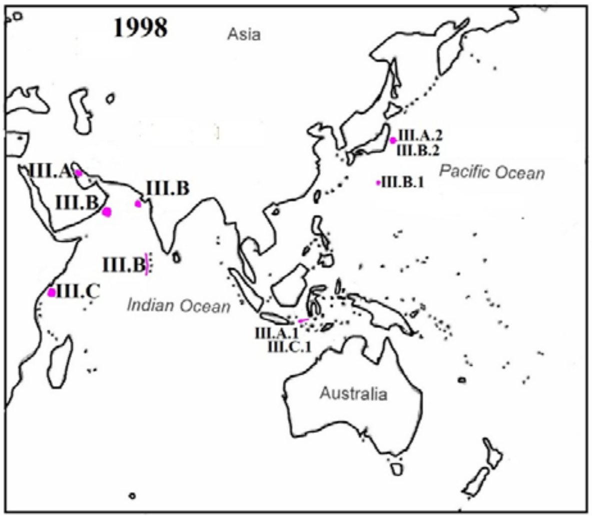

Figure-4. Coral bleaching and earthquake occurrence locations in 1998.

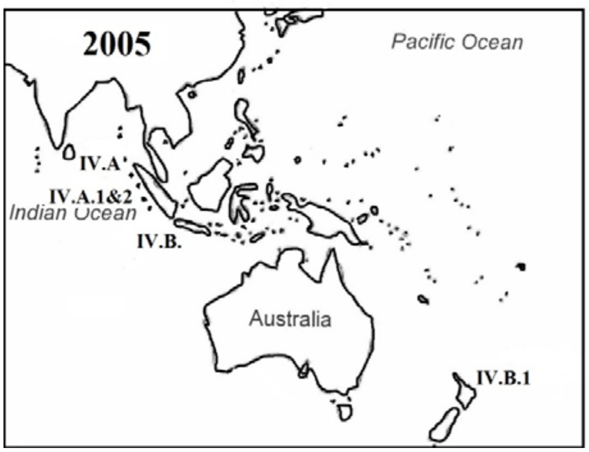

Figure-5. Coral bleaching and earthquake occurrence locations in 2005.

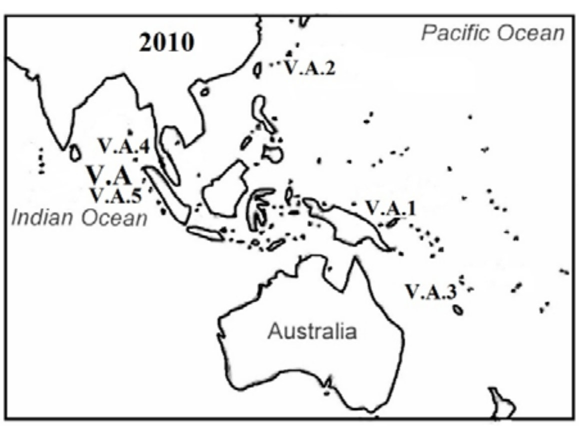

Figure-6. Coral bleaching and earthquake occurrence locations in 2010.

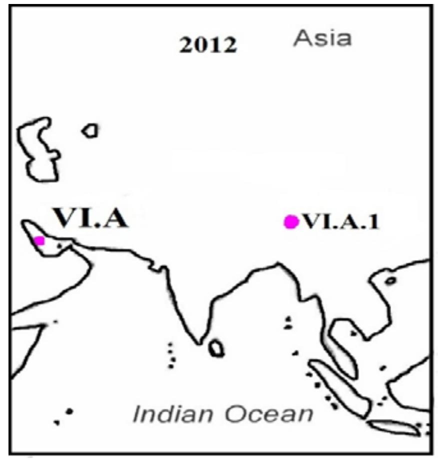

Figure-7. Coral bleaching and earthquake occurrence locations in 2012.

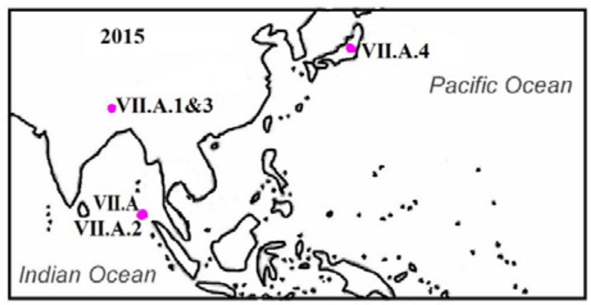

Figure-8. Coral bleaching and earthquake occurrence locations in 2015.

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