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GEOINDO 2015
TECHNICAL CONFERENCE SCHEDULE

Day 1: *Monday 23, 2015* **Morning**

07:30 – 08:45	**Registration**	
MAIN ROOM		
08:45 – 09:00	**Welcome address** by Assoc. Prof. Dr. Pornthap Thanonkeo, Dean, Faculty of Technology, KhonKaen University	**MC: Kritika Trakoolngam and Patthama Thukkhane**
09:00 – 09:20	**Opening Ceremony** by Assoc. Prof. Dr. Kittichai Triratanasirichai, the President of KhonKaen University	
09:20 – 10:00 **KN-1**	**Principal Keynote Address:** "Petroleum Exploration Plan under Oil Crisis in the ASEAN" by **Dr. Songpope Polchan**, Former Director General, Department of Mineral Fuel, Thailand	
10:00 – 10:20	***Coffee/Tea Break***	
10:20 – 10:55	**Principal Keynote Address** by **Yos Samuth**, Vice Director, Department of Mineral Resources, Cambodia	
10:55 – 11:25	**Principal Keynote Address** by **Mr. Khoune PHETSENGSY**, Director of Southern Geology and Survey Unit, Department of Geology, Laos PDR	
11:25 – 11:55 **KN-2**	**Invited Speaker : Dr. Hai Thanh Tran**, Vice Rector, Hanoi University of Mining and Geology "The role of active tectonic movement on the coastal geological hazards: a case study of central Vietnam's coastal zone" (Hai Thanh Tran, Thao Phuong Thi Phi, Hieu Minh Le, Dao Anh Vu, Men Thi Bui , Nam Xuan Nguyen and Do Tu Ngo Hoang)	
12:00 – 13:00	***Lunch***	

The role of active tectonic movement on the coastal geological hazards: a case study of central Vietnam's coastal zone

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ABSTRACT

In Vietnam, the central portion of coastal area, which extends more than 1000 km along tens of coastal provinces and major urban canters as well as economic hubs, is strongly affected by recent tectonic activities. The coastal zone is underlain by a complex basement comprising numerous rock types differing age, origin and have undergone multiphase of deformation. The basement rocks include high-grade Precambrian complex, Paleozoic to Cenozoic sedimentary and volcanic sequences, which are intruded by a large volume of Middle Paleozoic to Early Cenozoic magma. Cenozoic cover comprises thin sedimentary layers and subordinate Neogene-Quaternary basalts, which occur either in small deltaic basins or narrow, discontinuous coastal terraces. All of these assemblages are strongly dismembered as consequence of long-lived regional deformation, including active tectonic processes. The combination of lithological variation, tectonic dismemberment in conjunction with the sea actions has produced complicated coastal morphology. Active tectonic activities and their effects on coastal morphology is indicated by a number of markers. These include the presence of earthquake, volcanic eruption, active fault zones, modification of Quaternary morphologic features, local uplift and/or subsidence of coastal zone. Active tectonic movement has contributed to recent coastal hazards such as coastal erosion and sea invasion, and create long-term effect on land subsidence and relative sea-level rise or uplift and relative sea-level fall. Consequently, local relative sea-level change along Vietnam's central coastline is the combined output of local vertical geological motion and global relative sea level change , which has led to considerable spatial and temporal morphologic variability in the coastal area. In the case of global sea-level rise scenario, observed local subsidence or uplifting parameters caused by local verticalmovement provide more accurate information forpredicting local geological hazards..

Keywords: Central Vietnam, coastal hazards, land subsidence, land uplift, active tectonics.

1. INTRODUCTION

The central portion of the coastal zone of Vietnam, which extends more than 1000 km along tens of coastal provinces and major urban centres as well as economic hubs facing the East Sea, is strongly affected by natural calamities including recent tectonic activities. Active tectonics, indicating recent motion and deformation of the Earth's crust are common in the area and are indicated by numerous geological and geomorphologic signatures such as earthquake, volcanic eruption, subsidence or uplift and changing of landscape. Active tectonic movements along the coastal zone can contribute and/or lead to serious geological hazards such as tsunami, coastal erosion, landslide or land subsidence. Natural disasters are getting more frequent in many coastal areas, leading to great economic loss and threats to the local communities (e.g., Dao Manh Tien, 2004; Tran et al., 2015). With global prevention and mitigation of coastal hazards is largely depends on the understanding of all factors that govern the coastal zone evolution (e.g. Bell, 2003; Williams and Ismail, 2015). However, such relationships have not been adequately addressed in coastal areas of Vietnam. This warming and the rise in sea level, such hazards will be multiplied, which consequently threaten the coastal zones.

In general, the development of the coastal hazards such as subsidence and coastal erosion has widely been considered as the consequence of a combination of androgenic factors, such as the composition and occurrence of lithological units, tectonic deformation/movement coupled with exogamic processes (e.g., Bell, 2003; Burbeck et al., 2015; Montgomery, 2010; McGuire and Maslin, 2013) under heavy influence of local tropical monsoon climate. In addition, sea level fluctuations would also impact the coastal vulnerability against natural disasters (McGuire and Maslin, 2013).The importance of coastal geological structures and tectonic movement in shaping the coastal morphology and geo-hazards along the coastal areas in a regional context would be very significant. In the case of a relative sea level rise scenario, a best adaptive solution for

paper highlights evidences of the recent tectonic activities and their roles in controlling the formation and occurrence of coastal morphological features and geological hazards that were resulted from an integration of detailed field mapping and structural analysis and other geological date sources in central coastal zone of Vietnam. The new geological information will form a basis for future assessment, prediction and mitigation of coastal hazards in the coastal region of Vietnam.

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2. GENERAL GEOLOGIAL FEATURES OF COASTAL ZONE OF CENTRAL VIETNAM

2.1.Lithostratigraphy and magmatism

The central portion of Vietnam's coastal zone is located along the southeastern margin of the Truong Son fold-thrust belt that adjoins the tectonically complex, high-grade metamorphosed Kon Tum Massif in the south (Figure 1). The Kon Tum Massif, which is adjoined with the Truong Son fold-thrust belt in the north by the early-middle Paleozoic Phuoc Son-Tam Ky Suture Zone (Figure 1; Tran et al., 2014). Most of the coastal area is overlain or intruded by predominant Mesozoic to Cenozoic sedimentary and intrusive assemblages (Figure 1).

Results of recent regional geological works (e.g., Tran Duc Luong and Nguyen Xuan Bao, 1982; Nguyen Van Trang, 1986; Nguyen Duc Thang, 1988; Tong Duy Thanh and Vu Khuc, 2006; Tran Tinh, 1997; Tran Van Tri and Vu Khuc, 2011) have led to recognition that the central portion of coastal zone of Vietnam is underline by numerous lithotectonic assemblages of differing age and composition. The northernmost portion north of Phuoc Son – Tam Ky Suture Zone (Figure 1) is underlain by Neoproterorzoic to Early Paleozoic, strongly folded and thrusted sedimentary packages that are part of the Truong Son Fold-thrust Belt (Tran et al., 2014). These are either overlain by Mesozoic continental deposits or variably intruded by mid-Paleozoic to Meosoic magmatic complexes. South of the Phuoc Son – Tam Ky Suture zone, the Kon Tum Block is core by predominantly Precambrian high-grade metamorphosed para- and ortho-gneissic basement of the Kon Tum Massif, which are tectonically intercalated with remnant slides of Paleozoic sedimentary rocks and intruded by numerous magmatic complexes ranging in age from Early Paleozoic to late Mesozoic. In the southern part, the coastal zone area are underlain mostly of massive Mesozoic intrusive rocks and minor sedimentary and volcanic packages. Along the coastal area, the above rocks are variable unconformably covered by the Cenozoic sedimentary and subordinate volcanic formations, which are predominant and cover a large part of the lowland and coastal zone in the area, which form narrow coastal plains (Figure 1). These comprise two major associations, including the Neogene-Early Quaternary sedimentary and volcanic units and the Quaternary sedimentary sequences (Figure 1). The Quaternary deposits, whose ages vary from the Pleistocene to the Holocene and recent consist of many various sedimentary types and can be classified on the basis of their origin. The Pleistocene successions are composed of basalt, marine-fluvial deposits including sand and grayish-green clay that form the plains adjacent to the foot-hill areas in the west. In contrast, the aeolian-marine deposits occurs as remnants of fine- to medium-grained sand dunes of various sizes that occur locally along coastal zone. The Holocene sediments comprise the lacustrine/lagoonal dark-grey mud and silt, marine sand, silt and mud deposits, the aeolian medium-grained sand and the fluvial pebble, grit, sand, mud and clay deposits. These formations occur within the coastal area.

2.2.Structural features

All the rocks and Quaternary deposits in the area are variable fractured and partly dismembered, which have been triggered by various stages of regional deformation that extended at least from Silurian to present (Tran et al, 2014b, 2015). On the basis of field mapping and structural interpretation, numerous of tectonic structures were identified. The major structures include fracture and faults zones as well as folds of different orientations and ages (Figure 2), some of them demonstrate multiple reactivation and remain active during the Quaternary. The structures can be subdivided into the Paleo- and Neotectonic systems (Moores and Twiss, 1995; Pirazzoli, 2005).

2.2.1. Paleotectonic structures

The Paleotectonic structures are abundant and are commonly associated with regional deformation associated with major tectonic event that have taken place during the Phanerozoic (Tran et al., 2014a, 2014b, 2015). and include folds, ductile shear zones, brittle faults and fracture systems (Figure 3), which are those considered to be older than 5 Ma. in age (Moores and Twiss, 1995), developed widely within the pre-Quaternary units and formed several sets of orientation such as northwest-southeast, north-south and northeast-southwest trending systems (Figure 2).. Paleotectonic faults and fractures commonly produced large zones of mylonitization or brecciation. Kinematic indicators within the fault zones show that the relative movement along the faults are complex, including reverse, oblique or strike-slip motions (Figure 3). Apart from the major fault zones, fracture systems are also widespread, which are commonly infilled by quartz or calcite (Figures 2, 4).

2.2.2. Neotectonic faults and fractures

The Neotectonic faults and fractures are very common in the coastal zone of Central Vietnam. They are indicated by the occurrence of a number of kinematic and morpho-tectonic and surficial indicators (e.g., Bhat, 2013; Johnson et al., 2009; Keller, 1986; Martínez-Díaz and Hernández-Enrile,2004; Mayer, 1986; Schumm, 1986; Schumm et al, 2000). Direct evidences can be observed including unconsolidated brittle fault gouge zones, brittle slickensides that crosscut and/or deformed the Quaternary sediments and weathering profiles (Figures 2 and 4). Numerous open-spaced, brittle fractures that cut through Quaternary volcanic or sedimentary materials and weathering products are also considered parts of Neotectonic activities (Figure 4). In addition, many topographic features related to or resulted from fault movement such as lineaments, triangular facets, uneven shift of drainage pattern or distribution of drainage systems, sudden change of flow direction, abrupt uplift

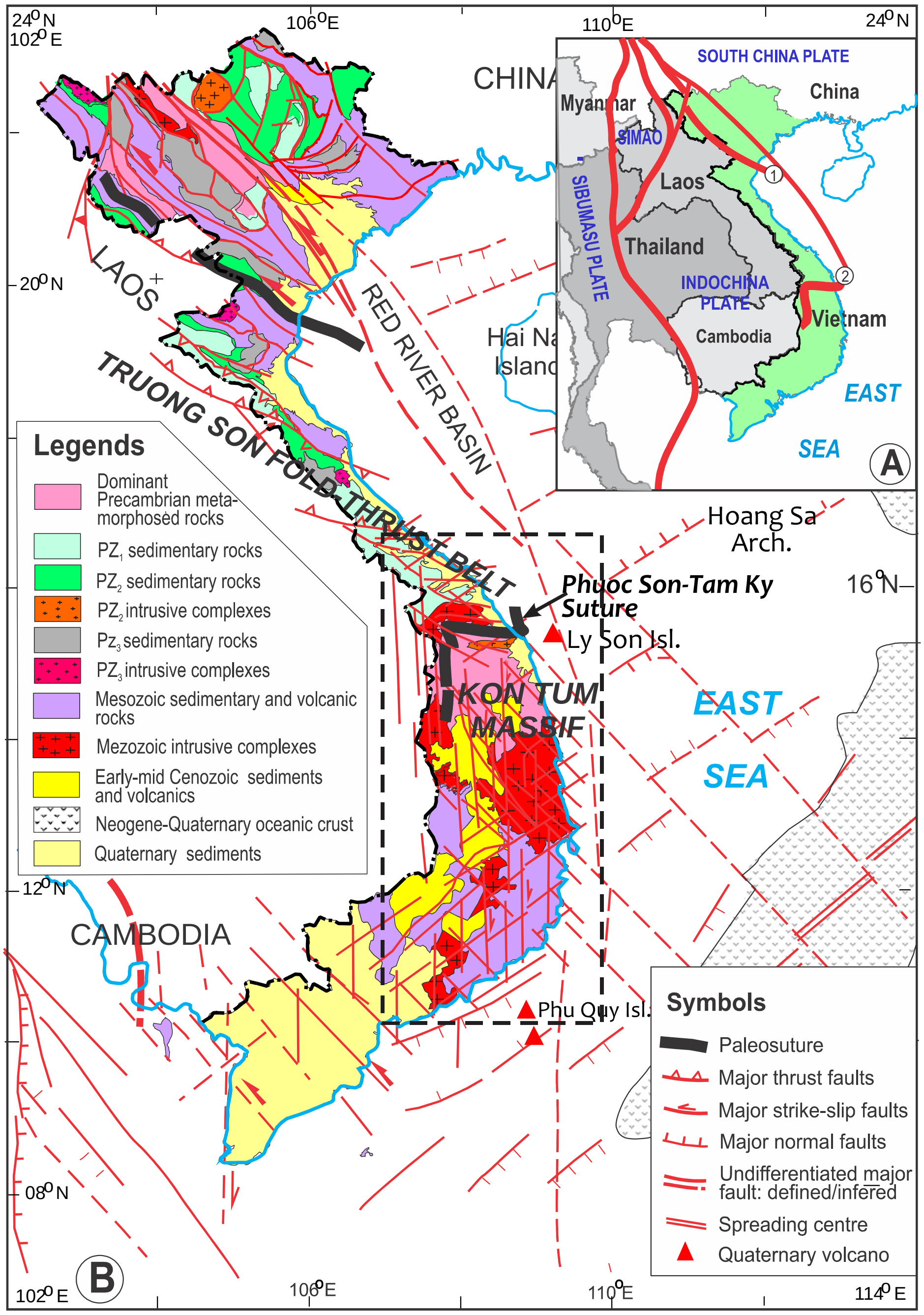

Figure 1. A. General tectonic position of Vietnam in Indochina. B. Summarized lithostructural map of Vietnam showing occurrence and relationship of major lithological assemblages as well as regional structural breaks. Black box is the area of this discussion.

or subsidence of the terrane that governed by faults and fractures (e.g., Burbank and Anderson, 2011; Hurtez et al, 1999; Keller, 1986; Martínez-Díaz and Hernández-Enrile, 2004; Mayer, 1986; Schumm, 1986; Schumm et al., 2000; Yao et al., 2013) are also common in the area and are used for extrapolation of faults. The Neotectonic faults and factures trends in many directions including northwest-southeast, north-south, east-west, or northeast-southwest trending systems, which form a complicated network and influence the morphological pattern of the coast line as well the coastal zone as well as geo-hazards in the area. The kinematic indicators show various senses of movement including reverse, normal, strike- or oblique-slip. In many places, the Neotectonic faults and fractures have also either reactivated the Paleotectonic faults or being multiple reactivated with opposing sense of movement, producing complex regional structural pattern and indicating a complicated tectonic motions in Central Vietnam during the Quaternary.

Furthermore, numerous evidences of earthquake, some with magnitude of nearly ca. 6 on Richter scale (Figure 3). Hot springs, which are widespread in the area and commonly occur along major fault zones, are also evident for active tectonics (Figure 3). In places, Quaternary volcanic eruption also evident in central Vietnam, some of them were erupted as recently as 1923 (e.g., Hon Tro Island, Figure 3).All of these evidences demonstrate that the coastal zone of Central Vietnam is the area of strong active tectonics.

Neotectonic fracturing and displacement also influence greatly to the coastal morphology of the coastal zone in the study area (e.g., Le Xuan Hong and Le Thi Kim Thoa, 2007).

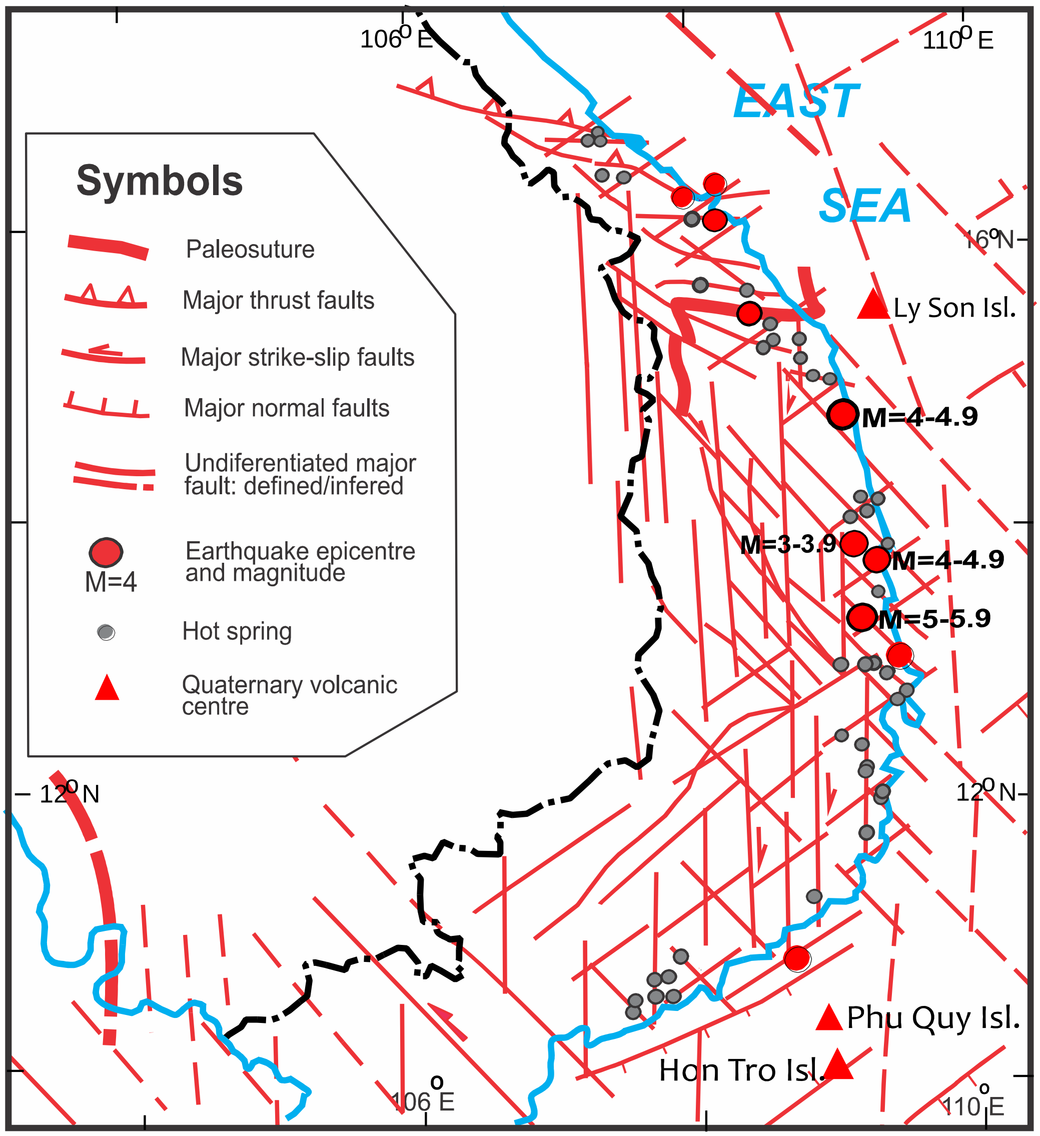

Figure 3. Generalized structural map of Central Vietnam, showing major faults and other tectonic elements with indicators of Neotectonics

2.2.3. Uplift and subsidence

Aside from evidences for recent fault movements, the Neotectonic activities in coastal area of Central Vietnam are also evident by strong vertical movement during the Quaternary, which have shaped the unique coastal morphology represented by mostly erosional landform, rocky coast and scattered narrow depositional marine and marine-fluvial landforms, which are closely related to the uplifting or subsidence of the coastal areas.

Terrane uplift commonly lead to the formation of erosional landform such as shore platform, horizontal terraces or plunging cliffs occur in large part of coastal zone of the study area. Many marine terrace levels can be observed, indicating periodic uplifting of the coastal area. In many places, several levels of coral reefs are exposed along the coast, indicating the relative uplift of the sea bed or the fall of sea level. Tectonic uplift has also commonly led to the development of V-shape valleys, angular and antecedent drainage systems and hence expansion of deltaic basins through time. Tran et al. (submitted) have demonstrated that in part of the coastal zone, the uplifting of the coastal area has been taken place during last several ka BP at the minimum rate of ca. 0.2 m per 100 ka.

The subsidence in the coastal area locally occur in the form of the formation and expansion of modern fault-controlled graben or pull-apart small basins along the coastal zones, the formation of inland swamps, lakes or coastal lagoons. In addition, the constant coastal invasion and beach loss, burial of ancient l architects below the current surface level in some place are all considered to be resulted from ground subsidence. Tran et al. (submitted) have identified a subsided rate of 0.1 mm/year for some areas in Tuy Hoa, Phu Yen Province. The subsiding areas commonly take place in the area of strong active faulting and appear to be closely governed by recent tectonic activities, especially the along the active fault zones.

2.3.Geo-hazards in the coastal zone

Along coastal zone of Central Vietnam, geological hazards are common, which mostly occur in the form of landslides, river bank and coastal erosion, which occur strongly in many areas and have led to significant fracture damages and economic loss of the local communities recently.

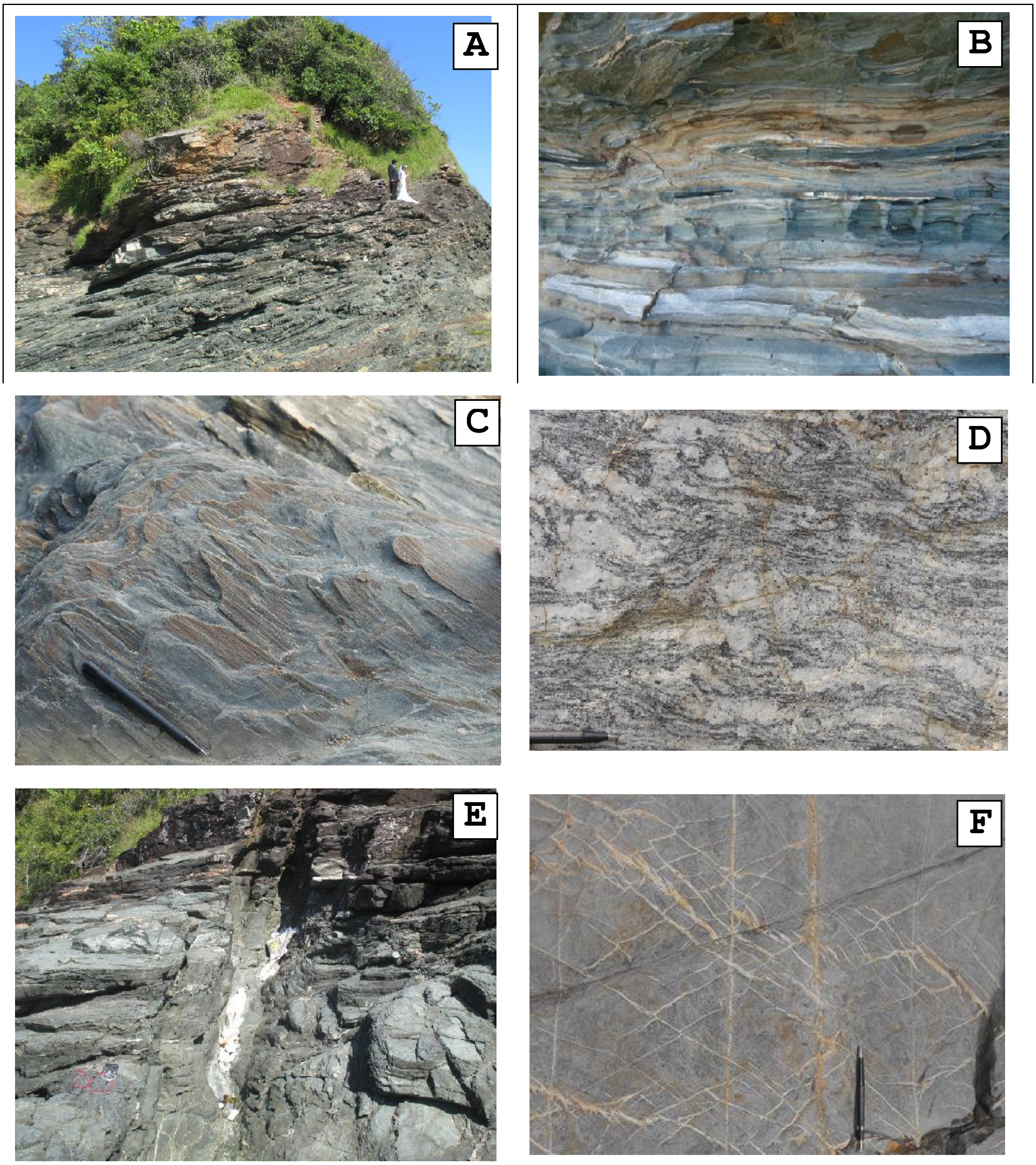

Figure 3. Photographs showing examples of Paleotectonic structures occurring along the coastal zones of central Vietnam. A . A large-scale ductile shear zone forming part of the Phuoc Son – Tam Ky Suture zone exposed in Tam Hai area, southern Quang Nam Province; B. Sheath folds associated with ductile shearing in the Phuoc Son – Tam Ky Suture zone seen in Tam Quang area, Quang Nam Province; C. Strong stretching lineation as part of B; D. Mylonitizated Mid-Paleozoic granite seen in Dung Quat area Quang Ngai Province; E. Overprinting of a brittle fault zone on ductile structures in Tam Quang area; F. Multiple phase fracture-filled veining and tension gash systems cut by brittle, open-spaced fractures, indicating multi-phase deformation seen in the north of Da Nang City.

Landslides in the area commonly occur in the form of creep, flow, slide, rock fall and debris flow. These are taken place along the river banks, on hill slopes and along the shore areas (Figure 5). It appears that the landslides are restricted into the areas where the basement rocks are strongly fractured, which would produce deeply weathered zones or cross-cutting join/fracture system (Figure 5). Along the river banks, many of landslides have taken place within the are of active faulting or fracturing, which commonly lead to the alteration of drainage systems, sudden change of flow pattern or uplift /subsidence of parts of the river systems.

Shore erosion and beach loss are locally occurred along the shoreline. These actions occur unevenly either in the river mouth area or in the shore areas that are currently affected by strong faulting and fracturing, and active tectonic subsidence (Figure 5).

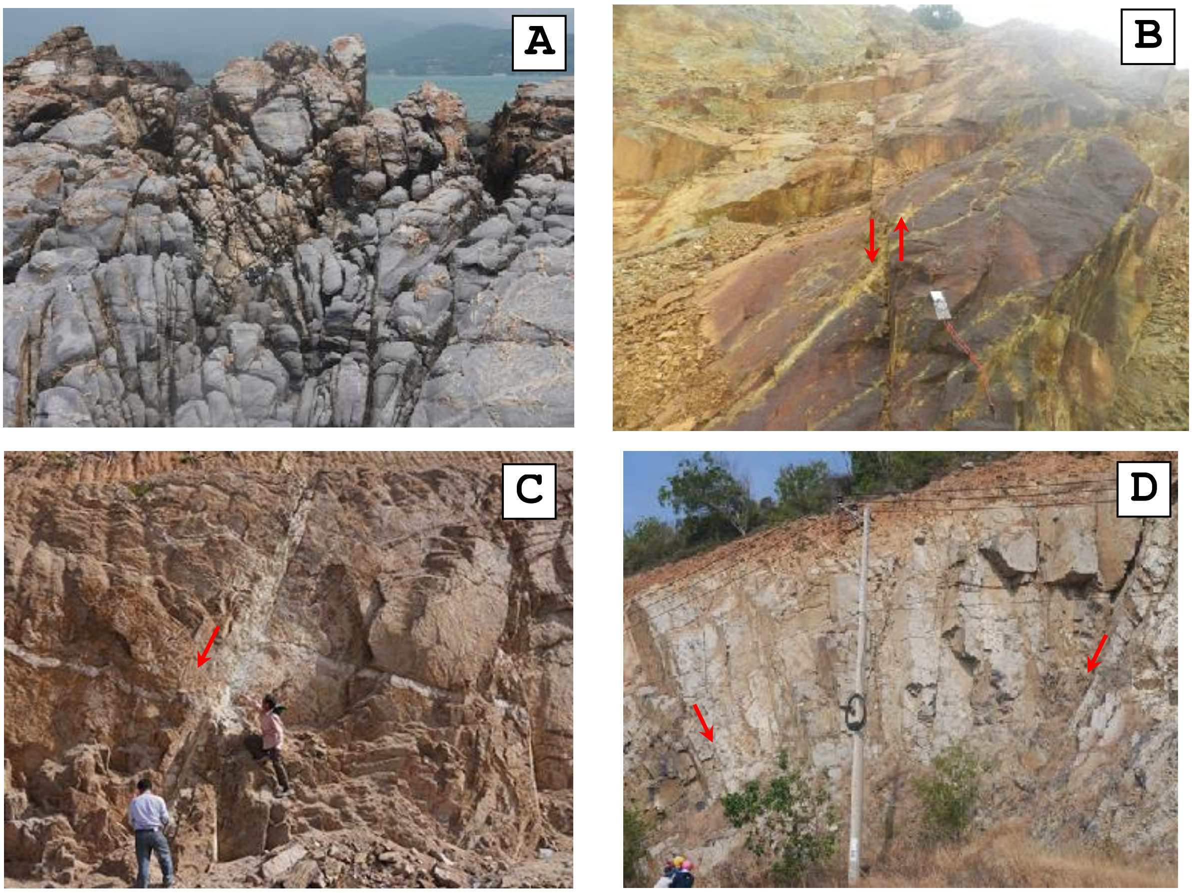

Figure 3. Examples of Neotectonic faults and fractures occur along the coastal zone of Central Vietnam. A. A zone of brittle faults forms a positive flower structure in the north of Da Nang area; B. Brittle faults cut through weathered granitic rocks in Tuy Hoa area, Phu Yen Province; C. A brittle, normal fault zone cut through weathered granite in Nonh Hai area, Ninh Thuan Province; D. An open-spaced normal fault zone forming negative flower structure in Cam Ranh area, Khanh Hoa Province.

3. THE ROLE OF ACTIVE TECTONIC MOVEMENT ON THE COASTAL GEOHAZARDS

In general, geological hazards are the combined results of natural and artificial phenomena, including the androgenic influence, exogamic conditions or man-made activities (*e.g.,* Clarke and Burbank, 2010; Eyles et al., 1997; González and Törnqvist, 2006; Holzer and Galloway, 2005; Keller and Pinter, 2001; Kooi, 2000; McGuire and Maslin, 2013; Montgomery, 2010; Willett, 2006.) As discussed above, geo-hazards including landslide, riverbank and coastal erosion, beach loss, subsidence and uplift are clearly evidenced in coastal zone of Central Vietnam (see above, Dao Manh Tien, 2004). Field observation together with data analysis show that these hazards are closely related to and governed by the active tectonic condition of the study area

3.1. Impact of subsidence and uplift on coastal flooding

Recent studies (Stattegger et al., 2013) have suggested a Holocene relative sea level change along the tectonically stable coastal zone in central and southeastern Vietnamese coast. Stattegger et al. (2013) argued that the Early to Mid-Holocene sea level rise was triggered by the last melting phase of the polar glacial ice sheets. This event was subsequently followed by a sea level fall after the Mid-Holocene high-stand and was suggested to be induced by the isocratic processes. Thus climate change coupled with isocratic rebalancing has given rise to continental uplift in low latitudes and depression of adjacent flooded continental shelf areas. However, despite a regional trend of relative sea level fall in a relatively stable coastal zone, the local active tectonic instability illustrated by the uplift or subsidence activities have locally been observed along the coastal area. The ground subsidence along the coastal zone would lead to the relative sea level rise and eventually result in flooding the subsided area as well as shoreline erosion and beach loss (Bloch, 2009; Burbank, 2002; González, and Törnqvist, 2006; Lajoie, 1986; NOAA, 2012). Current statistics shows that the average global sea level has risen at ca 2.5 mm/Yr. since 1900. New calculation based on more accurate data has indicated an average sea level rise of ca 3.0 mm/Yr. since 1992 (NOAA, 2012). In the case of central Vietnam, a recent calculation of relative sea level rise scenario during the next 100 years has predicted a range of ca. 0.81 to ca. 0.99 meters of sea level rise by the year 2100 respect to an estimation of high CO_2 emission scenario respectively (MONRE, 2012).

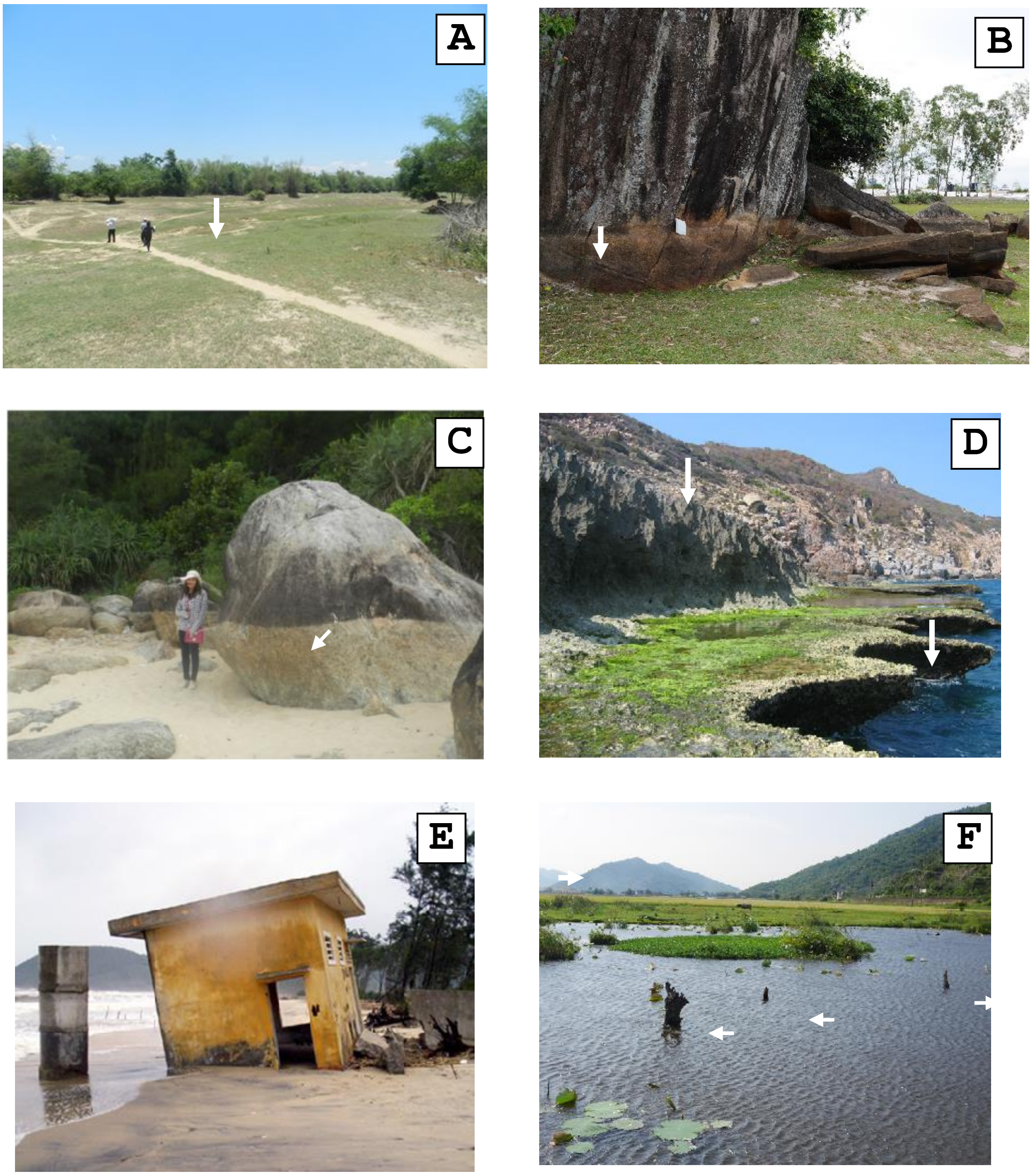

Figure 4. Examples of evidences for recent tectonic uplift and subsidence in coastal zone, Central Vietnam. A. Exposed river bed of a branch of Thu Bon river system caused by local uplift, Quang Nam Province; B. A paleo-strandline exposes at ca. 20 metres above sea level indicating relative coastal uplift in the Ngoc Son Dong area, Quang Nam Province; C. A paleo-strandline exposes at ca. 3 metres above sea level indicating relative sea level fall or coastal uplift in the Hoa Duan river nouth area, Thua Thien- Hue Province; D. Two levels of exposed coral reef originally formed at a minimum depth of ca. 6 metres, indicating strong ground uplift or relative sea level fall seen in Ninh Hai, Ninh Thuan Province; E. A pumping station originally constructed inland now submerged under sea water indicting rapid subsidence in Vinh Hai area, Thua Thien – Hue Province; F. Remnant of ancient trees (white arrows) in an active-tectonic controlled subsiding basin in Hao Son area, south of Phu Yen Province.

In the case of a predicted global relative sea level rise caused by climate change, the local sea level rise will be exaggerated by the amount of active tectonic subsidence. In this case the total amount of subsidence will be the sum of calculated regional sea level rise and amount of tectonic subsidence with a minor contribution of the ecstatic sea level change.

Figure 5. Examples of geological hazard types commonly seen along the coastal zone of Central Vietnam: A. Landslide taken places along a fault zone cross-cut granitic rocks south of Quy Nhon City, Binh Dinh Province; B. Riverbank collapse along left bank of Thu Bon River, Quang Nam Province; C. Strong erosion and collapse of the shore in Tam Hai area, southern Quang Nam Province; D. Part of a village in the south of Thuan An River mouth, Thua Thien – Hue Province were collapsed and burial caused by land subsidence and sea invasion; E. The destruction of a resort in northwest Cua Dai River mouth, Hoi An City, Quang Nam Province as consequence of relative land subsidence, beach lost and sea invasion; F. Remain part of a ship yard in the north of Da Rang River mouth, Tuy Hoa City, Phu Yen Province as consequence of beach lost and sea invasion.

As discussed above, subsidence has been identified in some areas along central Vietnam's coastal zone. Tran et al (submitted) have demonstrated a subsidence rate of ca.0.9 mm/year for the last several thousands of year and suggested that some areas will be affected by large amount of sea level rise as a combination of tectonic subsidence and climatic driven sea level rise. This could lead to the flooding of large areas that may not be affected if there are no tectonic subsidence.

The ground uplift, on the other hands, are common along the coastal zone of Central Vietnam, indicated by both morphologic features such as the occurrence of numerous river and coastal terraces, stable shoreline, expansion of the beach, shallowing sea bed, as well as dating results of the uplifted materials (Stattegger et al., 2013; Tran et al., submitted) in which the uplifting rate has been calculated some areas at an average of ca 2 mm/year. In the case of a predicted climatic-driven regional relative sea level rise, the total amount of flooding will be partly compensated by the amount of tectonic uplift. In this case, it is anticipated to suggest that the amount of flooding along the coastal zone in the uplifting areas could be lower than that predicted without tectonic movement (MONRE, 2012) by nearly 20 percent.

3.2. **Landslide, riverbank and shoreline erosion**

3.2.1. Landslide

In general, it has found that landslide commonly occurs in areas of strongly fractured and faulted rocks *(*e.g., Burbeck et al., 2015; Clarke and Burbank, 2010; Genter et al., 2004; Kenedy et al., 2014; Slemmons *and* Depolo, 1986). Tectonic deformation provides fractures within the rocks, which not only provide pathways for water flow to intensify weathering and further rock disintegration, but also fragments bedrock down to the scale of boulders or smaller pieces, producing debris that is readily removed and transported by surface processes (Molnar et al., 2007). The depth of bedrock fracturing influences the magnitude and frequency of landslide response to tectonic rock uplift (Clarke and Burbank, 2010). Shallow crustal tectonic deformation commonly takes place in brittle condition, producing pervasive fracturing and faulting in which large fault zones commonly comprise many smaller intersecting branches. In addition, local uplift, which resulted in the variation of relative base-level, also caused deep incision of valleys or erosion of hill slopes. The relative motions of fault zones also leads to differentiation on the topography such as sudden change in elevation along the dip-slip faults or horizontal displacement along the strike-slip faults. As a corollary, the brittle and recently-deformed dismembered rocks are likely to be more susceptible to detachment and subsequent transport by surface processes (Molnar et al., 2007) when outcropped, especially when facilitated by a slope instability, rain fall or other surface processes and man-made activities (e.g., Clarke and Burbank, 2010; Genter et al., 2004).

Riverbank and beach erosion

The destruction of the river bank or erosion of coastline constantly takes place along the river systems and their mouth or in other parts of the coastline that has led to significant retreat of the shoreline hundreds of meters landwards recently. The causes for coastal erosion have been supposed to comprise numerous natural factors such as geological conditions, relative sea level rise, long-shore and rip currents, wave/tide actions, storm or human effects (e.g., Coastal Wiki, http://www.coastalwiki.org). Some regional effects such as the global sea level rise, climate, sea current or wave action are region-wide and equally distributed and can be considered as constant parameters in the study area. Therefore, the localization of hazards within a small area with similar climatic, oceanic and other surface processes requires additional tectonic factors (*e.g.,* local subsidence, shoreline instability by active tectonic activities, zones of structural weakness) or man-made factors (e.g. construction of damp, dike and ground water exploitation). As most of the subsided areas along the coast in Central Vietnam occupied by a small population with minor or insignificant groundwater exploitation or mining activities indicating that these are unlikely to have caused the ground subsidence. The effects of sediment compaction are not significant either as some of the eroded areas occurred on crystallized bed rocks with very thin or no unconsolidated sedimentary layers. Damping of the upstream part of the river systems may have recently reduced sediment budget supplied to the river mouth, which can contribute to shoreline erosion and beach loss. In addition, the construction of sea walls, wave breaker, groin and tetrapod, etc. along the eroded area may also have adverse impacts on beaches because these could increase wave energy when the waves approach the shore and carry away sand from shore, leading to beach loss. These structures, however, have just been constructed during the past decade and were in many case for protecting the shoreline after serious erosion. In contrast, the river mouth migration and shoreline destruction have constantly taken place for long period of time, far before the man-made structures were constructed. As such, the man-made and surface activities may contribute, but cannot be the main cause, for shoreline erosion. Instead, the problem of shore erosion and beach loss will be exaggerated if the area is affected by modern tectonic activities (e.g., Genter et al., 2004; Kennedy et al., 2014; Swartz, 1982). Neotectonic faulting activity and differentiated movement of faulted blocks as they are very common along the coastal zone of Central Vietnam may play one of the most important roles in the development of modern delta or coastal zones (Yao *et al.*, 2013). It is suggested that the strongly fragmented and unstable basement and active tectonic motions within the coastal zone, as discussed above, are attributed the main driving factors for coastal erosion in Central Vietnam.

4. CONCLUSIONS

Field mapping and identification of geological structural pattern and its relationship to the active tectonic activities and geological hazards along the coastal zone of Central Vietnam reveal a multiphase deformational history that is presernly still in active. Modern tectonic activities have played an important role in shaping the present-day coastal landscapes of the area. The overprinting of Neotectonic activities, produced non-penetrative and highly fractured zones and localized vertical movements and horizontal displacements, which has led to the local uplift, subsidence, tilting, fracturing, and/or dismemberment of both basement and overlying sedimentary formations.

The combination of all structural elements with the exogamic processes have resulted in the various types of geological hazards. Neotectonic movements have led to local subsidence and uplift, which locally produced subsided basins or shoreline within areas of regional uplift. The empirical documentation of volume of tectonic uplift and/or subsidence have led to more accurate estimation and prediction of the degree of local subsidence and uplift in the context of sea-level rise scenario. Whereas, the cross-cutting brittle structures have led to bedrock fragmentation that enhanced significantly the exogamic processes and therefore importantly contributed to the enhancement of hazards such landslide, riverbank and coastal erosion in the area.

Thus, tectonic structures and Neotectonic movements in particular are important controlling factors for geological hazards of Central Vietnam coast. Proper identification of all types of structures, especially those related to Neotectonic movements, is therefore important and must be properly conducted in order to more accurately assess and predict natural hazards along the coastal zone, especially in the context of global sea level rise caused by global warming and climate change.

5. ACKNOWLEDGEMENTS

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