There is insufficient data to estimate resources in this area with a high degree of confidence but the inferred resources are significant. The Geological Survey has estimated that there is at least 6 Mt of fairly pure limestone resources suitable for Portland cement and for producing CaO-rich lime. The Soviets have indicated a large resource potential because they estimate that a 1-km2 block at Bonga-Da could contain about 10 Mt of limestone, which is known to occur over a much larger area. However, most of the limestone units occur beneath 15+m of chert and siliceous Voltaian sediments but some areas will have less overburden. It is also noted that the dolomite underlying the limestone will have considerably larger resources but more limited uses.

Again, it should be noted that core samples acquired by the Soviet team indicated bitumen in the fractures and joints of the dolomitic units, much the same as at Buipe.

Volta River Shell Deposits (Volta Region & Greater Accra Region)

Clam shell deposits, composed of white calcium carbonate ($CaCO_3$), occur extensively along the lower portion of the river, from about Akuse and extending for a distance of at least 50km downstream to the vicinity of Sogakope. The clam shells have formed in Recent times (approx. 10,000 BP) in brackish water, which is very favourable for their development.

The shells occur along the banks of the Volta and in the adjacent areas, as well as in sand bars along the course of the river. As far back as the mid-1960s the deposits were evaluated as a possible source of lime for use in cement and steel-making. The shell beds/deposits are quite variable in thickness, from 0.5m up to about 6m but are mainly 1-2m thick. They occur in a great variety of sizes; the smallest are confined lenses covering areas less than 1 hectare whereas the largest ones at Dorfor Gborkpo and Volivo cover approx. 10 and 20 hectares respectively. The clam shells are fairly pure and typically have compositions as follows: CaO 53-54%; MgO 0.5-1%; SiO_2 1-2%; Fe_2O_3 up to 0.4%; LOI 40+%.

The collective resource has been estimated to be about 700,000 tonnes, with the two largest deposits each contributing 250,000+ tonnes (Industrial Mineral Resources of Ghana, 1997). It is most likely that more detailed exploration will uncover additional shallow buried deposits along abandoned courses of the Volta River and in areas closer to the present coast, which was considerably inland when the sea level was up to 100m below current levels at the end of the last Ice Age, 10-15,000 BP.

At present, there is a modest cottage industry collecting the shells for use in terrazzo flooring and they are burned in small kilns to produce quite pure lime, mainly for whitewash paint. A larger, long term lime producing operation would require larger deposits than those currently identified.

Other Carbonated Deposits

There are numerous other occurrences of limestone and dolomite that have been reported in the literature. Virtually all of these are within the Volta Basin and although most are not very consequential, they do point to considerable potential in some areas.

Towards the very southern part of the Volta Basin, there is a cluster of occurrences along and adjacent to the **Afram valley** in the Eastern Region. One of the early occurrences in this area, very close to the village of Asuboni, was evaluated and considered as having good potential for use in Portland cement but unfortunately, it was inundated by Lake Volta in the mid 1960s. Not far from Asuboni and on the north side of the Afram valley, along the **Fo River valley**, a quite thick limestone bed was prospected and described by Soviets in 1964. The main limestone unit is up to about 30m thick and the Soviets estimated an inferred resource of about 1.5 million tonnes to a depth of only 15m. There are no apparent analyses of these carbonates but they are fairly pure limestone and were considered by the Soviets to be suitable for Portland cement.

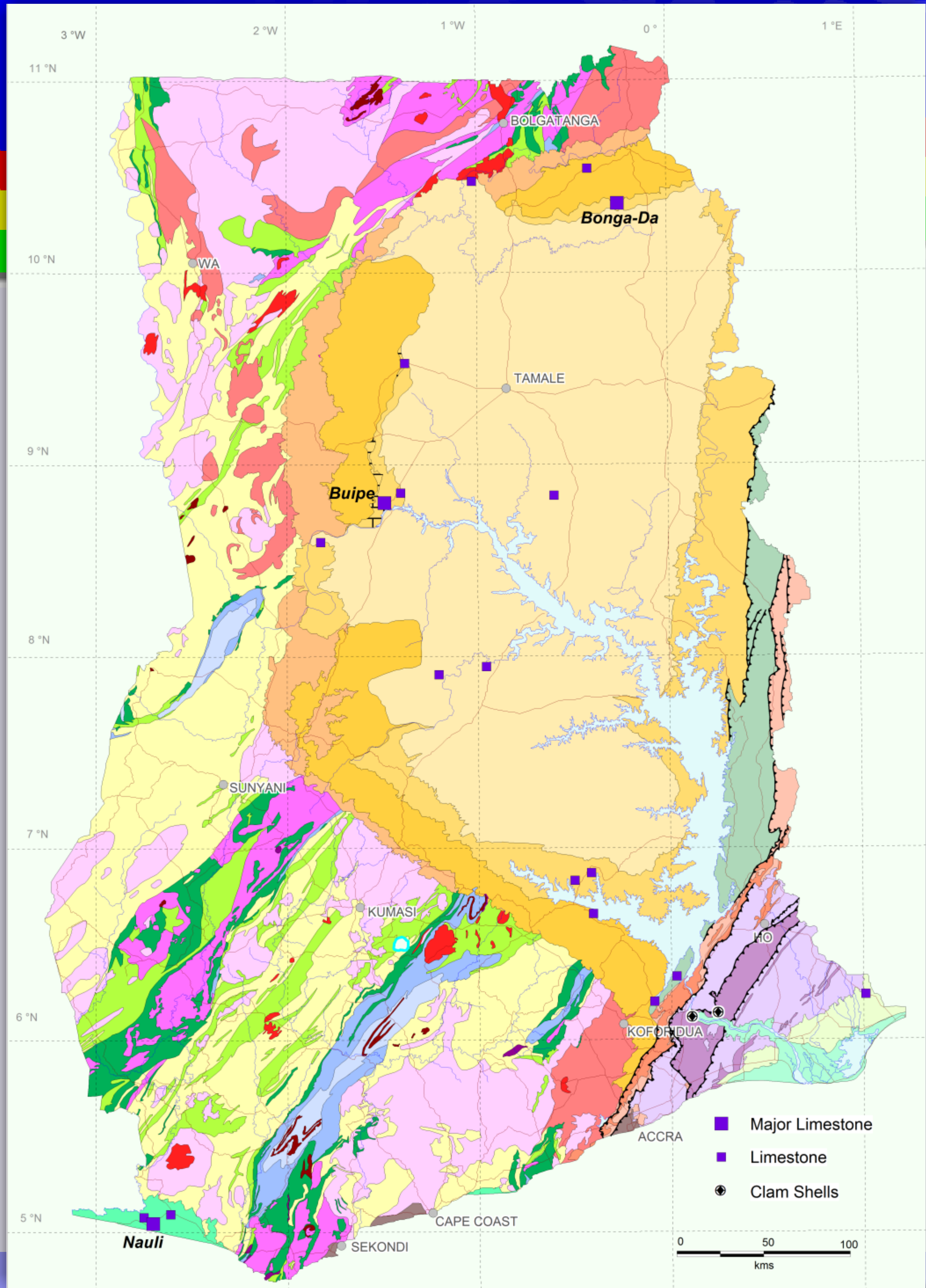
The carbonate occurrences in this general area are hosted in the **Afram Formation**, which is part of the extensive Oti-Pendjari Group; the Afram units are mainly fine-grained, shallow marine clastics (shale, mudstone, siltstone) close to 600 Ma in age and are interpreted to be slightly younger than the Buipe units to the north, which also host extensive carbonate units. Systematic exploration is likely to identify considerable carbonate resources at very shallow depths and the location very close to Lake Volta allows the potential to barge limestone products to nearby markets.

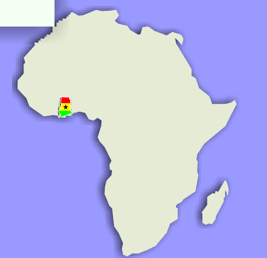
The Oterkpolu dolomitic limestone deposit is also located immediately adjacent to Lake Volta and about 26km NE of Koforidua, the capital of the Eastern Region. The grey to yellow-brown carbonates occur within the lower clastic units (Kwahu Group) of the Volta Basin and are believed to be close to 950 Ma in age. This area lies very close to the Pan-African thrust belt (Togo Structural Unit) and is therefore highly fractured and jointed. This occurrence was known for many decades and was a candidate for use in cement but it has a fairly high silica and dolomite content (CaO 35-40%; MgO 4-12%; SiO_2 8-17%; Al_2O_3+Fe_2O_3 3-4%; LOI 34-40%.). The size potential is modest (several million tonnes) but the location is quite favourable. Over the years this carbonate deposit has been quarried on a small scale, mainly for terrazzo chippings.

At the northern margins of the Volta Basin, a few minor occurrences of limestone have been described in the literature. Some appear to be associated with the same stratigraphic units (Oti-Pendjari Group) seen at Bonga-Da and Buipe and could well be indicative of more extensive carbonate sequences in the region.

It should be further emphasized that there have been persistent indications of viscous bituminous material at both the Buipe and Bonga-Da carbonate deposits. Even more significant are perhaps the **multiple indications of bitumen and oil** at depths between 500-760m in one of the Soviet hydrological drill holes at **Nasia** (approx. 140km south of Bolgatanga) in the Northern Region. These appear to be within the basal units of the Late Proterozoic Oti-Pendjari Group and could be related to significant **oil shale or tar sands**.

Limestone Occurrences in Ghana





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LIMESTONE, DOLOMITE AND LIME RESOURCES OF GHANA

INTRODUCTION

Limestone deposits are mainly sedimentary rocks of utmost importance to modern society and from them are derived a great variety of products with a myriad of uses and applications of immense value. The principal uses for limestone are in the making of cement, which is indispensable in all construction projects the world over, and it is used in the manufacturing of lime, which in turn has a multitude of uses in the mining, chemical, glass-making, steel, paper, agricultural, water treatment, food, environmental, health and pharmaceutical industries. Limestone is also used extensively to neutralize acidic soils and is widely used as filler in the production of paper; it is also commonly used as a dimension stone and as road metal.

Limestone is made up mainly of the mineral calcite (calcium carbonate or $CaCO_3$) but is often accompanied by variable amounts of other minerals such as silica, iron oxides, sulphides, and clay minerals. Most limestone deposits are formed in shallow marine environments and commonly contain substantial amounts of the mineral dolomite [$CaMg(CO_3)_2$], which is very similar to calcite. Usually the dolomite is formed after the sediment was first deposited by the introduction of Mg into the system during burial (diagenesis) or at a later stage. Although dolomite is the name of the mineral, it is also commonly used to refer to a carbonate rock, rich in dolomite; when a rock consists primarily (90+%) of dolomite, it is called a dolostone.

Metamorphosed limestone and dolomite deposits are called marble, which still consist mainly of calcite and/or dolomite but usually in a much coarser grained form and is used extensively as dimension stone. The calcite and dolomite in many limestone or marble deposits may also contain Fe and Mn, which fit easily into their crystal lattice structure or they may occur as separate carbonate minerals.

Dolomite is also used for many of the same purposes as calcite although not for Portland cement but it is used in some cement products. It is also widely used for the production of lime (dolomite lime), neutralizing soils, and especially as a flux in the production of steel and it is frequently used as a source to produce Mg metal and magnesia (MgO) for refractory bricks. It is also used extensively as dimension stone and as road metal. Lime commonly comes in two forms; quick-lime (CaO) and hydrated or slaked lime [$CaO(OH)_2$]. Both products are usually derived by calcining (heating up) calcite (+/- dolomite) to temperatures of around 10000C, which drives off CO_2 as gas and leaves a lime (CaO) residue. When water is added to the lime residue, hydrated lime is produced. In most parts of the world, lime is derived from fairly pure limestone but in Ghana, one of the prime sources is clam shells formed in brackish waters and found mostly along the margins of the Volta River. These shells are formed of quite pure calcite and are therefore a good source for lime. As noted above, lime is critical for many industrial, manufacturing and sanitation purposes and especially in many aspects of the treatment of water. It is used extensively to fix sulphur emissions and neutralize acids; the steel industry uses it as a key flux and it is an important chemical in the refining of sugar, alumina and gold; it is also used in paints, glass, abrasives, fungicides, and a variety of pharmaceuticals.

The use of limestone and products derived from limestone, especially lime, has increased dramatically over the past two decades in Ghana and currently exceeds 3 million tonnes annually and most comes as imported products. By far the largest import in value and tonnage is the clinker that is imported in bulk by the Ghana Cement Company (GHACEM). The clinker is further ground, mixed and bagged at the Port of Takoradi and then sold in the local market and in neighbouring countries to the north. Lime is also imported in bulk from Europe through the Carmeuse group of Belgium and then sold to local buyers, which are mainly the gold mines that use large amounts in their recovery plants. Increasingly, it is also exported to many neighbouring countries, especially the inland countries to the north.

For decades, the Government of Ghana has encouraged the development of local sources of limestone but to date this has been mostly on a small scale. However, very recently, a consortium of local and foreign companies, who use limestone products, is establishing a large mining operation at Nauli in the coastal area of the Western Region and Buipe in the Northern region. These two projects have the potential to meet most of the domestic needs and also to export to neighbouring countries in the ECOWAS region.

Ghana does not have very large limestone and dolomite resources but there are several well-known occurrences that have been studied extensively over a period of many decades by public and private sector groups. The following provides brief summaries of the main occurrences with considerable economic potential. Further details are available in Kesse's text on the Mineral and Rock Resources of Ghana (1985) and in the 1997 Minerals Commission report, Industrial Mineral Resources of Ghana, edited by K. Barning.

NAULI AREA (Western Region)

The first Director of the Ghana Geological Survey Dept. (then known as the Gold Coast), Sir Albert Kitson spotted the Nauli limestone beds in 1921 when he was carrying out reconnaissance mapping at the SW corner of the country, very close to the border with Cote d'Ivoire. However, very little was done in the area until World War II when the Marlu gold mining company developed a small quarry and kiln at Nauli to replace the lime it was importing for their gold plant at Bogosu. However, this lasted only until the end of the war and then, in the early 1950s, in the lead up to independence in 1957 and for decades thereafter, more serious efforts were made to evaluate the commercial potential of these limestones.

Much of the early work focused on obtaining estimates of the size potential and to assess the suitability of the limestone for Portland cement and/or as a flux for an integrated iron and steel plant located close to the Port of Takoradi. Much of the drilling was done by the Geological Survey as well as by British, Polish and Chinese groups; these and other groups also assessed the feasibility of utilizing the Nauli limestone for commercial purposes. Several of these studies had positive findings but the financing for a commercial project never materialized. Meanwhile the imports of limestone products, especially cement clinker and lime, continued unabated.

The Nauli limestone occurs in a narrow band of Late Cretaceous sediments along the margin of the Tano Basin and very close to the coast; it is exposed in a low ridge at the small village of Nauli and can be traced westwards along the ridge for 20+ km to the Tano River and the Cote d'Ivoire border. There has been drilling carried out along this stretch by different groups at different times; these have defined substantial resources of thinly bedded, highly fossiliferous, medium grey to fawn coloured limestone and clastic units that dip very gently (less than 50) to the SW. The cumulative thickness of the limestone beds is up to

7m and usually there are at least 5 persistent units that occur over large areas. The inter-bedded units include dark grey coloured clays and much lighter coloured sand and silty beds. Traces of gas and viscous bitumen have been reported from some of the earlier drilling of these Late Cretaceous sediments.

Resource estimates reported by G.O.Kesse in the Mineral and Rock Resources of Ghana (1985) for the open-pit potential indicate in excess of 20 million tonnes. Tests have indicated that the limestone can be utilized in the manufacturing of Portland cement, as a flux in steel-making and it is quite suitable for the manufacturing of lime. The range in composition of the various limestone units can generally be characterized as follows: CaO 48-52%; MgO 0.5-1.5%; SiO_2 1-5%; Al_2O_3 1-3%; Fe_2O_3 1-2%; S 0.5-1%; and the loss on ignition 38-42% (mainly CO_2 plus minor water and SO_2). A mining operation in this area is feasible but will be challenged by abundant rainfall and groundwater and the relatively thin nature of the carbonate units as well as the need to remove much of the inter-bedded clastic units and eliminate sulphur. The coastal location is quite advantageous and there is established infrastructure and power in the area. As noted above, a consortium of companies that includes GHACEM, have plans well underway to develop a large quarry in the area for the purposes of manufacturing cement. The project is expected to be launched very soon.

Buipe Limestone and Dolomite (Northern Region)

The carbonate units in the vicinity of Buipe were initially recognized by Sir Albert Kitson on a regional traverse in the earliest days of Geological Survey (1916); further work was carried out by the Survey in the mid 1920s but then it was another several decades before more attention was devoted to these resources. It was the potential impact of the building the large Akosombo Dam and the huge Lake Volta reservoir that stimulated interest in the area in the mid 1950s and again in the 1960s when a large Soviet technical mission was based in Tamale and assessing potential mineral resources throughout northern Ghana. Lake Volta could provide a convenient and cheap means of transporting mineral products to the southern markets, especially the Accra-Tema area where President Nkrumah had hopes of establishing a large industrial complex utilizing domestic resources in order to reduce the country's dependency on foreign imports.

The carbonates at Buipe are exposed immediately adjacent to the lake where the main road from Kumasi to Tamale passes and they can be traced in a broad band extending northwards for close to 50km. They are part of the vast Volta Basin sediment formations that cover much of northern Ghana and have a range in age from Late Proterozoic (approx. 1000 Ma) to early Paleozoic (approx. 400 Ma). These carbonates are amongst the Late Proterozoic units in the Volta Basin that have been dated at about 600 Ma and they appear to have been formed in a shallow marine shelf environment.

Diamond drilling (32 holes) over part of the Buipe area by the Soviet technical mission reveals that the upper section of carbonates are dominated by light coloured (grey, blue, white, brown, yellow) limestone beds (0.5 to 4.0m thick) with inter-bedded marls and clastic units, which overlie thicker (2-10m), fine-grained, grey dolomite and dolomitic limestone. These carbonates in turn overlie fairly extensive, coarse clastic breccias that have been interpreted to be glacial tillites, which are widespread throughout the region. Very interestingly, core samples revealed viscous bitumen in many fractures and joints within the dolomitic units.

The dolomite units, which are really impure dolomite and dolomitic limestones, clearly predominate over the limestone; various estimates (see Industrial Mineral Resources of Ghana, edited by K. Barning, 1997) reveal at least 20 Mt of inferred and indicated limestone resources suitable for the production of Portland cement and various other purposes, whereas there are well over 100 Mt of dolomitic resources that will be suitable for some types of cement and especially for the production of refractory bricks and flux needed in the steel industry as well as for lime, road metal and dimension stone. The following table (Table 1) gives an indication in the range of composition from fairly pure limestone to impure dolomite; in fact, the rocks described as dolomite in the literature are more correctly described as dolomitic limestones and impure dolomites, as the amount of CaO is usually almost twice the amount of MgO.

	Limestone	Dolomitic Limestone	Impure Dolomite
CaO	48-49%	30-35%	28-30%
MgO	1-2%	8-15%	15-20%
SiO_2	4-8%	4-12%	3-8%
Al_2O_3	2-3%	2-4%	1.5-4%
Fe_2O_3	0.5-1%	0.5-1%	0.5-1%
LIO	40+%	40+%	40+%

Table 1

The Buipe carbonates are the largest in the country and they are located in a favourable position immediately adjacent to the Kumasi-Tamale highway, which provides good access to northern Ghana as well as to Burkina Faso, Mali and Niger. Also, if plans to upgrade the barging facilities on Lake Volta come to fruition, these northern deposits could have easier access to the Accra-Tema industrial area. At present Savana Cement is developing this deposit for the production of cement.

Bonga-Da Limestone (Northern Region)

The Bonga-Da carbonates were first assessed by the Soviet technical team in the mid 1960s after brief reports about the occurrences from earlier Geological Survey traverses in the area, which is located in the NE sector of the Northern Region, about 28 km SE of Gambaga. The Soviet work included 7 shallow diamond drill holes. Later work was carried out by the Geological Survey in 1975 to assess the suitability of the limestone for the manufacturing of Portland cement. Neither of the above studies was very comprehensive but certainly sufficient to properly characterize the potential of the carbonates in the area.

The carbonates consist of two main light grey limestone units with inter-bedded mudstones and shales; the maximum thickness of the limestone is about 6m. These are underlain by similar units of rusty-grey dolomitic limestone and impure dolomites that are 2-8m thick. Overlying the carbonates are 15+m of grey cherts and brown silicified mudstones. These sediments appear to have a similar or perhaps slightly younger age (Late Proterozoic – approx 600 Ma) as the Buipe carbonates and also developed in a shallow marine environment.

The Bonga-Da carbonates display a wide range of composition as noted in the two end-members below (Table 2):

	Limestone	Dolomite
CaO	45-52%	30-36%
MgO	1-4%	12-20%
SiO_2	3-4%	3-12%
Al_2O_3	1-4%	1-2%
Fe_2O_3	Up to 1%	0.5-1%
LIO	40+%	40+%