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SOME PRELIMINARY RESULTS OF PALEO-TSUNAMI STUDY IN THE COASTAL REGION OF THE NGHE AN PROVINCE, VIETNAM

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ABSTRACT: In the coastal region of the Nghe An province, the geomorphology is characterized by appearances of fields of arca granosa with placura placenta and hills of placura placenta with arca granosa, namely: The hills of placura placenta with the arca granosa shells in the Quynh Van and Nghi Tien communes; the fields of arca granosa with the placura placenta: deep-seated in the Quynh Nghia, Dien Chau and along the Nghi Yen coast which have age of 4,500 - 4,300 yrs.; The appearance of the placura placenta-arca granosa shell's fields and hills which do not originate from either marine transgression in the Holocene epoch, tectonic movement or artificiality; Our results suggest that there were three tsunami events occurring in the past during the periods of 4,500 - 4,300; 4,100 - 3,900 and 900 - 600 yrs., respectively in the region.

Keywords: Paleo-tsunami, arca granosa, placura placenta, Nghe An province (Vietnam).

INTRODUCTION

Study of paleo-tsunami is a new research orientation in Vietnam. A number of investigations/surveys on paleo-tsunami vestiges have just been started since 2005 by scientists of the Institute of Geophysics, Vietnam and the experts from Russian Institute of Physics of the Earth. Since then, several research works have been published to confirm a possible appearance of paleo-tsunami along islands and coastlines of Vietnam [1-3]. Amongst these works, appearances of hills of placura placenta and fields of arca granosa in the coastlines of the Nghe An region are considered as results of paleo-tsunami. The following noticeable records on possible appearance of paleo-tsunami can be made.

In the early 60s of the 20th century, in Nghe An province, archaeologists discovered a cultural vestige of Neolithic people (an era, when people were able to sharpen stone, farm and breed), of which the Quynh Van and Thach Lac cultures were typical. Up to now, there are 21 discovered locations of the Quynh Van culture scattered in the Nghe An and Ha Tinh coastline deltas, mainly in the districts of Quynh Luu, Dien Chau and Nghi Loc of Nghe An province and in Nghi Xuan and Thạch Ha districts of Ha Tinh province [4, 5].

This report presents new material about specific geological formations on structure and composition, section surface, order of the geo-layers and ^{14}C dating at some studied locations in detail. The results of the restored Holocene coastline zone and the results of the surveys, analysis and synthesis have shown new evidence on possibility of occurrence of the tsunamis caused by earthquakes along the Nghe An coastline.

SEA WATER LEVEL - HOLOCENE COASTLINE

Based on results of the studies, field surveys and analysis of the sample's dating collected in some areas of the Nghe An coastline delta, where marine sediments are distributed, especially in the areas at which fields of shell of arca with placura placenta, hills of placura placenta and traces of marine level in the Holocene are existing (sand dune, field of arca mixed with gravel and pebble in coastline, abrasion traces by surfing), the relative dating reveals the sea levels in the Holocene epoch during the periods of 4,600 - 4,500 yrs.; 4,500 - 4,300 yrs. and around 4,100 - 3,900 yrs. from present, respectively, which are described in detail as follows (fig. 1, 2, 3, 4, 5).

The coastline during the period of 4,600 - 4,500 yrs. from present (fig. 5)

Fig. 1. Pebble layer mixed with blocked arca under coastline sand dunes in the village No.5 of Nghi Tien commune. Sample No.NL3-08 [*Source:* Cao Dinh Trieu (2010)]

As shown by the topography, a strip of hills is trans-going and projecting into the sea, under influence of the sea level fluctuation in the Nghe An region in general and in the Quynh Luu - Dien Chau areas in particular in the Quaternary period, especially in the Holocene epoch, and as a result, a twin coastline had been formed as sand dune in the coast and lagoon behind. Maximal marine transgression in the Holocene epoch was recorded by the sand dune in the west of the delta and the existence of nail shells (lack of placura placenta) with limed and blocked gravels was found (fig. 1). In an area within the village No.5 of Nghi Tien commune, in the sand dunes of 3 m height, two layers of pebbles and gravels containing limed arca of 4,520 $\pm$ 55 yrs. age were discovered. In correspondence and coincidence with the sea level vestige there exists wave surfing at a height of 3 - 4 m (fig. 2) at the wall of the remain mountain (Len Muc mountain in the Quynh Ba commune) on a delta at 2 m high (material of geomorphic map of 1:200,000 scale - Thanh Hoa - Vinh sheet 1980, the surf trace is determined as Middle Holocene age, at a height of 3.5 m).

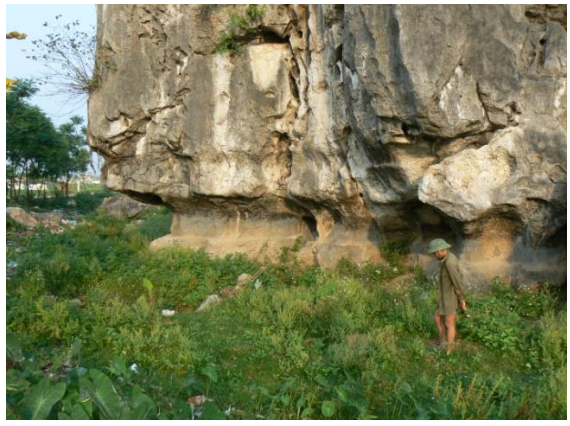

Fig. 2. Surfing trace on the Len Muc Mountain foot in Quynh Ba commune, Quynh Luu district [*Source:* Cao Dinh Trieu (2011)]

The coastline during the period of 4,500 - 4,300 yrs. from present (fig. 5)

Division of the coastal zone of 4,500 - 4,300 yrs. in the Dien Chau - Quynh Luu coastline is based on considering distribution of shells with placura placenta recorded in the past as follows:

According to historical notes and results of the archaeology, the area of arca with placura placenta in the Nghe An region is very wide, in some places, the distribution area may reach a thousand of km^2. For example in the Quynh Hoa commune of Dien Chau district, the absolute age of the arca with placura

placenta is determined in a period of 4,500 - 4,300 yrs. from present [4, 5].

A thickness of the arca with placura placenta along the national road No.1 within Dien Chau district may reach up to 5 - 6 m [4, 5], while a maximum height of the road surface is at 5 - 6 m high above the sea level. It means that in the past, during the period of 4,500 - 4,300 yrs. from present, in this region the coastline did not exist.

A layer of the arca with placura placenta in the Dien Chau region (and in some other locations in the Quynh Luu district) is naturally pure, but chaotically deposited (fig. 3), and its order was not following the order of the existing sedimentation in the region. This phenomenon can be explained by a sudden accumulation.

Fig. 3. Arca layer with placura placenta was cut into bricks for construction of house walls by Nghe An people [*Source:* Cao Dinh Trieu (2011)]

The coastline during the period of 4,100 - 3,900 yrs. from present

It is recognized that close to the modern coastline (and the sand dunes containing shells of arca and more ancient snails as mentioned above) shell snails (the common type of species arca granosa, arca sabence lin and ostrea calculuta boru), placura placenta is not found in any place (a species living in 9 - 10 m depth and clinging to the stone wall). In the modern coastline close to water edge (in a seaside edge of sand dunes) on upper sand dunes along the coastline of the Quynh Luu region, in such places as the northeastern part of the dragon Quen (Quen rivulet - canal), Dinh Cong mountain foot, Dien Chau… only hills of shell snails with mixed pebbles, gravels, stone species are observed. Behind the sand dunes, in some places (the Quen rivulet of Quynh Luu, along Nghi Yen, Nghi Tien coastlines of Nghi Loc district) shell samples were taken from these sand dunes having ages of 4000 $\pm$ 55 yrs., 4040 $\pm$ 55 (Nghi Yen), 3920 $\pm$ 55 and 4060 $\pm$ 110 (sand under the hill of placura placenta in Nghi Tien commune), which marked the age of the coastline (sea water level) as late, middle Holocene, i.e. on average 4,100 - 3,900 yrs. ago. The height of this region is about 1.5 - 2.0 m above sea level [4, 5].

In conclusion, there were 3 categories of coastlines with the Holocene age determined as follows:

In the time period of 4,600 - 4,500 yrs. from present, altitude of the sea water level was about 3 - 4 m. This is the maximum altitude of the sea level in the Holocene epoch.

For the coastline having age of 4,500 - 4,300 yrs. from present, altitude of the sea level was not determined in detail.

For the coastline having age of 4,100 - 3,900 yrs. from present, the height is estimated at 1.5 - 2.0 m and is very close to the modern coastline.

Fig. 4. Dyke, which consists of arca, snails mixed with pebbles along Lạch Quen coastline of Quynh Luu district [*Source:* Cao Dinh Trieu (2011)]

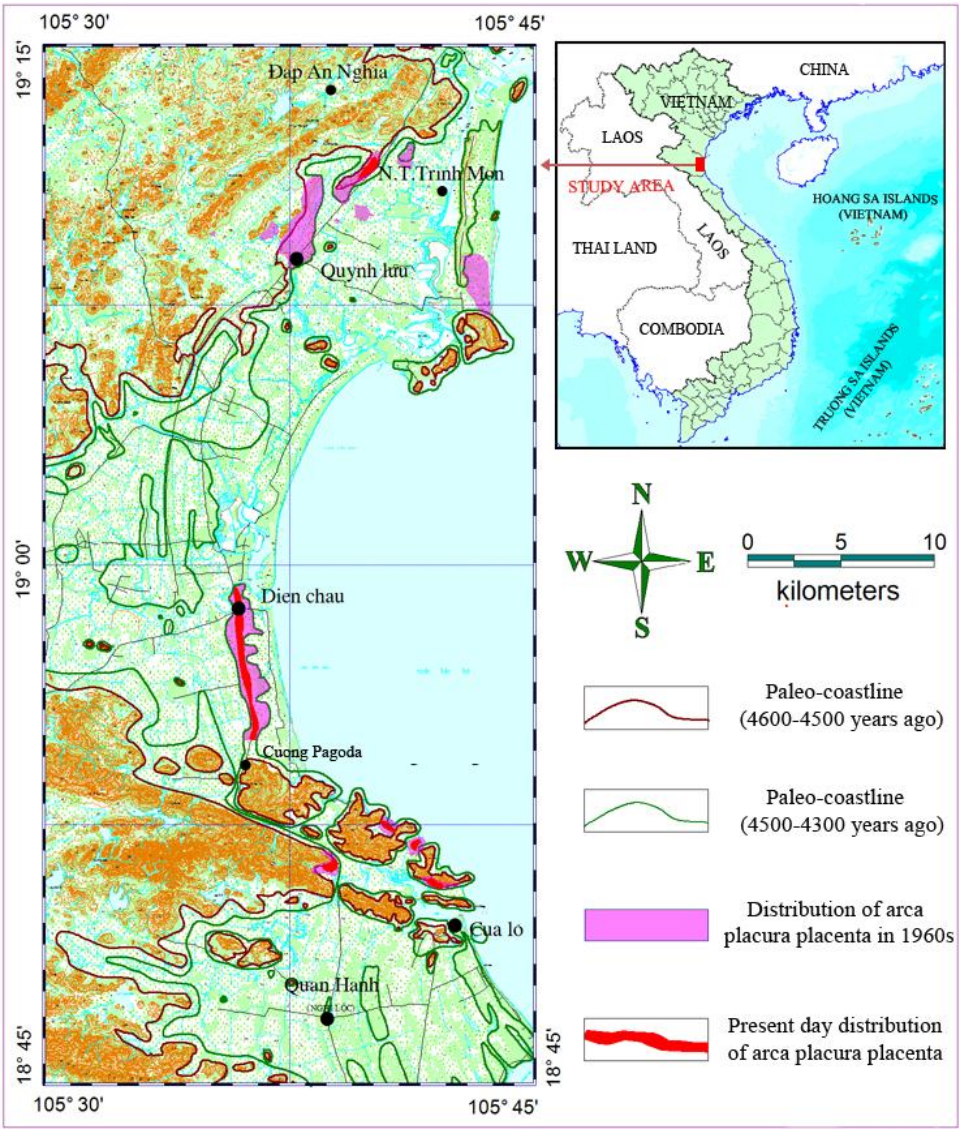

Fig. 5. Relationship between paleo-coastline in the Holocene epoch and distribution of arca-placura placenta

PALEO-TSUNAMI

The determination of traces of the paleo-sea water levels in the Holocene epoch mentioned above allows us to relatively and basically determine the vestiges and "abnormal" geological bodies (origin, distribution location, geo-layered orders, and size/scale) in the following areas (fig. 6, 73):

The "abnormal" bodies in geological sedimentation may suggest a tsunami ST1 occurring in the coastline of Nghe An (and maybe in Ha Tinh). The tsunami waves transported arca granosa and placura placenta from sea floor to onshore area and formed a field of arca granosa with placura placenta scatter distributed in the nearshore areas and paleo-coastlines such as Quynh Van, Quynh Hoa, Dien Chau etc. The process of forming the fields of arca granosa with placura placenta is the sudden one (due to a number of arca granosa and placura placenta still keeping their mouths shut), and these layers of arca granosa with placura placenta were chaotically arranged

(fig. 3, 4). The dating results of the placura placenta of the hills give the age of 4,500 - 4,300 yrs. from present. There is 'geological abnormal" in this region because the sea water level at that time was not recorded. In addition, species of placura placenta are living only under the sea water level of about 9 - 10 m in depth. Therefore, in normal conditions, the sea water level at that time must have been at 15 m or higher. This fact cannot be accepted (as trace of wave abrasion remained at 3 - 4 m in height). It must be suggested that an origin of hill of placura placenta in Quynh Van was due to huge waves swiping up from the bottom of sea floor which was considered as tsunami wave. If the above suggestions were true, then the tsunami ST1 during the time of 4,500 - 4,300 yrs. ago may have had a height of 6 - 8 m and transported arca granosa and placura placenta from a depth of 9 - 10 m into mountain sides.

Another vestige of the "abnormal" is a hill of placura placenta in Nghi Tien commune. This hill of placura placenta is relatively rounded and singly located on the surface of the coastline sand dune of the village No.9 of Nghi Tien commune (Nghi Loc district), which has a height of about 6 - 7 m. The hill consists of layers being arranged slopingly, sometimes curvingly and sub-vertically (fig. 4). Most of the layers contain placura placenta of 30 - 70 cm thick mixed with thin layers, lens of arca granosa, snails interblended poorly with polished stone pieces of sharp edges with different sizes from some centimeters to 15 - 20 cm. The placura placenta is overlaid on each other; arca granosa and snails are chaotically arranged. Some samples taken from the volumes of placura placenta mixed with arca granosa in lower part have ages of accordingly 4320 $\pm$ 60 yrs., 4380 $\pm$ 65 yrs., 4310 $\pm$ 110 yrs. from present. The samples taken from upper part, close to soil layers, have an age of 4150 $\pm$ 70 yrs. from present and the samples taken right under the hill of placura placenta have age of 4060 $\pm$ 110 yrs. from present.

More ancient volume of placura placenta (at age of 4,380 $\pm$70 yrs. from present) has been pushed up and overlaid on the younger sedimentary layer (at age of 4,100 - 3,900 yrs. from present) possibly by another strong tsunami (ST2) with larger amplitude, higher wave heights (the marine coastline of the age of 4,100 - 3,900 yrs. ago is found near the modern coastline mentioned above), which might reach up from 10 m to 15 m. It suggests that the tsunami ST2 is a reason for formation of the Nghi Tien hillock of placura placenta (at the age of about 4,500 - 4,300 yrs. from present), which was overlaying the sand dune of the age of 4,100 - 3,900 yrs. from the present under the influence of withdrawing waves. This can be proved by existence of the hill of placura placenta located far on-shore, in the edge of Than Vu mountain foot in the West (a promontory in the northern Cam bridge near the national highway No.1A discovered by archaeologists) and also the hills of placura placenta scatter distributed along the Nghe An and Ha Tinh coastlines.

A series of geological events attracting attention is a wide distribution of large-scale mountain sliding on the slopes of ranges of mountains along the coastline from Den Cong mountain (Cuong pagoda) in Dien Chau district to Hong Linh, Thach Hai- Thach Ha ranges of mountains (along northern Ha Tinh sea) [2, 3]. Radiocarbon dating ^{14}C determined from samples of sliding side (the large-scale sliding covering the whole surface of mountain from foot to ridge of one branch or the whole mountain) gives the age varying from 900 to 600 yrs. from present (the area of the village No.4 of Nghi Tien commune has the age of 750 $\pm$ 65 yrs. from present; the area of Northern Hong Linh mountain has the age of 750 $\pm$ 95 yrs. from present, and the area around the village No. 2 of Thach Hai commune has the age of 730 $\pm$ 65 yrs. from present). At the same time, the existing original "pebble dyke" in Su stream (near marine shore of the Dang Cong mountain foot in the northeast) has ages ^{14}C in order of 680 $\pm$ 75 yrs. and 795 $\pm$100 yrs. from present. This pebble dyke has a height of 6 – 8 m, and a width of about 50 m stretching over 200 - 300 m in length that barriers the Su stream flow. Pebbles of high-degree selections and the regular, clean overlaying surface of

terrace of 3 - 4 m in height consist of pebbles, chaotically craved stones of irregular abrasion to shaped edges (river terrace and marine abrasion?). Here the whole terrain is crossed by stream flow. Origin of the "pebble dyke" coincides with ages of the large-scale sliding events (possibly due to the occurrences of earthquakes, which were recorded by events in historical notes and in some family annals in the region, such as in Le family annals, family annals of Mr. Le Minh Thuong in Nghi Thinh commune, Nghi Loc district). According to these records, about 600 years ago, a giant deluge occurred, which swept away all villages to the sea and blew out, making Nghe An region a sand bank. All vestiges and events mentioned above allow us to suggest possibility of earthquake and tsunami (ST3) in the research area that occurred in the past 900 - 600 yrs.

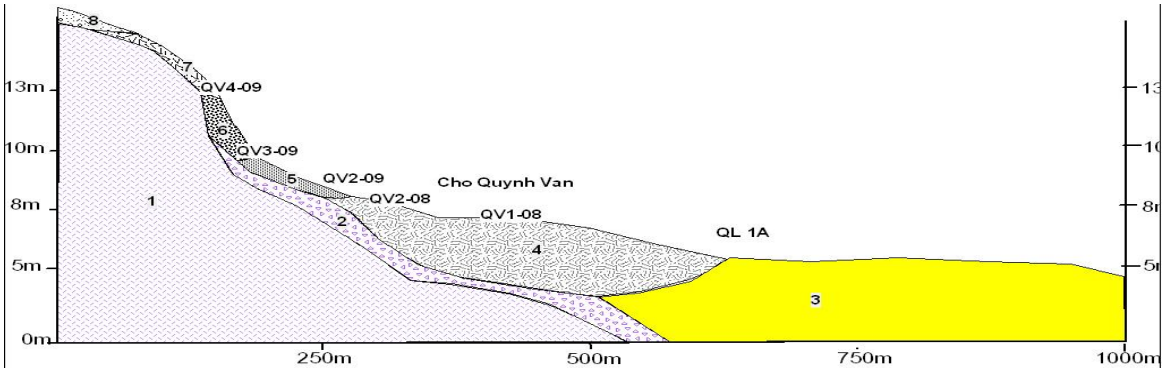

Fig. 6. Relative cross-section of layers of placura placenta interblended with arca snails and debris in Quynh Van. The numbers in fig. 5. Original rock of the Dong Trau formation; 2. Side sliding zone; 3. Sea sand of the Middle Holocene age; 4. Volume of placura placenta with thickness of 4 - 5 m; 5. Volume of placura placenta mixed with shell of arca snails interblended with stone fragments (debris); 6. Grit-macadam and soil layer; 7. Upper layer of placura placenta; 8. Sides covered by soil layer 9. Places, where samples were taken upwards to the cross-section

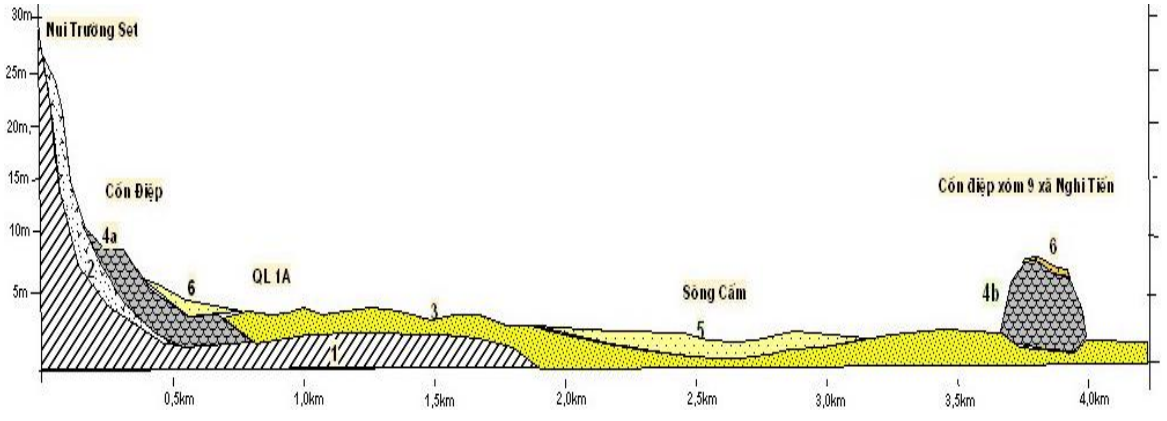

Fig. 7. Apparent cross-section from Truong Set mountain foot (Northern Cam bridge) in the West to hillock of placura placenta in village No.9 of Nghi Tien commune in the East: 1. Rock of the Dong Trau formation; 2. Gravelly soil of side sliding; 3. Middle Holocene marine sediment (at age of 4,100 - 3,900 yrs.); 4. Volume of placura placenta interbedded with layers/lens of shells, snails contains rubbles; 4a. at the hill of placura placenta in Truong Set mountain foot; 4b. Hill of placura placenta in the village No.9 of Nghi Tien commune (at age of 4,500 - 4,300 yrs.); 5. River sediment-river age interchanged in late Holocene; 6. Cover - soil layer

CONCLUSIONS

It is suggested that there were 3 tsunami events caused by earthquakes occurring along the Nghe An coastline in the past during the periods of 4,500 to 4,300 yrs.; 4,100 to 3,900 yrs.; and 900 to 600 yrs. ago, respectively. Among these events, the ST1 occurred during the time of 4,500 - 4,300 yrs., had made a formation of hill of placura placenta with acra granosa on a mountain slope in the Western Nghe An delta (wave height might be of 6 - 8 m). The ST2 occurred during the time of 4,100 - 3,900 yrs. with wave height of 10 – 15 m, had formed a volume of placura placenta on a mountain slope in Quynh Van (due to coming waves) and also formed Nghi Tien hill of placura placenta (due to withdrawing waves). Lastly, in latest time period of 900 - 600 yrs., possibly a strong earthquake occurred, which caused sliding on a large scale accompanied by a tsunami (ST3), which created a "pebble dyke" in Su stream - the biggest deluge occurring in the Nghe An and Ha Tinh coastal regions.

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