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Geological Evidence of Shoreline Erosion and Mitigation Challenges

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Abstract

A survey was carried out along parts of the coastal stretch of Accra, the capital of Ghana, to determine the existence and the extent of erosion. The survey was also to determine the effectiveness of the engineering solutions that have been put in place. Coastal land forms as evidence of erosion were identified during the field survey. These include landslides of steep coastal cliffs, coastal caves and arches, retreat of coastal cliffs, headlands, stacks and sand dunes. These pieces of evidence confirm earlier findings that the coastal shoreline of Accra is being eroded. The extent of erosion, however, is high in soft rocks and low in hard rocks. Several coastal protection measures have been put in place to address the effects of erosion by the sea waves and currents. These include revetments, jetties, ripraps and beach nourishment. Some of the mitigation measures however have shown signs of failure. The signs include rusted metal basket supporting cobbles of gabions, jetties causing down-current erosion of shoreline cliffs, and reduction in coconut population along the shoreline owing to human activities, such as sand winning and diseases attacks. Sand winning along the shore is lowering shoreline morphology and enhancing sea transgression and the destruction of coastal structures.

Keywords: Erosion; Coastal landform; Coastal protection; Revetments; Shoreline morphology

1. Introduction

Coastal erosion is known to occur along many shorelines all over the world resulting in many artificial coastlines (Bird, 1985). The erosion of coastal landscape, though a natural process, can be accelerated by human activities such as sand winning along the coast and coastal development (Beatley et al., 2002). Sand winning destroys coastal morphology and vegetation which protects the coast against erosion. Mensah (1997) attributed coastal sand winning in Ghana to socio- economic factors such as lack of employment and desire for development projects.

Coastal erosion can also be attributed to sea level rise owing to global warming (Armah et al. 2005; Zhang et al 2004). Sea level rise could lead to loss of beaches and developments along coastal areas (Zhang et al. 2004).

The coastal stretch of Ghana, from Axim to Aflao, has suffered varying degrees of erosion. According to Addo (2009) the rate of erosion of the marine shoreline of Accra varies between 0.2 m/yr and 1.9 m/yr. In order to curtail the level of erosion and the transgression of the sea and to keep the present shoreline in place several engineering protection measures can be introduced. They include beach nourishment, jetties, gabion revetments, ripraps, groynes and T-head groynes. T-head groynes combine the features of groynes and breakwaters (American Shore and Beach Preservation Association, 2011). These measures are meant to either prevent the shoreline from moving, as in seawalls or to stabilize shorelines such as in jetties and revetment (Mangor, 2004). Erosion mitigation strategies which are meant to protect the shoreline often increase erosion along nearby coastal areas owing to the varying wave refraction patterns and reduced sand supply.

A geological survey was carried out along parts of the coastal stretch of Accra (Korle Gonno to Sakumono), the capital of Ghana, to determine the existence and the extent of erosion. The survey is also to determine the effectiveness of the engineering solutions that have been put in place.

The main aim of this paper is to present geological evidence of coastline erosion along parts of the coast of Accra and to determine the effectiveness of the shoreline protection measures that have been put in place. An attempt is made to find the correlation between the geology and the erosion of the shoreline.

2. Geological setting of the marine coastline of Ghana

The marine coastline of Ghana lies within latitude 1° east and 3° west and covers a distance of about 400km. It is bounded by Aflao in the east and Half Assini in the west. This coastline region comprises different types of rocks whose ages lie between 400Ma and 2200Ma.

The older rocks belong to the Birimian Supergroup and are found between Axim and Takoradi in the western region of Ghana .

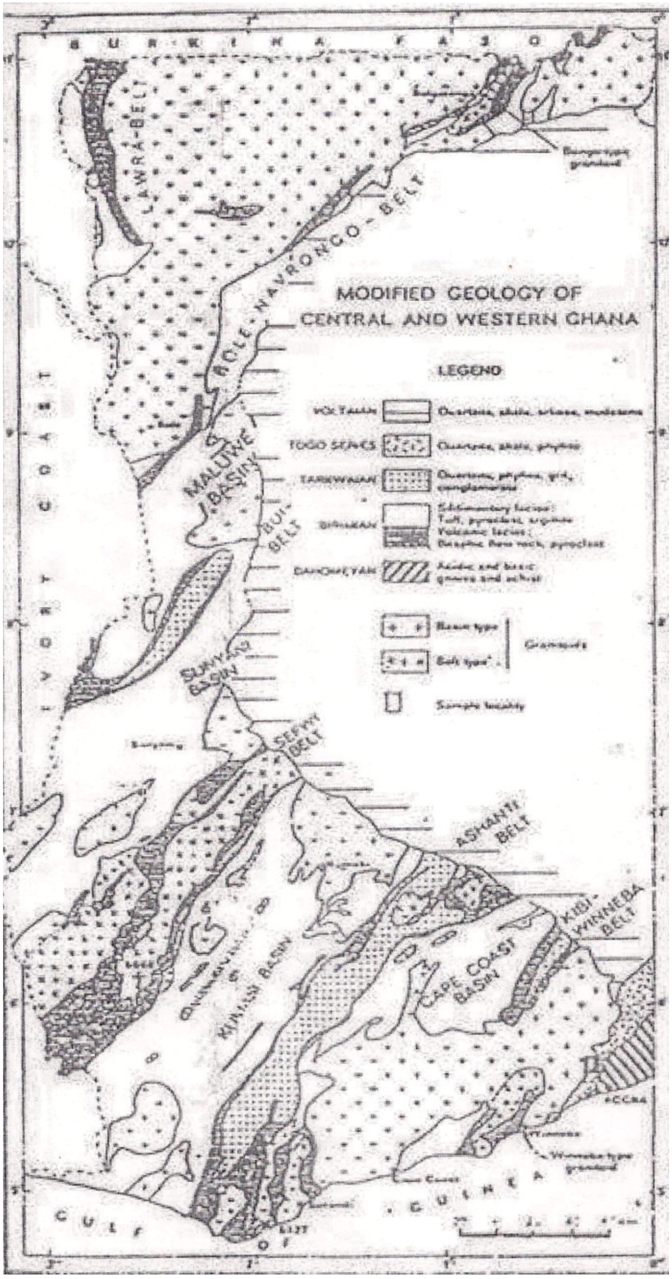

Fig. 1: Geology of central and western Ghana and sample localities of granitoidsunder investigation

These rocks are either volcanic or plutonic in origin. The volcanic rocks include rhyolites, andesites and basalts. The plutonic rocks are syn-volcanic and comprise hornblende-biotite granites and granodiorites, tonalites and diorites. Gabbro, peridotite and dunite occur as mafic intrusive in the Supergroup.

Other Birimian rocks which occur along the coastal region were metamorphosed by the eburnean tectonic movement and are found between Mumford and Winneba. The protolith of these rocks includes amphibolites, gneisses and schists. Overlying the Birimian supergroup is the Cape Coast basin rocks. The basin consists of granitoids which were emplaced during the eburnean tectonic movement of 2100Ma and include muscovite and biotite granites and granodiorites as well as hornblende-biotite diorites and tonalites. It outcrops between Saltpond and Sekondi . The Togo structural unit includes upper proterozoic (1000Ma) quartzites, shales, phyllites, sandstones and siltstones. This structural unit was thrusted over the Suhum basin which comprises Birimian rocks metamorphosed during the eburnean tectonic movement. The Suhum basin rocks consist of gneisses and migmatites. The Suhum basin and Togo rocks occur between Senya Bereku and Kokrobite. To the east of the Togo structural unit is the Dahomeyan Supergroup which includes mafic gneisses and ultra mafic rocks. The Supergroup consists of an orogenic belt formed after the closure of an oceanic basin by the collision of exotic blocks with the passive continental margin of the West African craton. It displays a peak metamorphic age of about 600Ma.

The formation of sedimentary basins along the marine coastal region of Ghana occurred within crustally weak zones created during the opening of the Atlantic Ocean. The coastal basins began with the deposition of the Sekondi group in the Ordovician. This deposition was followed by the formation of the Accraian group basin in the Devonian, the Amisian group in the upper Jurassic, the Apollonian group in the Upper Lower Cretaceous and younger (Tertiary and Quaternary) basin sediments in the Keta and Tano basins.

3. Methodology

A geological survey was carried out along some parts of the marine coastal stretch of Accra from Korle Gonno to Sakumono. This stretch of about 14km consists of Accraian group rocks and Dahomeyan Super group rocks. The survey confirmed previous findings that the Accraian group rocks are layered sandstones interbedded with shale, massive layered sandstones and finely laminated mudstone deposits. The Dahomeyan Super group stretches from La, where it shares boundary with the Accraian group, to Sakumono and beyond. It consists of heavily weathered garnet and amphibole gneisses as well as biotite and amphibole gneisses.

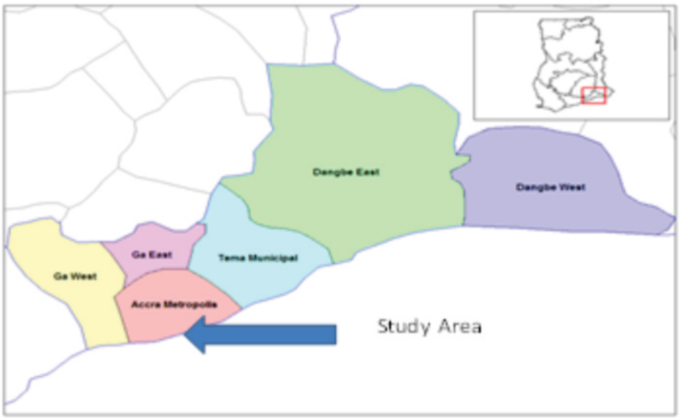

Fig 2. Map Of Greater Accra Region Of Ghana Showing Study Area.

4. Description of geological evidence of erosion

Erosion often results in the formation of landforms. Many coastal landforms are identified during the field survey. These landforms and where they occur have been presented in table 1.

Table 1

Geological evidence of erosion along Accra beach

Location	Geological evidence of erosion	Location Coordinates
James Town beach	Landslides of steep coastal cliffs	5° 31.89'N, 0° 13.08'W
Osikan beach	Coastal caves	5° 32.39'N, 0° 2.35'W
Osikan beach	Coastal arches	5° 32.39'N, 0° 2.35'W
James Town beach	Retreat of Coastal cliff	5° 31.89'N, 0° 13.08'W
Korle Gonno beach	Sand dunes	
Osikan beach	Headlands	5° 32.39'N, 0° 2.35'W
Osikan beach	Stacks and stumps	5° 32.39'N, 0° 2.35'W

High sea waves during high tides result in rapid undercutting of steep coastal cliffs (Plate 4) especially in weak soil. This undercutting has resulted in landslides. Apart from the high sea waves, which usually occur during high tide, the retreat of coastal cliffs (Plate 4) is also attributed to the engineering interventions up-current, such as the jetty at Accra old harbour, behind the James Fort Prisons, and the jetty located at Korle Gonno (Plate 2). The net effect is the alteration or loss of coastline ecosystems and properties and livelihood. Caves are common in steep cliffs of hard rocks (Plate 5). They are formed by sea waves gradually causing tunnels in rocky coastlines. Caves erode into arches and are common in rocks which seem to have been 'baked' around fault zones at the Osikan beach. Continued erosion has caused the collapse of some arches leaving behind sea stacks and stumps.

Budetta et al., (2000) studied the relation between the rate of erosion of coastal rocks and soils and the uniaxial compressive strengths of the soil and rock masses forming coastal cliffs. They obtained a relationship between the mechanical strength of the soil and rock masses and the rate of erosion, which indicates that the stronger the soil and rock masses the lower the rate of erosion. It was observed during field surveys that erosion is severe in the thin layers of sandstones inter-bedded with shale. The result is the formation of caves with widths of less than 1metre.The mudstone shows very severe erosion characterized by caves of widths greater than 1metre. The massive sandstone shows the least erosion evidence by the presence of holes of low diameter.

Table 2

Comparison of the extent of erosion in Accraian rock types

Rock Type	Extent of erosion	Evidence
Mudstone	**Very Severe**	**Presence of caves of > 1m width**
Sandstones inter-bedded with shale	**Severe**	**Presence of caves of < 1m width**
Massive sandstones	**Very Low**	**Presence of holes of < 6cm diameter**

Table 3

Coastal protection challenges in some parts of Accra

Mitigation Strategy	Location	Challenges	Recommendation	Location Coordinates
Beach Nourishment	James Town- opposite Fire Service Training School	Erosion still occurring	Bluffs should be reinforced	5^o 31.90'N 0^o 13.03'W
Revetment (Gabions)	La James Town and Sakumono	Metal mesh supporting cobbles have all rusted. Mesh with plastic coating have also rusted	Metal(eg Aluminium) mesh which can withstand corrosion by sea water should be used	5^o 31.88'N 0^o 13.08'W 5^o 36.79'N 0^o 01.99'W
Jetty	Korle Gonno, near the entrance of the korle lagoon into the sea and at the defunct Accra Harbour.	Results in sand accretion up-current and erosion down-current	Beach nourishment. Additional jetties have to be built down-current	5^o 31.80'N 0^o 13.28'W 5^o 31.97'N 0^o 12.63'W
Beach nourishment, Gabion and riprap	Sakumono	Rusted metal mesh supporting gabions	Embankment could be raised to prevent wave reaching the road during high tide and sea level rise	5^o 36.79'N 0^o 01.99'W
Vegetation	Korle Gonno Sakumo	Plants have been cut and some dead due to attack by diseases	Coconuts should be planted along shoreline	5^o 31.70'N 0^o 13.53'W

5. Description and discussion of coastal protection measures

Several erosion mitigation strategies (engineering measures) have been put in place in the area of study to reduce erosion by the sea waves and currents. The biggest obstacle, however, to using engineering solutions is that they often increase erosion along coastal areas near to the hard structure. Table 3 gives a summary of challenges in coastal protection measures in the study area and provides suggestions as to how they can be mitigated.

The jetty at the entrance of the Korle Lagoon (Plate 2) is causing sand accretion up-current and sand deficit down-current while currents are being broken up. The jetty at the defunct Accra harbour is also causing down-current erosion of sea cliffs behind the Ussher Fort prisons. Several other jetties will have to be built in the down- current direction. This is because without additional jetties, the areas immediately down-current will experience an accelerated pace of erosion as it is happening now.

Gabion revetments have extensively been used to protect the shoreline from erosion (Plate 3). The major challenge with its use is with regard to the fact that in some places the metal baskets holding the cobbles in place are all rusted.

A beach nourishment activity at the James Town beach (Plate 1) is meant to serve as a buffer zone to prevent erosion. The challenge with beach nourishment is that it often needs to be repeated to maintain the presence of the beach, and should be used in combination with hard engineered structures as it has been done at Sakumono (Plate 3). The beach nourishment at James Town is gradually being eroded (Plate 1).

Plate 1: Partly eroded beach nourishment at James Town beach

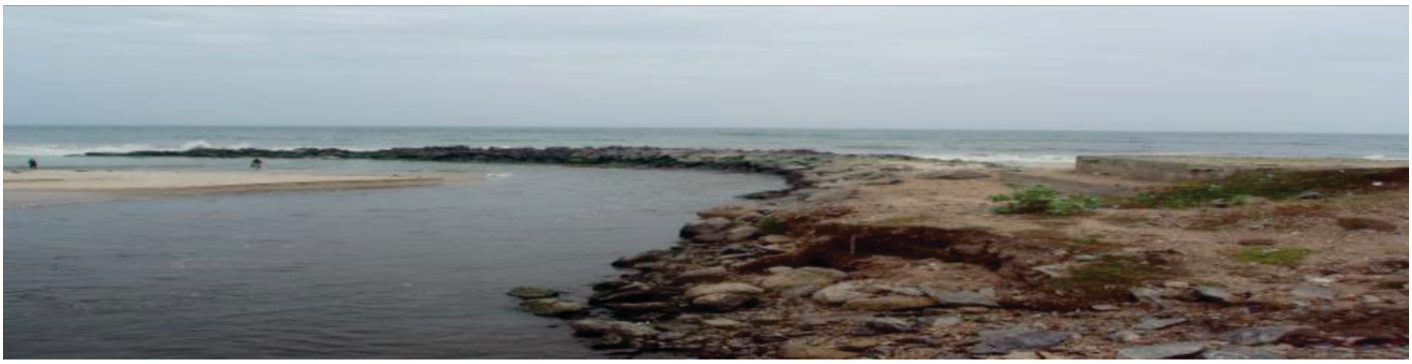

Plate 2: Jetty at James Town beach

Plate 3: Beach nourishment, gabion and riprap at Sakumono beach. Beach nourishment shows signs of erosion

Plate 4: Retreating coastal cliff near Osikan

Plate 5: Caves in rocks at Osikan

The roots and stems of coconut trees along parts of the shoreline trap sand and soil and form an erosion-resistant land layer. However, many of the trees have been cut and the land developed for other uses, and others are dead owing to disease attacks (Campbell, 2006). Sand mining along the beach is undermining sand accretion and promoting erosion and the transgression of the sea.

6. Conclusion

There are several pieces of geological evidence pointing to erosion along the marine coastline of Accra. The hard engineering mitigation strategies put in place to reduce erosion turn to increase erosion down-current. Some of the strategies are failing. Human activities such as cutting of coconut trees along the beach and sand winning are promoting shoreline erosion.

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