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Geomorphological Features of the Area to Be Established as a UNESCO Global Geopark in Phu Yen

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Abstract

The proposed area for establishment of Phu Yen Geopark is limited to 6 districts, towns and cities, including: Tuy Hoa City, Dong Hoa provincial town, Tuy An district, Song Cau provincial town and 3 communes, 1 town in Phu Hoa district town, 3 communes in Son Hoa district with an area of 1,575 km^2. Distributed in the central coastal line, the area's topography is quite diverse, including mountains, hills, plains and coastal areas, divided into 6 main origin types: *1) Terrain tectonics, volcanoes, architectural erosion, include: The tectonic and cavitation flanks of Pliocene - Quaternary age; Highland ridge, Neogene - highland Quaternary; Surface of the volcanic plateau has an elevation of less than 250 m; Surface of volcanic plateau is 300-400 m high; Cone ridge of Quaternary age crater; Structural eroded slope; Slope erodes edge of dome of the intrusive blocks, quartz fracture zones; 2) Terrain formed by erosion – cavitation, include: Pediple leveled surface, Miocene age 750 - 1100m high; Pediple leveled surface, early Pliocene age 450 - 600 m high; Pediple leveled surface, late Pliocene age 300 – 400 m high; Pediment leveled surface, Late Pliocene - Early Pleistocene age 150 - 250m high; Early - middle Pleistocene pedimen surface, 50 - 120 m high; Cavitation flank; Cavitation flanks of crevices and ditches of Quaternary age; Cavitation – erosion flanks; Collapsed erosion flank in Neogene - Quaternary age; Synthetic erosion flank Neogene - Quaternary age; Abrasion flank Quaternary age; 3) Terrain formed by rivers, include: River shelf level II, late Pleistocene age; River shelf level I, middle Holocene age; River accumulation delta, late Holocene age, early age; River bed and low alluvial ground along the riverbed, late Holocene age, late age; 4) Terrain formed by the sea, include: Abrasion – marine accumulation surface, Early – Middle Pleistocene age; Abrasive seashelf – accumulation level III, late Pleistocene age, early age; Abrasive seashelf – accumulation level II, late Pleistocene age, late age; Sea shelf level I, middle Holocene age, 5-10 m high; Surface of the sand dyke connecting the island, late Holocene age, early age; Modern beaches are flooded with frequent tides; 5) Terrain include:formed by the mixed impact of rivers and sea, include: The river-sea delta (shelf) of the Late Pleistocene age, Late and Middle Holocene age; Modern sea-swamp plain; Modern river-swamp plain; 6) Terrain formed by wind, include: Terrain type of sand dunes with elevation of 15-25 m; The terrain is sandy hill with an altitude of 105 m.* Each terrain type is associated with diverse geological heritages: paleontological heritage; geomorphological heritage; stone heritage…

Keywords: geomorphological features of Phu Yen, Vietnam

1. Preface

The proposed construction area of the UNESCO Global Geopark in Phu Yen is limited to 6 districts and towns, including: Tuy Hoa City, Dong Hoa provincial town, Tuy An district, Song Cau provincial town and 3 communes, 1 town in Phu Hoa district town, 3 communes in Son Hoa district with an area of 1,575 km^2. This is a coastal area with a diversity of geological, petrographic, and topographic structures, which has created many attractive landscapes, is a convergence of tectonic zones, has a long history of development from the Ancient Cambri to date. Along with the participation of most geological processes such as magma (intrusion, eruption), metamorphism; sediment (river, lake, sea, wind); tectonic activities such as compression and expansion with fault systems, cracks in many different directions combined with the carving of exogenous processes (weathering,

erosion, abrasion, material transportation of rivers, streams, sea, wind…) to reveal the diversity of formations creating the specificity of the landscape and topography of the area. Some famous landscapes have been recognized at national level such as O Loan lagoon, Ganh Da Dia (Sea Cliff of Stone Plates), Xuan Dai bay, and Vung Ro pool. With the above manifestations, the study area has the potential to become a UNESCO Global Geopark. However, in order to prepare a dossier for the establishment of a Geopark, the Ministry of Science and Technology has carried out a national-level scientific project "*Research and evaluate the value of geological and other heritage sites as the scientific basis for establishment of a UNESCO Global Geopark in Phu Yen*", code DTDL.CN. 05/21. The article titled "***Geomorphological features of the area to be established as a UNESCO Global Geopark in Phu Yen***" is the product of the above research.

2. Documentary Basis and Research Methods

The objective of this study is to determine the geomorphological characteristics and their relationship with the geological - geomorphological heritage in the proposed UNESCO Global Geopark in Phu Yen province.

To achieve the above objective, in addition to the materials that have been collected from different sources, field research and investigation according to the main research methodologies have been employed as follows:

Method of collecting and synthesizing documents: Collecting documents reflecting natural geographical features for reference and serving the research process. The collected documents include: topographic maps 1/25,000, 1/10,000; Geological and mineral maps, geomorphological maps at 1:50,000 scale of Quy Nhon group sheet (Tran Van Sinh, 1999) and Tuy Hoa group sheet (Truong Khac Vy, 1997) remote sensing images; overview of both the natural conditions and the geomorphological processes taking place in the area. The method also shapes the features and conditions of the research object. Apply DL (deep learning) trained models to monitor coastal erosion in Vietnam (Van Bao Dang…, 2022)

Morphometric measurement method: Geomorphological research method includes all methods of morphological identification, morphometric measurement (shape of terrain surface), phylogenetic origin, development history of the terrain on the earth surface. The role of geomorphological research focuses on morphometric features (topography, slope, cross section, deep division). Using topographical maps, geology and remote sensing images... to interpret the topography to understand the geomorphological characteristics of the study area. This morphometric measurement method allows the analysis and quantification of the terrain surface, includes the study of topographic morphological features as well as their representation on topographic maps. By using different methods, from manual methods to the use of machines, especially applying GIS enables to study topography, absolute altitude, relative elevation, slope, degree of horizontal cleavage, degree of deep cleavage, base surface. The morphometric measurement method is based on the analysis of the morphology of the river valley network on topographic maps, the morphology of the deflected valleys, the water dividers, the river basins and analysis of a series of maps: Base surface maps, remnant elevations, leveled surfaces, erosion maps, etc; analyzing and interpreting the topography, thereby forming a geomorphological map.

Field method: Field method to check and evaluate the accuracy of desk research results and correct if necessary, and at the same time add features and factors that cannot be identified on the topographic, geological maps. Accordingly, the geomorphological characteristics of the study area are synthetized and established, which is the basis for completing the geomorphological map of the study area.

3. Geomorphological Features and Related Heritage

Results of synthesizing and processing research materials on geology, geomorphology (Nguyen Xuan Bao et al., 2015), soil (Nguyen Van Toan et al. 2005) and additional field survey results of the project in 2021, 2022, based on the principle of co-origin surface classification, the topography of the proposed Geopark established area in Phu Yen has been determined, including the origin types with the main topographic forms are as follows:

3.1 Terrain Tectonics, Volcanoes and Architectural Erosion

a. The tectonic and cavitation flanks of Pliocene - Quaternary age

Distributed in southern Van Hoa plateau, along faults. They are formed in relation to the displacement of the blocks along the sliding surface of the fault, the sliding surfaces are strongly eroded. However, their primary form is still represented on the terrain in the form of a straight slope, the foot of the ridge route transitioning between two massifs of different heights or between mountains and plains, with a slope of over $35\text{-}45^0$, the difference in elevation of the slopes is from 300 to 1000 m. The slope surface has many eroded grooves, and the slope foot accumulates many boulders. Currently, the slope is controlled by the process of deep erosion and strong landslide. This place formed geomorphological heritages: Vuc Hom Waterfall, Vuc Song An Linh Waterfall, Tuy An; The geological heritages of rock type: An Tho columnar basalt, An Linh columnar basalt, Tuy An.

b. Highland ridge, Neogene - highland Quaternary

Distributed in Van Hoa, north of Ca Lui, developed at the edge of plateaus and highlands. They are mainly related to the process of infiltration and mountain-forming eruption.

The slope is convex, short, sloping 25 - 35^0, the elevation difference of the slope is from 150 - 350 m. The dynamic of the slope is not sustainable and being controlled by erosion and landslides, there are many fissures developed that cut both the plateau surface and highland.

c. Surface of the volcanic plateau has an elevation of less than 250 m

Distributed from the coast to Tuy An, the eastern part of the Van Hoa plateau. This is a type of dome-type volcanic basalt accumulation and overflows along cracks and faults. The topographical surface is quite flat, from a few hundred meters to several thousand meters wide, creating flat peaks in Song Cau - Tuy An. On these surfaces, laterite weathering shell containing aluminum is very developed, from tens of meters to several tens of meters thick. These basalt deposits cover the Neogene Lake sedimentary basins of the inland-continental type with diatomite sets that are being exploited, such as An Nghiep. It is also a recognized geological heritage.

d. Surface of volcanic plateau is 300-400 m high

Figure 1. Van Hoa Plateau (Photo: Nguyen Van Toan)

Distributed in Van Hoa, 300-400m altitude, basalt terrain surface is quite flat, spreading to create plateau. They are divided and destroyed by the system of rivers and streams, with a cross-sectional density of 0.6-2 km/km^2, and a depth of 150-250m along rivers and streams. In Van Hoa, later arch elevation and block differentiation, combined with the process of deep erosion and washing divided the surface of the basalt eruptive rock topography into narrow bands, independent of each other (Nguyen Xuan Bao et al, 2015). At the edge of Van Hoa Plateau, most of the basalt surface is eroded to leave behind fragments or craters containing precious stones. On the basalt surface, a laterite bauxite weathered crust is formed from a few meters to 15m thick. Here, geological heritage of rock type is formed: Columnar basalt in An Xuan, Tuy An; Geomorphological geological heritage: Van Hoa Plateau; Mineral type geological heritage: Aluminum Thach Thung Hill - Hon Dung, An Xuan, Tuy An.

e. Cone ridge of Quaternary age crater

Morphologically, the craters look like truncated cones with a bottom diameter of about 10.5 - 1.5 km, a height difference of about 40 -100 m from the basalt plain surface, concave peaks found in An Tho commune, at Doc Suc quarry, An Tho, An My communes, Tuy An district, the average slope is 5-15^0, particularly 25^0. Geological heritage type of columnar basalt, geomorphological type. In general, they have not been eroded much, related minerals have precious stones.

f. Structural eroded slope

The slopes extend in the direction of sedimentary rock, slopes is 15 - 25^0 to 25 - 35^0. Based on the position of the sedimentary rock, the slope direction can be divided into 2 types:

+ The slope is opposite to the direction of the rock layer: short slope, slope above 25-35^0, many steep cliffs hundreds of meters high, at the foot accumulate many boulders. The slope is controlled by the process of erosion - landslide.

+ Slopes in the same direction of the rock layer: long undulating slopes, slope 15-25^0. The slopes are controlled by the process of cavitation - erosion.

g. Slope erodes edge of dome of the intrusive blocks, quartz fracture zones

The topography is eroded by intrusive rock bodies developed on the bedrock of granite of the Deo Ca Complex. They create slopes above 35^0, unstable slopes, controlled by the process of erosion and landslides.

The terrain developed along the tectonic fracture zones is morphologically extended hill ranges in the form of sub-meridian lines, narrow peaks in the form of buffalo ridges, short slopes and slopes >30^0. On the slope surface exposed quartz or large eluvia rocks.

3.2 Terrain Formed by Erosion - Cavitation

a. Pediple leveled surface, Miocene age 750 - 1100m high

This leveled surface is distributed in the Deo Ca massif, with an altitude of 900 - 1000 m, cut into the Mesozoic intrusive formations and modified rocks, so the exposure of the intrusive rocks is wide. The surface is transitioned to the lower surface by the cavitation flank, cavitation - landslide, and cavitation tectonics slopes above 35^0. In addition, many cavitation grooves develop extending from the shear slope to the surface, so the surface tends to split into many independent bands. This topographical surface is differentiated right after the formation process, partly uplifted to create mountains, partly subsided. This denuded surface corresponds to the accretionary formations present in the area.

Figure 2. Topography of Deo Ca area (Photo: Nguyen Van Toan)

b. Pediple leveled surface, early Pliocene age 450 - 600 m high

Distributed in the north of Deo Ca mountain range and in the north of the study area. The surface is quite flat, wavy in the form of gentle hills, with a surface slope of $5\text{-}10^0$, a few hundred meters to 1-2 km wide.

In the north, Deo Ca mountain range exists in the form of a flat plateau, or as a wavy hill, 0.5-5 km wide (Tran Van Sinh, 1999), extending in a linear form and hugging the massifs of the mountain range. At present, this surface is destroyed, strongly divided by erosional slopes.

In the northern part of the study area, they exist as gently arched top surfaces, having the same height. Cavitation groove system strongly divides this surface.

c. Pediple leveled surface, late Pliocene age 300 – 400 m high

The surface is relatively well preserved, in the form of apical surfaces of similar elevation, several hundred meters to several thousand meters wide. The dissected surface creates sloping domes from 5 to 10^0, the depth of cleavage ranges from a few tens of meters to hundreds of meters. Here, geoheritage of rock type: Son Xuan, Son Hoa gabbro rock is formed.

d. Pediment leveled surface, Late Pliocene - Early Pleistocene age 150 - 250m high

This surface is popular and best preserved in the region. The surface is weakly dissected, fairly flat, several hundred meters to several kilometers wide. It cut into the slopes of massifs, older leveled surfaces, and through different bedrocks ranging from basalt to intrusive magma. On this terrain, there is a well-developed and well-preserved weathered crust, from a few meters to several tens of meters thick. Here, geological heritage of rock type is formed: Columnar basalt at Xuan Duc, An Phu, Tuy An quarries. Geological heritage of mineral type: Diatomite An Xuan, Tuy An.

e. Early - middle Pleistocene pedimen surface, 50 - 120 m high

This terrain is distributed at the edge of the plain, morphologically characterized by low hills with small changes in elevation, gentle dome tops, short convex slopes, separated by crevices of cavitation troughs. On this terrain, the weathering crust is quite developed.

f. Cavitation flank

Cavitation *flank* is widely developed in Van Hoa plateau and Deo Ca mountain range. Slope $25\text{-}35^0$, grade I straight flow network, with strong valleys in the shape of a balanced V or a deviated V. Canyons, rapids have many steps, dominated by deep erosion, reflecting the superiority of neo-tectonics over erosion.

g. Cavitation flanks of crevices and ditches of Quaternary age

This ridge pattern usually develops along young cavitation systems. The slope profile is usually concave, slope of the flank is quite large from 30-40^0, sometimes larger. Along these flanks the process of landslides is common. The weathered crust on these flanks is thin, often exposing the bedrock.

h. Cavitation – erosion flanks

This type of terrain is common in the massifs adjacent to the plains, along major faults. The flank profile is straight, slightly concave. Slope of flank >15-35^0. The characteristic of this flank is that on the surface of the flank there are many deep cavitation grooves dividing. The weathered crust is usually from a few meters to tens of meters thick. Here, geological heritages of geomorphological type are formed: Mom Don, An Ninh Dong, Tuy An basalt cliffs; An Ninh Dong, Tuy An basalt pebble beach,.

i. Collapsed erosion flank in Neogene - Quaternary age

Distributed in Song Cau, Tuy An and Deo Ca mountain ranges. The elevation difference of the flank is large up to several hundred meters, the slope is over 25-35^0, there are places where the cliff is hundreds of meters high, straight flank along with strong valley reflects the superiority of the neo-tectonics to erosion. (Tran Van Tri et al, 2009). The flank root accumulated many large boulders. Here, geomorphological heritage of ancient environmental type is formed: old sea level at the base of Mu U mountain, Geomorphological heritage: Mu U mountain, Xuan Thanh ward, Song Cau town.

j. Synthetic erosion flank Neogene - Quaternary age

It is widely distributed in mountainous terrain. The elevation difference of the flank varies from region to region. On a certain level, the synthetic erosion flank is a collection of some types of flanks described above. Here, geological heritages of geomorphological type are formed: Cu Mong pass, Xuan Loc, Song Cau town; Nhan Mountain, Ward 1, Tuy Hoa City; Deo Ca - Hon Nua landscape protection area. Geological heritage of stratigraphic type: The facies of the volcanic gully of Chop Chai mountain, Tuy Hoa city…

k. Abrasion flank Quaternary age

Distributed on the flanks of mountain massifs, mountain ranges protruding into the sea. The elevation difference of the flank is from 40-50m to 100-120m. Short, straight, steep slopes > 15 - 35^0, sometimes creating steep cliff, many exposed parts of bedrock or large boulders with smooth flat surfaces. The flanks have accumulations of boulders, pebbles, and sand that are being rounded and selected. Here, geomorphological-type geological heritages are formed: Ganh Da Dia (Sea Cliff of Stone Plates), An Ninh Dong, Tuy An Cliffs; Phu Yen, Hoa Tam, Dong Hoa; Bai Tien, Hoa Tam, Dong Hoa capes …

3.3 Terrain Formed by Rivers

a. River shelf level II, late Pleistocene age

Distributed along river valleys, with a relative height of 10-15 m, the surface is quite flat, less fragmented and has not been washed or eroded much. The section of the shelf consists of pebbles below, turning to the top is sand, yellow-brown clay powder of late Pleistocene age (Truong Khac Vy, 1997). Here, geomorphological-type geological heritage is formed: Dong Tron lake, An Nghiep commune, Tuy An province.

b. River shelf level I, middle Holocene age

Widely developed in the study area. Surface of the shelf is flat in primitive form, from a few hundred meters to several kilometers wide, extending along the river valley, with a relative height of 5-7 m. The sedimentary composition that makes up the shelf consists of gravel and pebbles transferred to gray, yellow-gray clay-silty sand, 4-6 m thick.

c. River accumulation delta, late Holocene age, early age

Widely distributed in Tuy Hoa plain, forming a strip along Da Rang river and other rivers running to the sea. The material composition of the plain is mainly sand, grit, and powder.

d. River bed and low alluvial ground along the riverbed, late Holocene age, late age

Widely distributed in the region along the valleys of rivers and streams, from a few tens of meters to hundreds of meters wide. Typically, on the Da Rang River, the section flowing through Tuy Hoa plain is from 500 to 1000 m wide. They are formed by sand or gravel. The low-lying alluvial deposits are often influenced by the flow, so their width changes with the seasons and contain gold and tin placer., Sand, gravel, riverbed and low-lying alluvium are the source of valuable construction materials. The outstanding geological heritage is the tectonic type: Ba River

deep fault system, section passes through Phu Yen province…

3.4 Terrain Formed by the Sea

Unlike the terrain formed by rivers, the terrain formed by the sea is not only accumulation but also due to abrasion exposing bedrock, so the composition is very different. This terrain type can be divided into details as follows:

a. Abrasion – marine accumulation surface, Early – Middle Pleistocene age

This surface clings to the foothills of mountainsides or older surfaces, they are weakly dissected undulating hills, several hundred meters wide, 50-100 m high. Structure of the shelf is the bedrocks with different composition, sometimes with the accumulation of pebbles and sand grit with thin thickness.

b. Abrasive seashelf – accumulation level III, late Pleistocene age, early age

Limited distribution, scattered in the north of Tuy Hoa. They are divided to form hills in the northwest of Tuy Hoa plain, at the foot of the mountain forming narrow strips with a few meters wide to hundreds of meters wide, 20-40 meters high. Gentle inclined surface.

c. Abrasive seashelf – accumulation level II, late Pleistocene age, late age

d. Sea shelf level I, middle Holocene age, 5-10 m high.

e. Surface of the sand dyke connecting the island, late *Holocene age, early age, 4-6 m high.* Here, geomorphological-type geological heritage is formed: Long Thuy beach, An Phu commune, Tuy Hoa city.

f. Modern beaches are flooded with frequent tides.

Modern beaches are widely distributed along Tuy Hoa coast. They form geomorphological-type geological heritages: Bai Om beach, Xuan Phuong, Song Cau town; Vinh Hoa Beach, Xuan Thinh, Song Cau Town; Village 2 Beach, Xuan Canh, Song Cau town; Ganh Do, Xuan Dai Ward, Song Cau Town; Rang Beach, Xuan Phuong Ward, Song Cau Town; Tu Nham beach, Xuan Thinh, Song Cau Town; Bai Goc beach, Hoa Tam, Dong Hoa town; O Loan lagoon, Tuy An…

3.5 Terrain Formed by the Mixed Impact of Rivers and Sea

This terrain type is formed by the impact of mixed alluvial products of rivers and sea, the distribution of these plains depends on the capacity of carrying mud and sand materials of the Ba and Ky Lo river systems.

Figure 3. Xuan Dai Bay, Song Cau Town (Photo: Nguyen Van Toan)

a. The river-sea delta (shelf) of the Late Pleistocene age, Late and Middle Holocene age is distributed along the Ban Thach - Da Nong river basin, this is a tributary of Da Rang river in the territory of Hoa Hiep Nam ward and Hoa Tam commune.

b. Modern sea-swamp plain is distributed in the south of the railway in An My and An Chan communes and a part in An Hoa Hai commune of Tuy An district.

c. Modern river-swamp plain occupies the main area of Tuy Hoa plain, distributed mainly in Dong Hoa town, Tuy Hoa City and a part in Phu Hoa district.

Figure 4. Tuy Hoa Plain (Photo: Nguyen Van Toan)

3.6 Terrain Formed by Wind

a. Terrain type of sand dunes with elevation of 15-25 m

In the coastal districts, emerging sand mounds can be seen at some locations such as An My, An Chan, An Hoa Hai, Tuy An communes; Binh Dien Sand Dune, Tuy Hoa City. These sand mounds have common height of 15-25 m,

b. The terrain is sandy hill with an altitude of 105 m

Tu Nham sand dunes have a height of up to 105 m, these sand dunes have the same characteristics of running parallel to the sea, with a late Holocene age.

Figure 5. Tu Nham Sand Dunes, Song Cau Town (Photo: Nguyen Van Toan)

4. Conclusion

From the research results, conclusions are as follows:

1. The study area has a long history of terrain development under the mutual influence of endogenous and exogenous factors. 6 terrain origin types were formed:

Terrain tectonics, volcanoes, architectural erosion;

- Terrain formed by erosion – cavitation, *include: 1 The tectonic and cavitation flanks; 1 Highland ridge; 2 Surface; 1 Cone ridge; 1 Structural eroded slope; 1 Slope erodes edge*
- Terrain formed by erosion – cavitation, *include: 5 surface; 6 flank*
- Terrain formed by rivers, *include: 1 River shelf level II; 1 River shelf level I; 1 River accumulation delta; 1 River bed and low alluvial ground along the riverbed.*
- Terrain formed by the sea, *include: 1 Abrasion – marine accumulation surface; 1 Abrasive seashelf – accumulation level III; 1 Abrasive seashelf – accumulation level II; 1 Sea shelf level I; 1 Surface of the sand dyke connecting the island; 1 Modern beaches are flooded with frequent tides*
- Terrain formed by the mixed impact of rivers and sea, *include: 1 The river-sea delta; 1 Modern sea-swamp plain; 1 Modern river-swamp plain.*
- Terrain formed by wind, *include: 1 Terrain type of sand dunes with elevation of 15-25 m; 1 The terrain is sandy hill with an altitude of 105 m.*

2. Corresponding to the diversity of topographical types is the diversity of geological heritage with many rich heritage types according to each distribution area:

- Coastal area: there are bays, pools, lagoons, beaches, sea cliffs, islets, capes, etc.,
- The plain area has lakes, river alluvial plains, irrigation dams, hydropower plants, breakwaters, etc.,
- Hills and mountains with peaks, passes, waterfalls, cliffs, plateaus, craters...

3. The most valuable geomorphological landscapes in the study area are the landscape of Ganh Da Dia (Sea Cliff of Stone Plates) heritage cluster, Xuan Dai Bay; Deo Ca - Hon Nua landscape protection area; mountains associated with historical and cultural relics: Da Bia Mountain; Deo Ca Pass, Cu Mong Pass; Vuc Song Waterfall; Vuc Hom Water fall, etc; and beautiful beaches. These are the highlights that create the value of Geomorphological Heritage in the study area in particular and Phu Yen province in general.

References

Nguyen Van Toan, & Nguyen Vo Linh. (2005). Explanatory report attached with the soil map at scale 1/100,000 of Phu Yen province. *Archived at the National Institute of Agricultural Planning and Projection.*

Nguyen Xuan Bao, Duong Van Cau, & Trinh Van Long. (2015). Tectonic zones of mainland South Vietnam. *Geology*, (352-354), 11-27.

Tran Van Sinh. (1999). Final Report of the Project of Geological Surveying and Mineral Search in Quy Nhon Group sheet at the scale of 1:50,000. *Geological Archives,* Hanoi.

Tran Van Tri *et al.*. (2009). *Geology and natural resources of Vietnam*. Natural Science and Technology Publishing House, Hanoi.

Truong Khac Vy. (1997). Geology and Minerals of Tuy Hoa group sheet at 1:50,000 scale. *Geological Archives,* Hanoi.

Van Bao Dang, Dinh Bac Dao, Quang My Nguyen, Van Thai Vu, & Hieu Nguyen. (2002). Map of places with warning of flooding in the coastal plains of Central Vietnam. *Journal of Science: Natural Science and Technology*, Vietnam National University, Hanoi, (2).

Van Bao Dang, Van Liem Ngo, Kim Chi Vu, Hieu Nguyen, *et al.*. (2022, August). Application of deep learning models to detect coastlines and shorelines. *Journal of Environmental Management*. https://doi.org/10.1016/j.jenvman.2022.115732

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