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How Did Vinh Moc Village, Located near Vietnam DMZ, Protect Their Villagers from United States Air Force Bombardment during the Vietnam War?

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Abstract

The buried village is Vinh Moc where more than 1200 Vietnamese, including soldiers, who lived underground during the Vietnam War (1965 to 1972) were hand dug into red basalt bedrock. The Vinh Moc Village was strategically located on the border of North Vietnam and South Vietnam approximately 14 km north of the DMZ and along the shoreline of the South China Sea. During the Vietnam War, the US Air Force heavily bombed Vinh Moc. The North Vietnamese Army (NVA) had an important military base on nearby Con Co Island. Brave civil volunteers from Vinh Moc would make the 28 km dangerous journey to the island, disguised as fishermen, to deliver supplies to the soldiers stationed there. The people who remained at Vinh Moc dug tunnels into red basalt hills in order to survive this onslaught. The American forces assessed the villagers of Vinh Moc were supplying food and armaments to the NVA garrison on the island of Con Co, which was in turn hindering the American bombers on their way to bomb Hanoi. The US military objective was to force the villagers of Vinh Moc to leave the area. The villagers initially dug the tunnels to a 10 m depth but the American forces designed bombs that burrowed down 10 m before exploding. The soil tunnels were then deepened to 30 m to provide safety for the soldiers and civilians working there during the intense US Air Force bombing. The primary objective of the research study was to determine how the soils and parent material of Vinh Moc Village, protected their villagers from the United States Air Force bombardment during the Vietnam War. In addition, the natural parent material at both the Vinh Moc and Cu Chi were assessed to determine why the tunnels were so resilient. The Cu Chi and Iron Triangle soil tunnels were dug by hand

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in the Old Alluvium soils and parent material where iron in solution precipitated and became the soil binding material. The Vinh Moc tunnels were hand dug in porous, red basalt (bedrock) hills where the consolidated rock structure itself provided the required binding material. Neither site needed support beams to hold up the ceilings.

Keywords

Vinh Moc Village, South China Sea Shoreline, Con Co Island, Bombing, Huang Tri Province, Soil Tunnels, Ground Penetrating Bombs, Cu Chi Soil Tunnels

1. Introduction

Earthen tunnels have been used to cross country borders, in military conflicts and to smuggle supplies, people, weapons and drugs. Tunneling is a battle military tactic that goes back more than 2500 years [1]. Earthen tunnels have been dug between Lebanon and Israel, Syria and Israel, Gaza and Israel, Egypt and Gaza, North Korea and South Korea, Cambodia and Vietnam and Mexico and the United States to permit the movement of soldiers, supplies, weapons and drugs under the borders. North Korea, Iraq and Iran used tunnels to hide weapons, including nuclear, and other military equipment and supplies. In the early 2000s, ISIS created many earthen tunnels under Iraqi and Syrian cities for military use [1].

For more than 2500 years, soil tunnels have been used in warfare and smuggling [2] [3]. Initially, tunnels were utilized to attack fortresses that were underlain by unconsolidated (non-bedrock) soil materials. Later tunnels provided housing and served as smuggling corridors. The medieval warfare undermining technique involved digging soil tunnels with wooden or beam props to hold up the soil ceilings. Then flammable material, such as hay or straw, was put in the tunnel and set on fire. The fire burnt the support beams, which collapsed the soil tunnel ceilings and undermined the overlying perimeter wall. Later gunpowder and dynamite replaced fire when attempting to collapse a tunnel, fortress or perimeter defense [1]. Modern warfare soil tunnels were the pathways used to move troops, weapons and supplies to the other side of a border or wall for surprise attacks. Most of the soil tunnels were placed in easy-to-dig unconsolidated soil materials that had a low water table and were not subject to flooding. Eventually, machinery was used to drill through bedrock permitting deeper and longer tunnels for troop movement or smuggling. However, when drilling through bedrock under international borders, the process created both noise and vibrations, which were often detected by the enemy. Once discovered the tunnels were often collapsed by blowing up the tunnel, injection of gas, filling it with water or wastewater, or inserting barriers [1].

The soil tunnel complex was Son Vinh Tunnels (**Figure 1**). "Son" means

Figure 1. Entrance gate to the Vinh Moc Memorial Tunnels located 14 km north of the DMZ and along the shoreline of the South China Sea.

mountain and "Vinh" refers to the Vinh Moc and Vinh Linh people. "Their real name is Son Vinh Tunnels", one tunnel designer said, "From the very beginning we called it Son Vinh tunnels. Son means mountain and Vinh not only refers to Vinh Moc, but to the Vinh Linh people. The people of Son Trung and Son Ha communities and the men of border-post also helped build the tunnels."

Vinh Moc is the remains of a coastal North Vietnamese village, which was forced underground by American bombing during the Vietnam War (1965-1972). Between 60 and 90 families (**Figure 2**) and an unknown number of soldiers (logistical planners, supply specialists, tunnel construction engineers and medical staff) lived in the three levels of these 2 km long tunnels. The locals began to dig tunnels in 1965 and finished in 1967 with simple hand tools, which required 18,000 labor days to dig. The total length of the tunnels is nearly 2000 m long with six entrances to the tops of hills and seven entrances on the shoreline to the South China Sea. They worked and lived while bombs rained down. The bomb shelter outlets are to the South China Sea. The tunnel complex is in Quang Tri, Vietnam and is strategically located on the border of North and South Vietnam (**Figure 3**). The soil tunnels were built to shelter the Vietnamese from Son Ha and Son Trung villages in Vinh Linh county of Quang Tri Province and north of the Vietnamese Demilitarized Zone (DMZ). The U.S. military believed that Vinh Moc villagers were supplying food and transporting armaments to the NVA garrison on the island of Con Co, which was located approximately 28 km east of the North Vietnam coastline and in the South China Sea. Disguised as fishermen, they rowed off shore to deliver supplies to the soldiers stationed there. This supply line was part of the Ho Chi Minh Trail of the Sea, which made this area a prime target for American bombardment.

Figure 2. The civilian chamber for a family on the third level of the Vinh Moc tunnels. Dolls were placed in the space to indicate the size of the opening carved out in the red basalt for one civilian family.

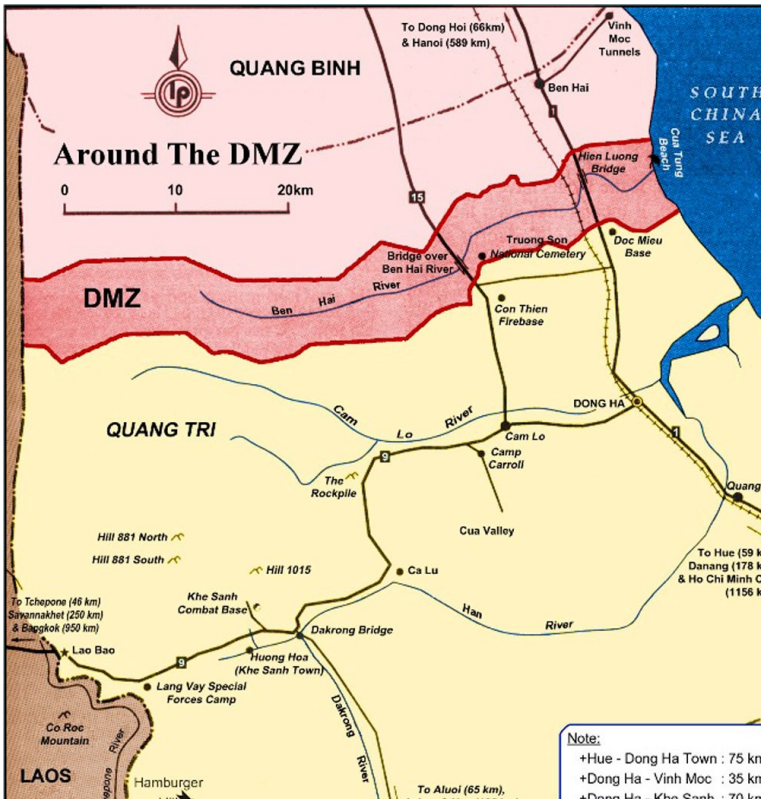

Figure 3. Map of the Vietnam DMZ. The 10 km wide DMZ stretches from Laos to the South China Sea.

The Vinh Moc villagers initially cultivated the soils and weathered red basalt (bedrock) parent material (Figure 4) for decades. During the Vietnam War, these villagers dug tunnels to a depth of 10 m to escape the US Air Force bombs. The American forces were eventually able to create bombs that could burrow to a 10 m depth before exploding. The villagers later deepened the tunnels to 30 m (Figure 5) and (Figure 6) and were then able to live safely underground during the seven years of American bombardment. The workers had to remove and transported more than 6000 m^3 of rock to create a massive village tunnel system in the red basalt hills adjacent to Vinh Moc village and overlooking the South China Sea (Figure 7). The parent material is red basalt, which was porous and

Figure 4. Cultivation of soils formed in red basalt. The red color is from the parent material that the soil formed weathered under a tropical climate.

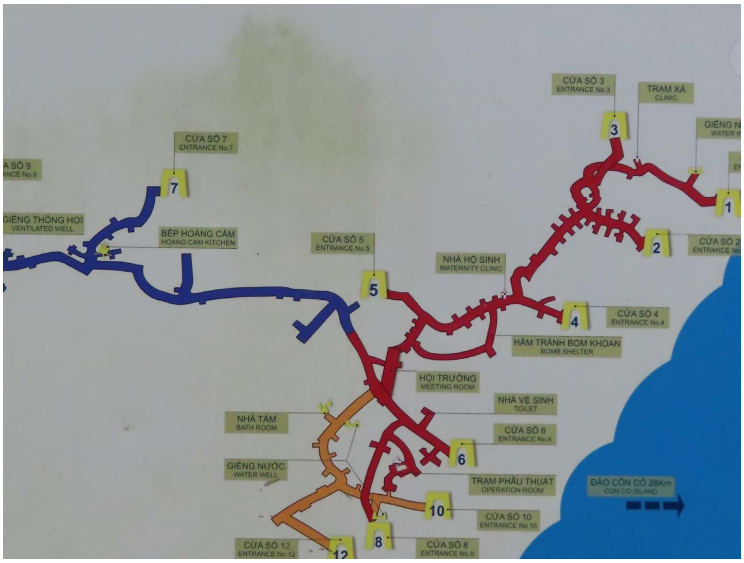

Figure 5. The location of the three Vinh Moc soil tunnel levels and entrances. The orange color tunnels are the deepest and are designed to protect civilians.

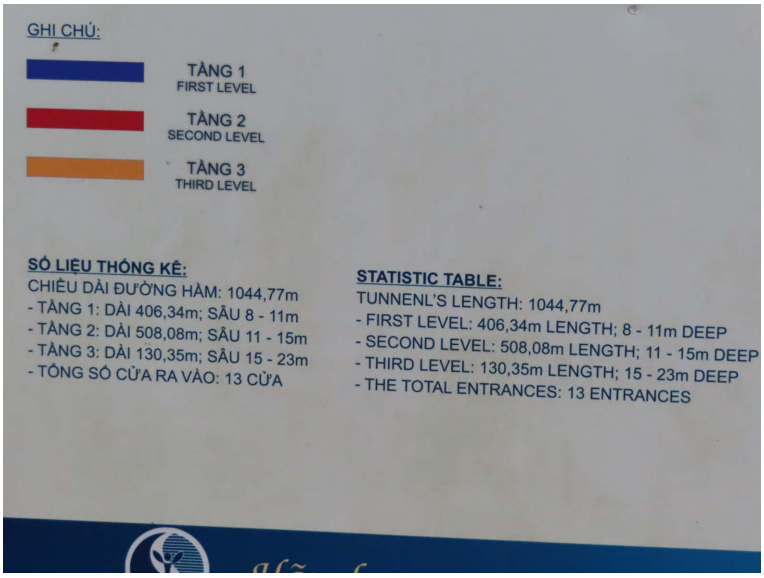

Figure 6. Color-coded legend for the three Vinh Mock tunnel levels and connection locations. The blue legend block color is for the first level of soil tunnels for supplies and ammunition. The second level is red and is for the North Vietnamese Army soldiers.

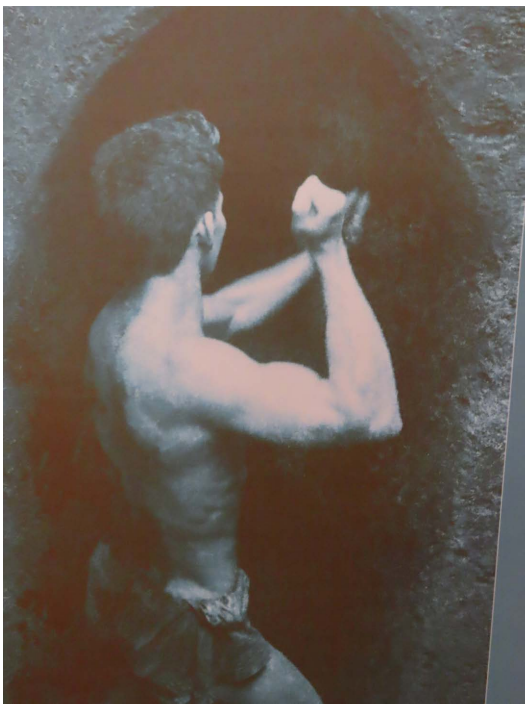

Figure 7. DMZ museum picture of a villager digging a soil tunnel by hand.

soft enough to allow hand digging. The tunnel floors, walls, chambers and ceiling remained structurally sound bedrock. The red porous basalt tunnels (**Figure 7**) required no support beams, except at the entrances and exits. The tunnel complex was constructed in stages beginning in 1966 and used until 1972. A work force of approximately 250 people dug the tunnels, which housed up to 600 villagers and NVA soldiers. The complex included rooms, kitchens, wells and

waste disposal systems for each family and spaces for medical treatment. Between 60 and 90 families occupied the lower level of the tunnel complex at any one time. The families were almost 30 m below the soil surface; the tunnels successfully protected the villagers. Surprisingly no one lost his or her life because of the bombing. Only one bomb scored a direct hit on the upper tunnel but failed to explode and the villagers later used the crater as a ventilation shaft. During the seven years of bombing 17 children were born in the soil tunnel complex (Figure 8).

At the first sight of enemy aircraft, a security guard hammered out a rhythm on the casing of a bomb (Figure 9). The clanking of the homemade gong warned the villagers of the impending attack and they ran on the soil surface for the nearest trench or tunnel entrance. Hidden beneath the undergrowth, the trenches led to the tunnels where (Figure 10) NVA soldiers and civilian families could safely wait out the air strike. The Vinh Moc tunnels served as a bomb shelter (Figures 11-13) and underground village for the people living through some of the heaviest bombardment of the Vietnam War.

The goal of the bombing was to force the villagers to move and stop supplying (Figure 14) Con Co Island (Figure 15, Figure 16). The soldiers at Con Co were using Surface to Air Missiles (SAM) to attack American bombers on their way to bomb Hanoi and disrupted possible troop landings via ships on the shoreline. The United States Air Force released over 9000 tons of bombs on the area with a ratio of 7 tons of bombs/person.

The tunnels were constructed at three different levels (Figure 5 and Figure 6) with the total length of nearly 2000 m long with six entrances to the tops of hills

Figure 8. DMZ museum picture of babies in the lower level tunnel.

Figure 9. A bomb collection exhibit at Vinh Moc of the various types of bombs dropped on tunnel complex.

Figure 10. DMZ museum picture of armed North Vietnamese Army (NVA) soldiers in soil tunnels.

Figure 11. Vietnam Tours guide and tourist at entrance no. 3.

Figure 12. A Vietnam Era veteran is climbing the stairs in the Vinh Moc tunnels. It requires approximately 150 moist and slippery basalt steps to climb up 30 m to the soil surface during the monsoon season.

and seven entrances to the East Sea. The first level, 12 to 15 m below ground, was used as a warehouse for logistics, food and ammunition for Con Co Island (**Figure 15**, **Figure 16**) and the civilians and soldiers in the tunnel. The second level, at a depth of 20 m, served as the Headquarters of the Party Committee, the People's Committee and Military Command. The third level, 28 m below the ground surface, was where the civilians lived.

Figure 13. Tourist at a Vinh Moc tunnel entrance with vegetation covering the entrance from the air.

Figure 14. A view of the South China Sea and beach from a Vinh Moc tunnel exit. Supplies and ammunition were transported from the tunnel complex to Con Co Island by boat.

In 1969, half the villagers decamped north to the relative safety of Nghe An province. In 1972, the villagers of Vinh Moc were finally able to abandon their underground existence, rebuild their homes, and were rejoined by relatives from Nghe An a year later [4].

Figure 15. Con Co Island in the South China Sea. It was home to a garrison of NVA soldiers who tried to intercept the US Air Force bombers on the way to Hanoi by firing surface to air missiles.

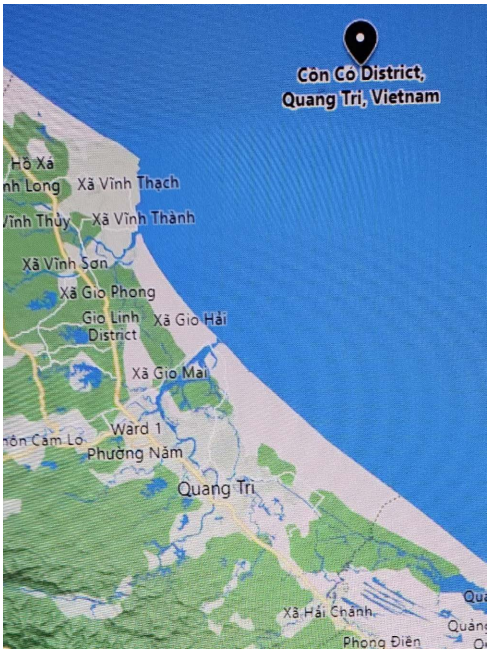

Figure 16. Location of the Con Co Island in South China Sea off the coast of Vietnam.

The primary objectives of the research study were to determine: 1) how Vinh Moc Village, protected their villagers from United States Air Force bombardment during the Vietnam War, and 2) why both the Vinh Moc and Cu Chi soil tunnels were so resilient to US Air Force bombardment. The Cu Chi and Iron Triangle soil tunnels were dug by hand in the monsoon season in the Old Alluvium parent material where iron in solution precipitated as the water evaporated into the tunnel and became the soil binding material. The Vinh Moc tunnels were hand dug in both the dry and monsoon seasons in porous, red basalt (be-

drock) hills where the consolidated rock structure itself provided the required binding material. Neither site needed support beams to hold up the ceilings (except for the entrances). The Cu Chi and Iron Triangle tunnels were built to facilitate the movement of NVA soldiers to the Republic of Vietnam (RV) the Ho Chi Minh trail. The Vinh Moc tunnel complex, part of the Ho Chi Minh trail of the sea used to provide supplies to the Con Co Island garrison, was designed to shelter weapons, supplies, civilians and NVA soldiers from the US Air Force bombardment.

2. Location

2.1. Vinh Moc Soil Tunnel Complex

Vinh Moc is located on the northern edge of the DMZ and near Hien Luong Bridge (Figure 17) which was established in July 1954 as the dividing line between North and South Vietnam at the conclusion of the First Indochina War. The Vinh Moc DMZ Soil Tunnel Complex (a tunnel complex of Vietnam), lies along the South China Sea and north of Ben Hai River (Figure 3). Within this complex, Vinh Moc tunnel is located in Vinh Moc, Vinh Thach Commune, Vinh Linh District, Quang Tri Province in the Vietnamese Demilitarized Zone. The complex in Vinh Linh has as many as 60 tunnels such as Tan My, Mu Gia, Tan Ly tunnels, among which Vinh Moc is the most solid (red basalt bedrock) (Figure 18) and firm village tunnel, with three floors and round staircase, remaining as in its past days.

The village tunnels were built in a little over two years and required the removal of approximately 6000 m^3 of earth. The main inner axis tunnel is 2034 m long, 1 - 1.2 m wide, and 1.5 - 4.1 m high. The two side cliffs were molded into small temporary houses every 3 m. The tunnel center had a 150 seated hall, clinics

Figure 17. Hein Luong Bridge with a white DMZ line painted on it, which separated north and south Vietnam.

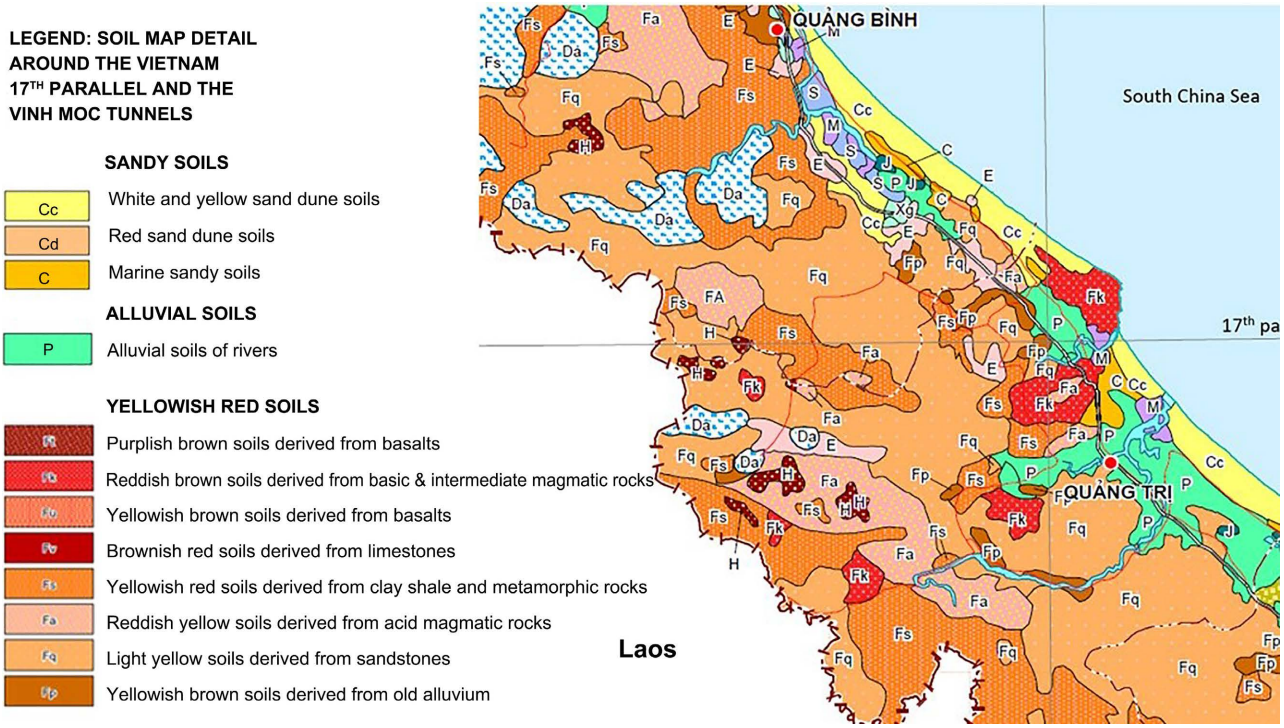

Figure 18. A soils and parent material map of the DMZ area.

and maternity room. The soil tunnel complex is linked to the sea by seven exits, which also function as ventilators and to a nearby hill by another six entrances. The entire tunnel structure system has a size of 0.9 m × 1.75 m, a length of 2034 m, including many branches connected through the main axis of 870 m long. The tunnel has 13 doors, of which six are connected to the hill, seven to the sea with well (Figure 5, Figure 6). The hatches have wooden pillars to prevent collapses and landslides, slope in the direction of the wind to ensure ventilation and are disguised by the hillside vegetation. The lower level of the Vinh Moc tunnel was dug to a depth of 5 m above sea level, inclined from 8 - 120 degrees from South to North and from West to East to allow water to drain easily. This drainage system works normally even during the monsoon season.

This was not just a simple battle village like other constructions, but also an underground living space for soldiers and local people. They had turned the underground into strong fortresses with three connected floors (Figure 5, Figure 6). It can be said that the Vinh Moc Tunnels was an underground village with constructions such as a water well, a rice warehouse, a Hoang Cam kitchen, a guard station, a telephone station, a clinic, a surgery room, a house, maternity center, and bathroom. The long tunnel was cut, 1.8 m deep and 0.8 m wide, into small cells, which are rooms for households of 3 - 4 people can function. Inside the tunnel, there is also a hall used as a meeting place, performing arts, films were shown with a capacity of up to 50 people.

The Vinh Moc tunnel complex was built to shelter the people of Son Trung and Son Ha commune in Vinh Linh county of Quang Tri Province. It was con-

structed in several stages, beginning in 1966 and coming into use until 1971. The complex grew to consist of wells, kitchens, rooms for each family and clinics [4]. Around 60 families lived in the tunnels (Figure 2, Figure 8). Finally, the tunnels were a success and no villagers lost their lives thanks to the tunnels. The only direct hit was from a bomb that failed to explode, the resulting hole was utilized as a ventilation shaft.

2.2. Cu Chi Soil Tunnels

The Cu Chi and Iron Triangle tunnel systems are northwest of Ho Chi Minh City (Saigon) (Figure 19) and both tunnel systems were used by Viet Cong to get from Ho Chi Minh Trail at the Vietnam-Cambodian border to Saigon and South Vietnam. These adjacent tunnel systems served as a stronghold of NVA (Figure 20) during Vietnam War. During the Tet Offensive in 1968, the network of tunnels in the Iron Triangle and at Cu Chi linked the Ho Chi Minh Trail and Cambodian border to the outskirts Saigon. In the early 1960s, the United States escalated its military presence in Vietnam in support of a non-Communist regime (RV) in South Vietnam. The NVA troops and the local guerrilla's gradually expanded the tunnels.

US soldiers and their vehicles could move easily in this Old Alluvium area during the monsoon seasons (May to October) so it became a good staging area for a base camp. Traffic ability was an important clue as to where tunnels could be built; but it took a while before the American forces realized the significance of the link between traffic ability, tunnel construction, and soil characteristics. The reason for ease of movement of vehicles relates to the nature and properties

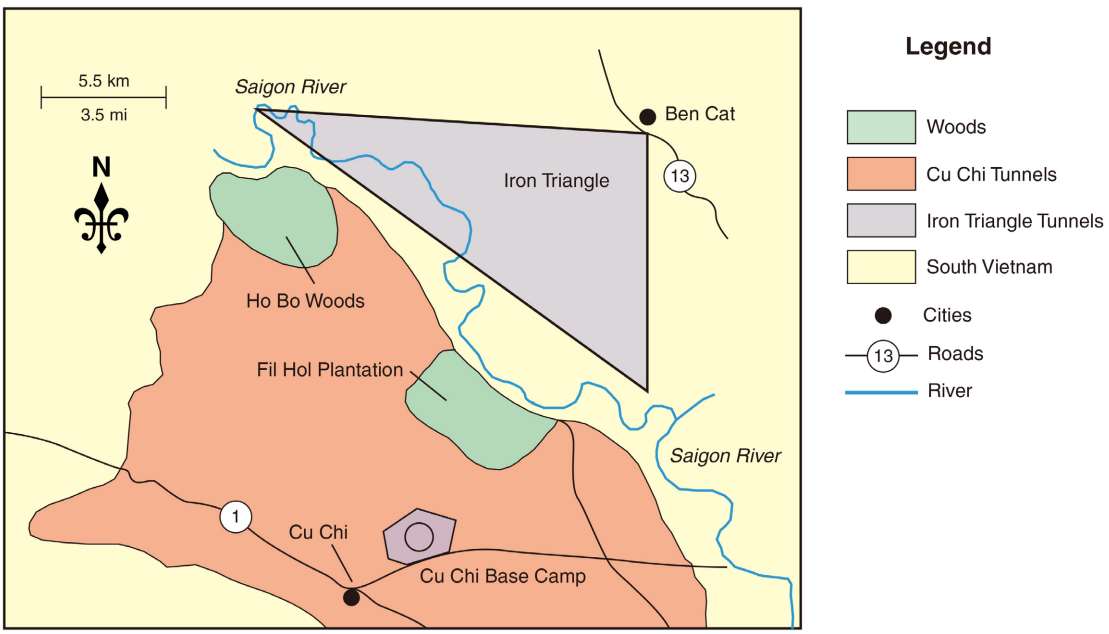

Figure 19. The Iron Triangle and Cu Chi soil tunnel areas and the Cu Chi US Military base camp located near the Saigon River about 80 km northwest of Ho Chi Minh City, Vietnam. Reprinted with the permission of the Managing Editor of Open Journal of Soil Science.

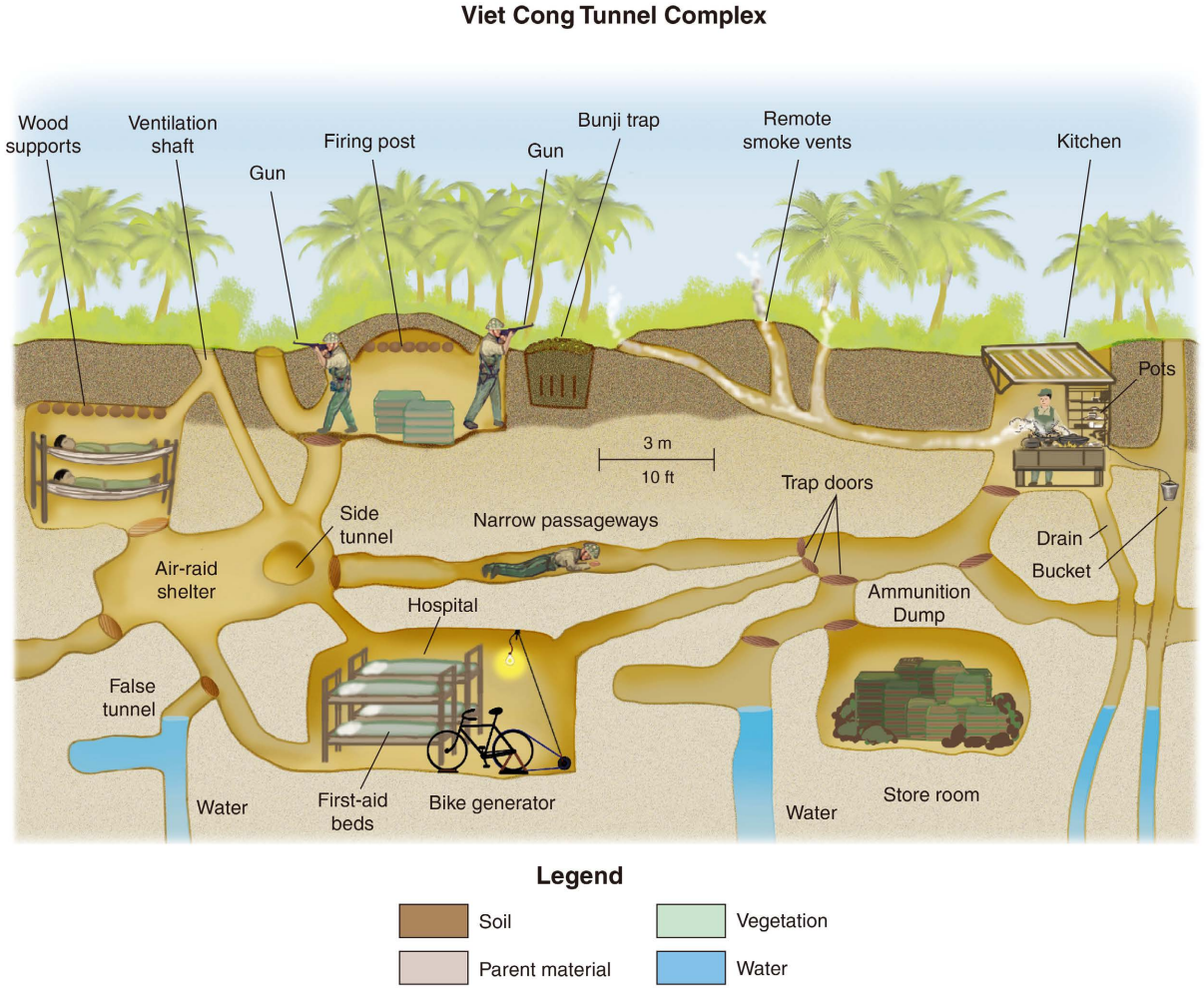

Figure 20. This diagram illustrates a multi-level North Vietnamese Army headquarters at Cu Chi soil tunnel complex used for living quarters and fighting. Diagram was based on displays at Vietnam Memorial at Ben Dinh near Ho Chi Minh City. Reprinted with the permission of the Managing Editor of Open Journal of Soil Science.

of the soils (Ultisols and Oxisols) (**Figure 21**) on the Old Alluvium terraces [5] [6] [7] [8]. The Old Alluvium terraces were of strategic significance since the tunnels linked to the mainland and the NVA to transport supplies and troops from North Vietnam into South Vietnam via the Ho Chi Minh Trail (**Figure 22**) could use the Saigon River. The districts of Cu Chi and Iron Triangle (**Figure 19**) became the most bombed and defoliated areas in war history [9]. Soils were stripped of their protective vegetative cover and became degraded, disturbed, polluted and eroded [10] [11]. The sediment was transported by rain events into the Saigon River, which also became degraded and polluted. The Cu Chi and Iron Triangle tunnels were located in III Corps Tactical Zone (**Figure 19**). Four major efforts were made by the US military to locate and destroy these tunnels. These included Operation Crimp, a search and destroy mission, which began in 1966, and a geological and soil survey approach was used to detect NVA tunnels. Later in 1967, General William Westmoreland tried launching a larger assault on Cu Chi and the Iron Triangle areas. The operation called Operation Cedar Falls

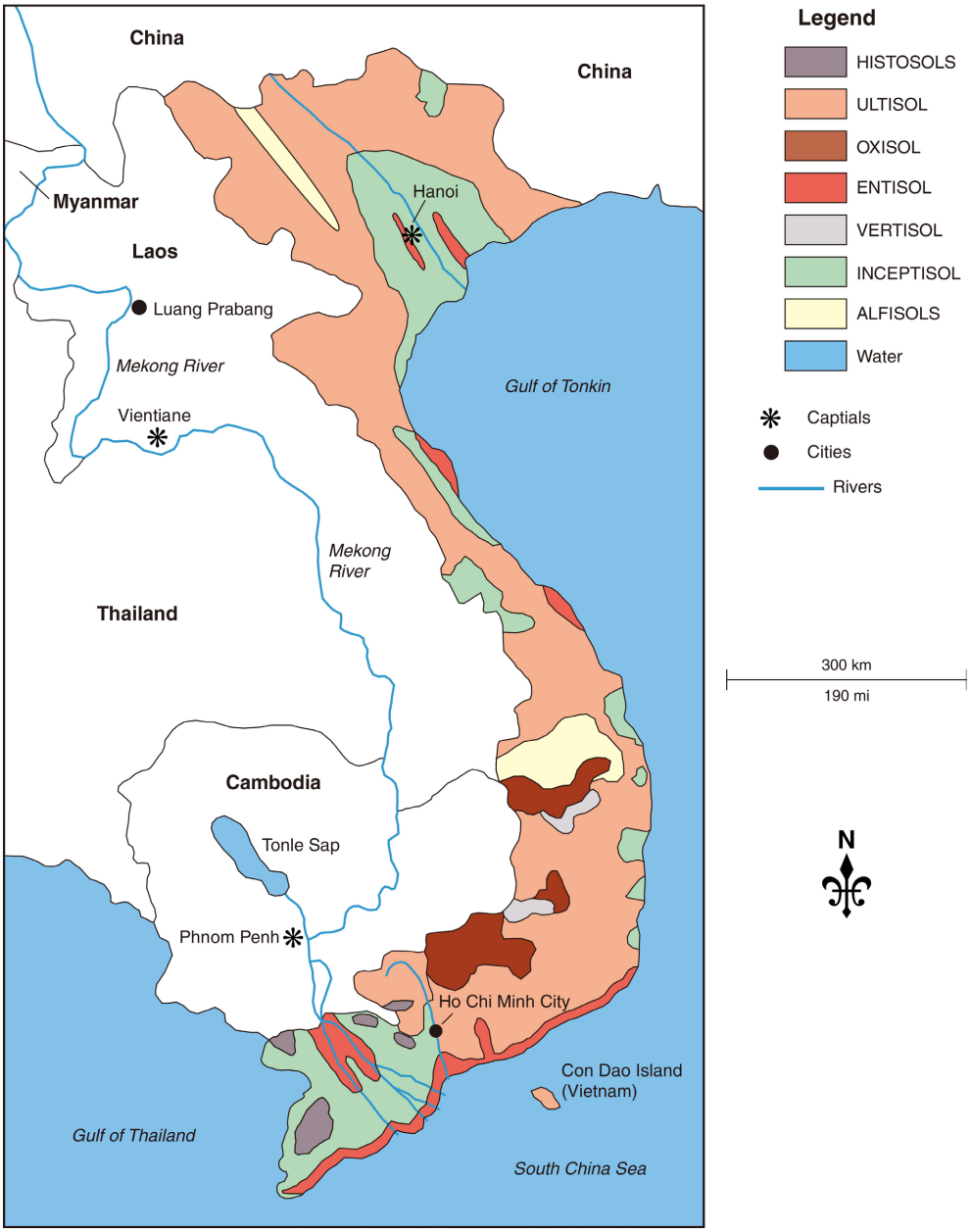

Figure 21. Soil map of Vietnam. Adapted from FAO/UNESCO Preliminary Definitions, Legend and Correlation Table for the Soil map of the World. World Resources Report No. 12; Rome, 1964. Adapted from [7] [11] Moormann *et al.* The Soils of the Republic of Vietnam, Saigon: Ministry of Agriculture, 1961. Reprinted with the permission of the Managing Editor of Open Journal of Soil Science.

was an expanded version of Operation Crimp [5]. Finally, in 1969, B-52s started "carpet" bombing the Cu Chi and Iron Triangle areas and destroyed many of the tunnels. However, not before the tunnels had proven very effective in the 1960s at hiding and protecting the RVA during the US occupation of the area.

The NVA moved underground in response to US artillery, aircraft, bombs, and tactical herbicide warfare. The Iron Triangle was 103 km^2 of jungle and thick undergrowth covering an intricate network of tunnels and bunkers approximately

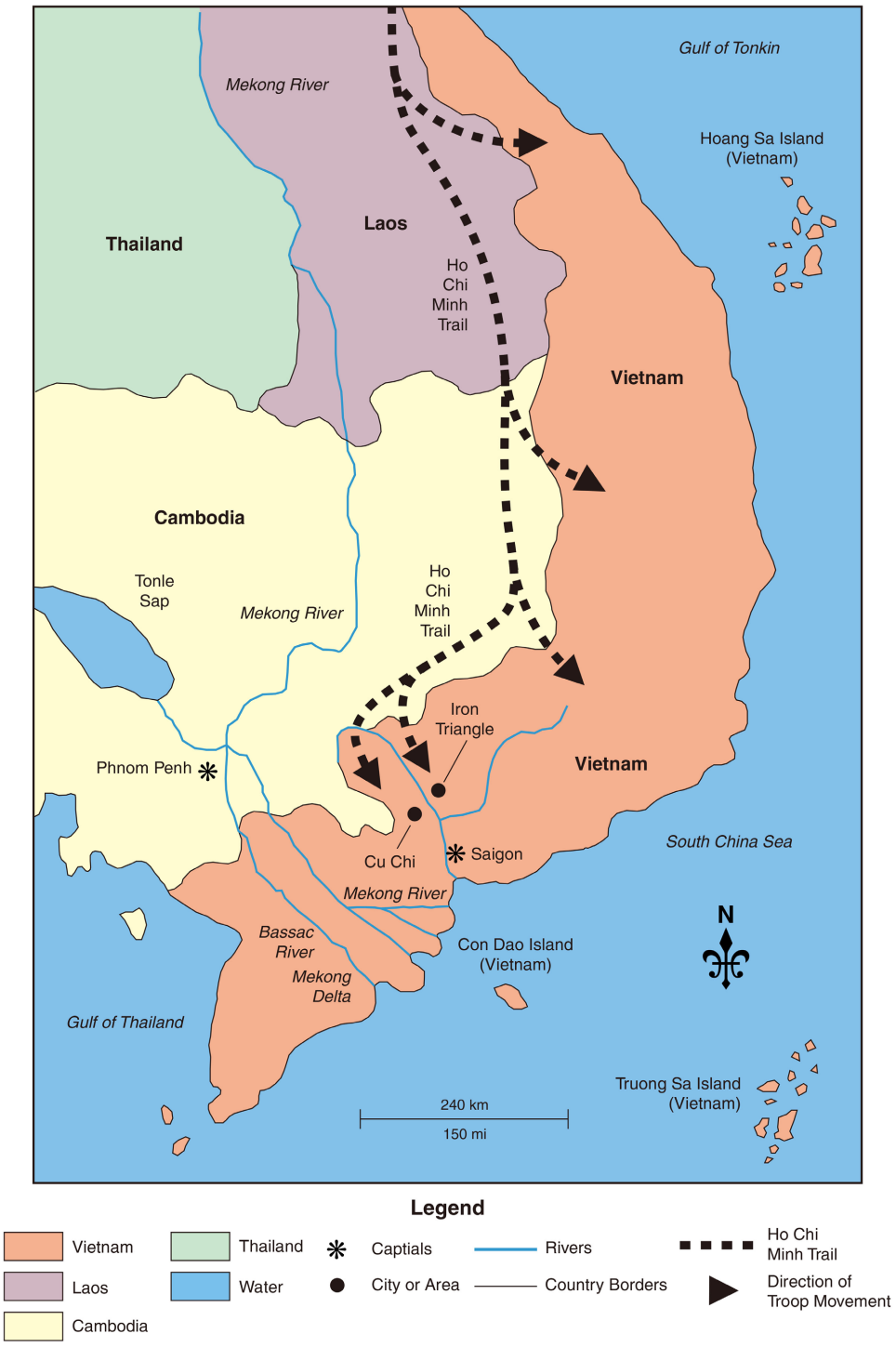

Figure 22. Ho Chi Minh Trail through Vietnam, Laos and Cambodia was a main route for moving food, military equipment and North Vietnamese Army soldiers from North Vietnam into the Cu Chi and Iron Triangle region of South Vietnam. Reprinted with the permission of the Managing Editor of Open Journal of Soil Science.

80 km northwest of Saigon. The Cu Chi area was 40 km west of Saigon and about 51 km^2 in size. The tunnels were between 1.5 m and 20 m deep in the Old Alluvium parent material (**Figure 23**) where the water table was low [5].

Figure 23. The Mekong River Delta region has an extensive system of canals, ditches, and dikes and polders built by the French in the 1800s that was expanded for Vietnam troop movement and post-1970s by Vietnamese farmers to intensify agricultural cropping systems. Old Alluvium terrace is shown in orange. Reprinted with the permission of the Managing Editor of Open Journal of Soil Science.

At the peak of the Vietnam War, the network of tunnels in the Iron Triangle and Cu Chi linked NVA support bases over a distance of some 120 km, from the Ho Chi Minh trail and Cambodian border to the outskirts Saigon [12]. In the early 1960s, the United States escalated its military presence in Vietnam in sup-

port of RV, a non-Communist regime in South Vietnam. The NVA gradually expanded the tunnels [13] [14]. Tunnels frequently were dug by hand in Old Alluvium terraces, and only a short distance at a time (**Figure 19**, **Figure 23**).

2.3. Vinh Moc Tunnels vs Cu Chi Tunnels: Red Basalt Hill vs. Old Alluvium Terraces

The Vinh Moc villagers initially dug the tunnels in to a red basalt hill to a 10 m depth but the American forces were able to created bombs that could burrow to that depth. The villagers then deepened the tunnels to 30 m. The parent material is red basalt, which is porous and soft to dig through yet structurally sound. The red basalt allowed easy hand digging of the tunnels and no support beams were required.

Soils located in Old Alluvium terraces at Cu Chi and Iron Triangle had high levels of clay and iron. Iron (Fe) leached from the upper soil layers (0 to 1.5 m), accumulated in the lower layers (1.5 to 20 m), and became a cement-like binding agent. When dried the soil layers took on properties close to concrete, and were resistant to ever becoming soft and moist again especially around the aerated tunnel walls. The tunnels were dug in the monsoon season when the upper layers of soil were soft and moist but not in dry season. The soils were highly stable without any lining or support. After drying out, the soil materials surrounding the tunnel turned into concrete like material that could withstand adjacent explosive blasts.

Cu Chi tunnels were used in a combat situation (**Figure 20**), whereas Vinh Moc tunnels were used as permanent bomb shelters, an entire village lived underground. Bigger than Cu Chi tunnels where you need to crawl, at Vinh Moc tunnels, you can stand (if less than 5 ft in height) and walk inside but were rather wet and slippery during rainy season.

Although located on a very pleasant oceanfront, Vinh Moc tunnels receives fewer visitors compared to than Cu Chi tunnels, adding to the vividness of the tourist underground experience the unexpected with other people in seemingly remote parts of the tunnel (**Figure 2**). A visit to Cu Chi is a half-day trip from downtown Ho Chi Minh City, where Vinh Moc is a full day trip from Hue. For the tourist/historian it will be a great idea to visit to both those tunnel complexes to see the differences as well as to learn their important roles in American-Vietnam War as each one has its own value.

Vinh Moc is not the only tunnel system (**Figure 5** and **Figure 6**) in the Vinh Linh district. However, it is the longest and largest tunnels of the 114 tunnels found, with kilometers of trenches connecting village to village. The nearest town to Vinh Moc is Dong Ha and many people use this as a base for exploring Vietnam's DMZ. These are historical sites of significant value reflecting Vietnam's history and its people's patriotism bravery and creativity.

When entering the Vinh Moc tunnels, people over 5 ft in height have to stoop low in an attempt not to bang their heads on the ceiling. The tunnels were made for Vietnamese and not the western giants. Descending further into the darkness

(with a flashlight), you can feel the heat and the clammy walls. On a chilly grey day, the constant warm humidity of the tunnels was greatly appreciated. Reaching the third level at around a 28 m depth, one can find the residential area. Small alcoves had been cut into the walls, one for each family. The families had to be crammed in like sardines. It was hard to believe but the NVA soldiers have even less space on the second level. Not the most comfortable place to spend what could be days at a time underground. In the midst of this family area, was a maternity room (Figure 8). It was no bigger than the other alcoves but 17 babies were born in this room during the Vietnam War. The meeting room was the brightest room and was the only place one could stand up. This wider stretch of the tunnel was used as a classroom for children during longer periods underground. The third level also had the well and shower room with drainage to the South China Sea. The meeting room provided relative brightness.

3. Results

3.1. History of Vinh Moc Tunnels-Legend of "Steel" Heroes

In many revolutionary bases on the "fire land" (Figure 4) of Quang Tri, the system of the tunnels of Vinh Moc village is symbolic of the strong will, not stepping back before the enemy of the ancestors. In 1965, Vinh Moc village was destroyed under American artillery and Air Force bombs. The NVA and people of Vinh Linh then quietly transferred life from land to the underground. After 18,000 workdays (Figure 7), they created a system of a massive village in the basalt hills with red soil (Figure 4) south of Vinh Moc village, close to the sea. The entire dome-shaped tunnel system is 2034 m long, including many branches connected through the main axis, which is 870 m long. The tunnels have 13 doors, including six doors to the hill, seven doors to the sea, and three vented wells (Figure 5 and Figure 6). It can be said that the Vinh Moc tunnels are an underground village with features such as wells, rice warehouses, Hoang Cam stoves, guard stations, telephone stations, clinics, operating rooms, bathrooms, etc.

In the mid-1960s, the area was a burnt and blackened wasteland, constantly under attack from the US. During a meeting of the local Vietnamese soldiers to discuss on how to stop all the constant casualties and protect the community better, some put forth the idea of moving the people underground (Figure 12). For them, it would be meaningless if the local people could not be protected since without the people their post would cease to exist.

After the meeting, an initial plan to construct an inverted U-shaped tunnel (Figure 7) on the seaside cliff was put forward. The US Air Force had not yet begun using the infamous B-52 bombers at Vinh Linh, but it was only a matter of time. As the plan developed, the soldiers followed up with two inverted U-shaped tunnels, connecting them and forming a chain of tunnels and bomb shelters (Figure 5, Figure 6). This initial network also acted as a base to retaliate against the enemy if they landed at Vinh Linh and conveniently as an entry point (Figure

14) for supplies to the nearby Con Co Island (Figure 15).

Yet, of course, it was not that simple. The tunnels needed 5 m-deep ventilation openings, and as the community within expanded, they had to develop wells, kitchens, bedrooms and health-stations. The tunnels also had to store provisions for the army and locals, and had to be able to house as well as transport hundreds of tons of rice. The tunnels are not just famous for the uniqueness of the constructors' endeavor, but for the meticulous ingenuity of their design. All the kitchens required chimneys, which had to be able to disperse their smoke without attracting enemy planes, no easy feat for a designer who was trying to fight a war.

3.2. Architecture of Vinh Moc Tunnel

When the underground channels were designed, the designers had the foresight to consider their protection as well as their construction. They must fare well against damage long, tropical rains, and monsoon. Architects would like to visit this historical and solid shelter to figure out how their elders could succeed in constructing such a complex, huge, but firm and sufficient place of living (Figure 5, Figure 6). This site was unique for the presence of the basaltic bedrock near the South China Seas. The tunnel is accurately a miniaturized image of a deep underground village with all necessary services (houses for all families, birthplace, health-stations, etc.), but can stand still firmly until now. The answer may be revealed in a heroic tenacity, intimate knowledge of the land from forefathers living as tillers and miners and great endeavor of the people in that historical period.

Today, people no longer need the tunnel to shelter but consider it as one of the top destinations of some history-discovering tour (Figure 1). If you are fond of history and you prefer adventure, the foremost suggestion is a visit to Vinh Moc tunnel. Vinh Moc tunnel is located in Vinh Moc hamlet, Vinh Thach commune, Vinh Linh district, Quang Tri province. If you follow the road from the North to the South along the road on Highway 1A, near the Vinh Linh Martyrs Cemetery, you turn left about 13 km to the sea (Figure 16) and to Vinh Moc Tunnels. On the lush, shaded bamboo road, few people know that right below their feet is a tunnel system, an "underground" world of the army and people of Vinh Linh during the years of resistance from 1965 to 1972.

3.3. Historical Use of Cu Chi Soil Tunnels for Housing and in Warfare

The French were not the first to colonize the lands now known as Vietnam. Long before the ethnic Viet moved south from the Red River basin of northern Vietnam, the Jarai, Cham, Khmers, Tai and over fifty other ethnic groups lived along the central coast, throughout the Mekong Delta, and in the highlands adjacent to the Red River lowlands [12]. The cradle of Vietnamese civilization traces its heritage to the Red River Delta of North Vietnam. Adjacent to southern China, this region was settled by people arriving by sea and overland from China [14]. The

name Viet Nam is Chinese; with the word "Viet" describing the peoples as "those from beyond" China and joined with the word "nam" meaning south. As the Chinese empire attempted to control these southern lands, they also transferred agricultural practices, dikes and canal building, social customs, culture, uniform language and administrative rules as well as patterns of trade into Indian Ocean markets. It is likely the Viet people acquired tunnel building knowledge from the Chinese and carried it forward into Vietnamese culture [12].

During the 16th century, millions of Chinese were living in caves and tunnel systems in China. Most of these sites were well-drained with a low water table [5]. Tunnels and caves dug in loess soils (Mollisols or prairie soils) were easy to dig by hand, but they lacked the iron oxide binding and/or bedrock structure cements that make soil tunnels more stable. In the 16th century one of the deadliest sequence of earthquakes in Chinese history occurred; and many of these tunnels collapsed killing approximately 830,000 people [12].

The Viet's began building their own empire and expanded southward as Chinese colonialism loosened its hold on the Red River valley. As part of nation building, Viet colonialism was "marked by violent confrontations with indigenous peoples whom they conquered" [12]. From the 18th through 20th centuries, Viet and non-Viet people in the region engaged in many rounds of civil war punctuated by colonial occupations by the Russians, French, and Americans. Prior knowledge of soils best suited for tunnel construction could explain the speed and skill with which the NVA employed tunneling in times of occupation and war.

Military use of tunnel networks under the jungle terrain of South Vietnam started during World War II (late 1930s and early 1940s) when Viet Minh national guerillas fought the Japanese prior to the Japanese overthrow in 1945 of the French who claimed Vietnam as colonial territory.

Tunnels extending short distances were hand dug during the rainy season when the soil was moist for small local units to use. In the early 1960s, the US, concerned about the aggressive expansion of communism in Vietnam, increased its military presence to support the RV, the non-Communist regime in South Vietnam. NVA troops expanded the tunnels and used them in conjunction with their guerrilla warfare tactics. The network of tunnels in the Iron Triangle and Cu Chi (**Figure 19**) connected NVA support bases running from the Ho Chi Minh Trail (**Figure 22**) and Cambodian border to the edge of Saigon, a distance about 120 km.

As the United States increased their aerial bombing, NVA soldiers used the tunnels to survive and conduct guerrilla warfare against the well-equipped American enemy. People living in these areas spent much of their life underground. The tunnels of Cu Chi grew from temporary quarters for a few soldiers to encompass entire underground villages of soldiers with kitchens, living quarters, hospitals, ordinance factories, and bomb shelters (**Figure 20**) [5]. Some tunnels had large underground theaters and music halls to provide entertainment

for the peasant soldiers. The tunnels proved very effective in hiding and protecting the NVA in 1960s at the height of the US Vietnam occupation. The soil tunnels at Cu Chi and the Iron Triangle (**Figure 19**) were so extraordinarily stable and resilient that they withstood three years of US military aerial bombing [5].

3.4. Cu Chi and Vinh Moc Tunnel Tourism

The tunnels of Cu Chi and Iron Triangle are an immense complex of interconnected underground tunnels located in the Cu Chi District of Ho Chi Minh City (Saigon), Vietnam. They are part of a much larger tunnel network that underlies other parts of Vietnam [5]. The RV government has preserved much of the 120 km long tunnel complex at the Cu Chi district and made it a war memorial park. Tourists can see first-hand the tunnels at Ben Dinh and Ben Duoc. They can crawl through a few of the tunnels and see command centers such as the underground conference rooms where the Tet Offensive and other campaigns were planned. A below ground conference center features a 15 millimeter black and white film that documents how the NVA liberated South Vietnam from the US occupiers. Some of the tunnels have been enlarged to accommodate the larger size of Western tourists. These tunnels have low-power lights to make crawling through the passageways easier, a luxury the NVA and US tunnel rats did not have. A variety of booby traps and how they work are also on display. Tourists can fire an AK-47 rifle on a firing range and taste a meal of cassava, one of the staple foods of the Vietnamese during the war [5].

Ten years after the war had ended; the Vinh Moc Tunnels were opened to tourists. Arriving at the tunnels tourists always put their hands on the wooden planks to feel how cold they were. These days, the government is striving to preserve their existence. With these great historical values, in 1976, the Ministry of Culture and Information (now the Ministry of Culture, Sports and Tourism) specially recognized the Bay Moc Tunnels as historical and cultural relics at the national level. In 2014, Bay Moc Tunnels continues to be recognized as a special national monument. This is one of the attractive destinations of the DMZ tour (non-military region) and attracts many tourists to visit and learn (**Figures 24-27**). In the relics area, there is also the Bay Moc Tunnels Museum where exhibits of war remnants, especially the famous painting To Be Or Not To Be (existence or non-existence).

Vinh Moc Tunnels—a unique building in the Quang Tri fire ground is a cultural and historical relic with many great historical and educational values, a symbol of the immortal patriotism and the will to strike, fortitude and creativity during the years of resistance. With such great historical values, in 1976, the Ministry of Culture and Information (now the Ministry of Culture, Sports and Tourism) specifically recognized the Vinh Moc tunnels as historical and cultural relics of National level (**Figures 24-27**). In 2014, Vinh Moc tunnels and relics continued to be recognized as special national monuments.

Figure 24. A museum in southern section of the Vietnam DMZ.

Figure 25. Ho Chi Minh statue in the Vietnam DMZ museum. All major memorials, parks, museums, public buildings and schools have paintings or statues of Ho Chi Minh.

This is one of the attractive destinations of the DMZ (demilitarized zone) tourist route, appealing to many tourists to visit and learn. Within the site of the ruins, there is the Vinh Moc tunnels museum (Figure 24) which showcases the war evidence, especially the famous painting "To Be Or Not To Be." Vinh Moc tunnels—the unique works in the "fire land" of Quang Tri is a cultural and historical relic with great historical and educational values, a symbol of immortal patriotism, strong will, and creativity of the ancestors in the years of resistance.

Figure 26. The monument on the museum grounds in southern section of the DMZ.

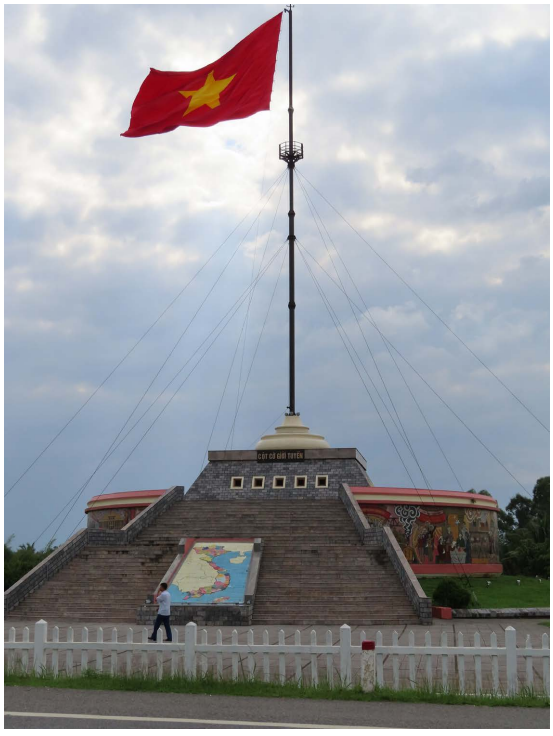

Figure 27. The Vietnamese flag, Vietnam providence map, monument and museum in the northern section of the DMZ.

4. Conclusions

The primary objective of the research study was to determine why both the Vinh

Moc and Cu Chi soil tunnels were so resilient to US Air Force bombardment. The Cu Chi and Iron Triangle soil tunnels were dug by hand in the monsoon season in the Old Alluvium parent material where iron in solution precipitated as the water evaporated into the tunnel and became the soil binding material. The Vinh Moc tunnels were hand dug in both the dry and monsoon seasons in porous, red basalt (bedrock) hills where the consolidated rock structure itself provided the required binding material. Neither site needed support beams to hold up the ceilings (except for the entrances). The Cu Chi and Iron Triangle tunnels were built to facilitate the movement of NVA soldiers to the RV via the Ho Chi Minh trail. The Vinh Moc tunnel complex, part of the Ho Chi Minh trail of the sea used to provide supplies to the Con Co Island garrison, was designed to shelter weapons, supplies, civilians and NVA soldiers from the US Air Force bombardment.

In many revolutionary bases on the Quang Tri "fire ground", the Vinh Moc tunnel village system is a symbol of strong will and refusal to back down from invading enemies. In 1965, Vinh Moc village was destroyed under the devastating destruction of the US military air power and artillery. With the will of "an inch not to go, a glass does not leave", Vinh Linh army and people quietly transferred life from the ground to the underground. After 18,000 person-days of hard work, the soldiers of the Border Guard 140 along with the people of Vinh Moc and Son Ha dug and transported more than 6000 m^3 of rock to create a massive village tunnel system on red basalt hills of Vinh Moc village and overlooking the South China Sea. Those known of Vietnam's heroic historical war must have some understanding of the tunnel network in Quang Tri citadel—a witness of the severe war. The Vinh Moc spectacular tunnel network within the zone stands as a testament to the endurance, wisdom and bravery of the Vinh Moc villagers in their fight for independence.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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