A Ground-Water Reconnaissance of the Republic of Ghana, With a Description of Geohydrologic Provinces

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1757-K

Prepared in cooperation with the Volta River Authority, the Ghana Division of Water Supplies, and the Geological Survey of Ghana under the auspices of the U.S. Agency for International Development

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By H. E. GILL

CONTRIBUTIONS TO THE HYDROLOGY OF AFRICA AND THE MEDITERRANEAN REGION

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1969

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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A GROUND-WATER RECONNAISSANCE OF THE REPUBLIC OF GHANA, WITH A DESCRIPTION OF GEOHYDROLOGIC PROVINCES

By H. E. Gill

ABSTRACT

This report gives a general résumé of the availability and use of ground water and describes the occurrence of ground water in five major geohydrologic provinces lying in the eight administrative regions of Ghana. The identification and delineation of the geohydrologic provinces are based on their distinctive characteristics with respect to the occurrence and availability of ground water.

The Precambrian province occupies the southern, western, and northern parts of Ghana and is underlain largely by intrusive crystalline and metasedimentary rocks. The Voltaian province includes that part of the Voltaian sedimentary basin in central Ghana and is underlain chiefly by consolidated sandstone, mudstone, and shale. Narrow discontinuous bands of consolidated Devonian and Jurassic sedimentary rocks near the coast constitute the Coastal Block Fault province. The Coastal Plain province includes semiconsolidated to unconsolidated sediments of Cretaceous to Holocene age that underlie coastal plain areas in southwestern and southeastern Ghana. The Alluvial province includes the Quaternary alluvial deposits in the principal river valleys and on the delta of the Volta River.

Because of the widespread distribution of crystalline and consolidated sedimentary rocks of low permeability in the Precambrian, Voltaian, and Coastal Block Fault provinces, it is difficult to develop large or event adequate ground-water supplies in much of Ghana. On the other hand, small (1 to 50 gallons per minute) supplies of water of usable quality are available from carefully sited boreholes in most parts of the country. Also, moderate (50 to 200 gpm) supplies of water are currently (1964) obtained from small-diameter screened boreholes tapping sand and limestone aquifers in the Coastal Plain province in southwestern and southeastern Ghana, but larger supplies could be obtained through properly constructed boreholes. In the Alluvial province, unconsolidated deposits in the larger stream valleys that are now largely undeveloped offer desirable locations for shallow vertical or horizontal wells, which can induce infiltration from streams and yield moderate to large water supplies.

The principal factors that limit development of ground-water supplies in Ghana are (1) prevailing low permeability and water-yielding potential of the crystalline and consolidated sedimentary rocks that underlie most of the country, (2) highly

mineralized ground water which appears to be widely distributed in the northern part of the Voltaian province, and (3) potential problems of salt-water encroachment in the Coastal Plain province in the Western Region and in the Keta area. On the other hand, weathering has increased porosity and has thus substantially increased the water-yielding potential of the crystalline and consolidated sedimentary rocks in much of central and northern Ghana. Also, with proper construction and development, much larger yields than those now (1964) prevalent could be obtained from boreholes tapping sand and limestone aquifers in the Coastal Plain province.

INTRODUCTION

PURPOSE AND SCOPE

In most of Ghana, including all the northern and eastern administrative districts and some coastal areas, seasonal shortages of water, and especially of potable water, are chronic. The seasonal distribution of precipitation is such that many streams and springs fail in the dry season. Moreover, the yield of most shallow dug wells declines sharply during the dry season, and many wells go dry. The basic problems are, therefore, the improvement, utilization, and conservation of the available sources of water, as these are essential for continued economic growth.

Ghana's undeveloped mineral wealth and the national will for greater economic self-sufficiency have led to increasing emphasis on industrial development, which is dependent on adequate sources of water and power. The Volta River Project, designed to dam, control, and regulate the flow of the Volta, utilizes the impounded water to generate power for industrial, municipal, and rural use. The impoundment of the Volta by a dam at Akosombo has necessitated the resettlement of a large rural population that formerly lived in the inundated area. The need for providing adequate potable water supplies for resettlement villages, as well as for industrial development, has stimulated new interest in more complete knowledge of the ground-water resources of the country. The Volta River Authority requested the services of a hydrogeologist through the U.S. Agency for International Development (USAID) to advise the Volta River Authority on problems related to exploration for new ground-water supplies. This writer was assigned by the U.S. Geological Survey to this work and during early 1964 made a 3-month reconnaissance study of ground-water conditions in Ghana which are summarized in this report. Publications of the Geological Survey of Ghana and unpublished data from the files of the Division of Water Supplies at Kumasi were used to aid the reconnaissance.

PREVIOUS INVESTIGATIONS

Ground-water studies, related chiefly to the location or siting of boreholes for local water supplies, have been made by the Geological

Survey of Ghana for the past 30 years. Results of these studies are published in the annual reports of the Director of the Geological Survey for the years 1925–26, 1934–39, and 1946–61. The section "Selected references" includes other geologic reports which contain reference or information on the occurrence of ground water.

ACKNOWLEDGMENTS

Acknowledgment is made to officials of the Volta River Authority and the Ministry of Communications and Works for their assistance in furthering the objectives of this reconnaissance. Personnel of the Water Supplies Division and the Geological Survey of Ghana were especially helpful. The Director and staff of USAID provided administrative support as well as essential contacts for the successful completion of the fieldwork. Special acknowledgment is due Mr. Wallace Lewis and Mr. John Gillman of the Water Supplies Division, Kumasi, for their efficient handling of the arrangements for field trips and guide services.

GEOGRAPHY

The Republic of Ghana, centrally located in west Africa, is roughly rectangular in shape (fig. 1). It is bordered by the Republics of Upper Volta on the north, the Ivory Coast on the west, and Togo on the east. Its southern limit is formed by a coastline, approximately 345 miles long on the Gulf of Guinea. Cape Three Points, at the extreme southern tip of Ghana, lies at lat 4°44′ N. The northernmost point in the country, at lat 11°11′ N., occurs near the point where the White Volta enters Ghana from the Republic of Upper Volta. The extreme western and eastern margins of Ghana lie at long 3°15′ W. and 1°12′ E., respectively. The Greenwich meridian traverses the eastern part of the country through the port of Tema, 15 miles east of the capital at Accra.

The area of Ghana is about 91,800 square miles. The 1960 census indicated a population of approximately 6.7 million; greatest densities are along the coast, in the central part of the forest zones, and in the compound farming areas in the northeast and northwest of Ghana.

The latitudinal banding of vegetation zones in Ghana, (pl. 1) as well as in the rest of west Africa, is controlled chiefly by the amount and seasonal distribution of rainfall. The vegetation grades with increasing latitude and decreasing rainfall from equatorial rain forest in the southwest through a transition zone to a belt of moist semi-deciduous tropical forest. Northward this belt grades into Guinea savannah, where woodland predominates over grassland. This is the most extensive vegetation zone in Ghana (pl. 1). In the extreme northeast, Ghana extends into the Sudan savannah, where grassland predominates over woodland. In the southeast, however, the even banding of vegetation zones in Ghana is interrupted by an area of savannah and scrub forest vegetation, resulting from an orographic anomaly in the amount of rainfall. Also, in the low-lying land along the Gulf of Guinea are coastal thickets and grasslands and, where brackish water prevails, mangrove swamps.

Ghana as a whole is classed as a lowland, even though the upland area of the Volta Region is occasionally referred to as "mountainous."

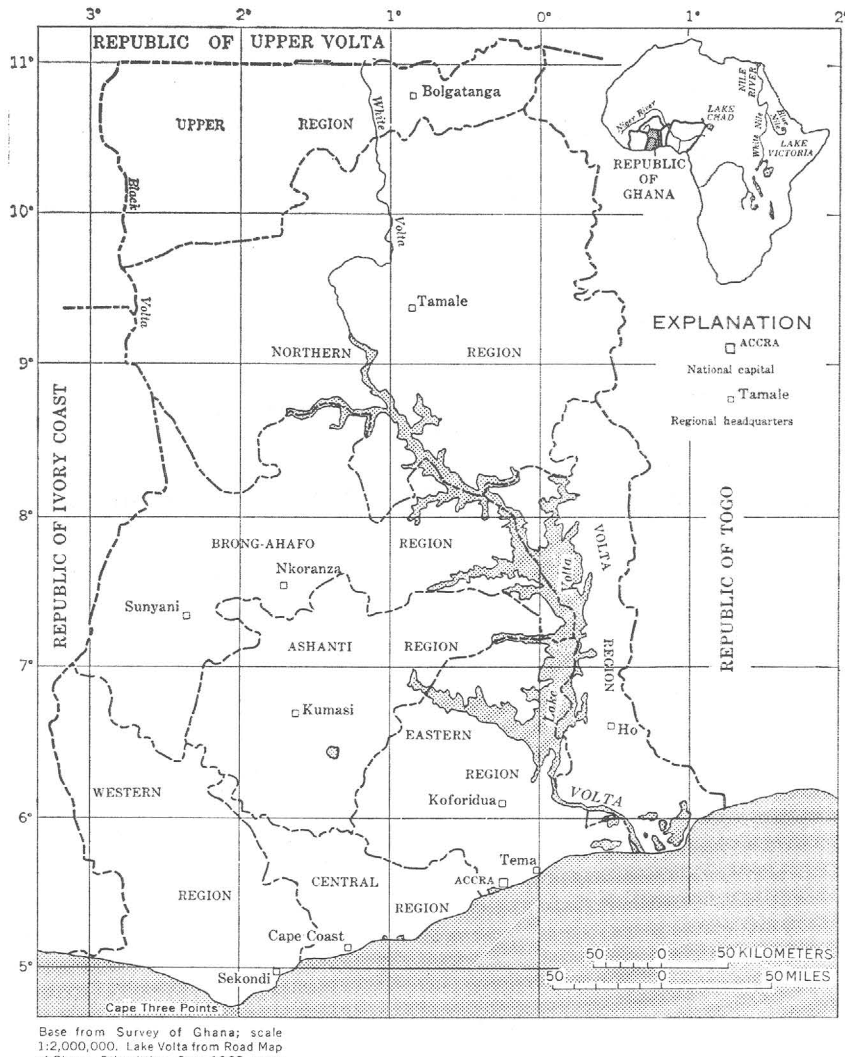

FIGURE 1.—Location map showing political subdivisions.

The greater part of the country is less than 1,000 feet above sea level. No ridges exceed an altitude of 3,000 feet, the highest being Afadjoto at 2,905 feet in the Volta Region (pl. 1) on the Republic of Togo border.

The most notable topographic feature in Ghana is the escarpment forming the southern limit of the Voltaian sedimentary basin (pl. 1). The escarpment is marked throughout most of its length by a single or double ridge. It rises from an altitude of about 500 feet to about 2,500 feet and runs essentially unbroken from Koforidua to Wenchi, a distance of some 160 miles. Elsewhere in Ghana the greatest variations in local relief occur in the rain, transition, and semideciduous forest zones. In the rain forest the hills commonly rise about 150 to 250 feet above the general level of the surrounding plains. Further inland, however, in the transition and semideciduous forests, the hills rise as much as 1,000 feet above the plains. This topography is contrasted with the gently rolling terrain found in the Guinea savannah. Inselbergs marked by steep slopes are characteristic of the southeast and northwest parts of the country.

The escarpment at the southern limit of the Voltaian sedimentary basin forms a drainage divide separating the Volta River system from several smaller river systems which drain southward to the sea. The Volta, one of the major river systems of west Africa, drains with its tributaries all the northern and central parts of Ghana. The mouth of the Volta, on the Gulf of Guinea, is marked by a small delta and extensive tidal lagoons (pl. 1). The flow of all the rivers in Ghana is markedly seasonal. In the Volta River basin, only the major tributaries are perennial; the minor tributaries are ephemeral or intermittent.

CLIMATE

The characteristic features of Ghana's climate are prevailing high temperature and marked variation in the amount, duration, and seasonal distribution of rainfall. The dry seasons, which separate the rainy seasons, are longer and more intense with increasing latitude.

Ghana receives abundant solar radiation at all times of the year because of its nearness to the equator. The mean annual temperatures for stations in Ghana generally range from 79° to 84°F. Temperatures are somewhat lower near the coast than they are further inland, because of the cooling effects of the sea. The daily mean range of temperature is 12° or 13°F near the coast and as much as 18° to 30°F further inland. Over the greater part of the country, the monthly mean maximum temperatures occur in March or February, while the mean minimum occurs in August. The annual mean maximum temperature is greatest (94°F) in the extreme north and least on the coast (85° to

86°F). The lowest monthly mean minimum temperatures occur in January in the interior of the country and in August along the coast, while the highest absolute temperatures are recorded in March. Generally, high temperatures occur in February and March just before the onset of the rainy season. The lower temperatures occur at night in inland districts when the prevailing air mass is relatively cool and the skies are sufficiently clear to permit rapid radiation. Near the coast, where the influence of the "harmattan" or continental airmass is not as strong, such conditions are found during the dry month of August. This is also the time when day temperatures are lowest, owing to mist from the sea.

Rain in Ghana results from the interaction between the northeast trade winds and the southwest winds or monsoon. The meeting of the northeast trade winds with the warm moist air of the monsoon promotes cooling and condensation which are necessary for rain to form. The highest annual rainfall occurs near Axim, which has more than 85 inches, and diminishes gradually northward to that between 40 and 50 inches in the Northern and Upper Regions and between 30 and 40 inches in the northeast (pl. 1). The only major departure from this general pattern is in the area lying south and east of a line between Takoradi and Ho, where the annual rainfall decreases from 50 inches to less than 30 inches. The zone of least rainfall lies in a belt along the coast to the east and west of Accra.

GEOHYDROLOGY

About 45 percent of Ghana is underlain by a wide variety of Precambrian igneous and metamorphic rocks. This area constitutes the Precambrian geohydrologic province, which, for purposes of description of geology and ground-water conditions, can be further divided into three subprovinces. The Voltaian geohydrologic province includes an area underlain by consolidated sedimentary rocks of the Voltaian Formation of Paleozoic age. These rocks, which are flat lying or gently dipping, occur in extensive sedimentary basin that includes about 35 percent of Ghana. The Coastal Block Fault province consists of a narrow, discontinuous belt of Devonian and Jurassic sedimentary rocks that have been broken into numerous fault blocks and are transected by minor intrusives. The Coastal Plain geohydrologic province is underlain by semiconsolidated to unconsolidated sediments, ranging from Cretaceous to Holocene age in southeastern Ghana and in a relatively small isolated area in the extreme southwestern part of the country. The Alluvial geohydrologic province includes narrow bands of alluvium of Quaternary age, occurring principally adjacent to the Volta River and its major tributaries and in the Volta delta. The alluvial bands along the lower reaches of the Volta and its tributaries are now covered by the new Lake Volta reservoir. Some narrow bands of alluvium, however, not shown in plate 2, occur in reaches of these streams upstream from Lake Volta. The areal extent of the geohydrologic provinces of Ghana is shown in plate 2.

PRECAMBRIAN PROVINCE

LOWER PRECAMBRIAN SUBPROVINCE

The Lower Precambrian subprovince includes the area where rocks of the Dahomeyan Formation underlie the Accra plains and the southern parts of the Eastern and Volta Regions. These rocks also extend across Togo, Dahomey, and into Nigeria. They consist mainly of crystalline gneisses and migmatites, with subordinate quartz schist, biotite schist, and other sedimentary remnants. The rock types occur as persistent parallel belts several miles wide that strike north-northeast and dip about 25° towards the southeast.

The area underlain by the Dahomeyan rocks is one of low relief on a gently sloping peneplain. Inselbergs of mafic gneiss rise sharply from this plain. The gneisses including both silicic and mafic varieties, are generally massive and have few joints or fractures. The silicic gneiss commonly weathers to slightly permeable clayey sand, whereas the mafic gneiss weathers to impermeable calcareous clay. The generally impervious nature of the weathered zone and the massive crystalline structure of the rocks limit the available ground water that can be developed by wells or boreholes. Present usage in Ghana defines a well as a shallow, hand-dug waterhole. A borehole is generally of small diameter, relatively deep, and put down by cable tool or hydraulic rotary drilling rig.

Northeast of Accra in the Accra Plains, 25 boreholes have been drilled in Dahomeyan rocks for water (pl. 2). Nine boreholes were considered successful with an average yield of 1,078 gph (gallons per hour) or 18 gpm (gallons per minute). The yields obtained from the nine boreholes range from 120 to 2,500 gph. All gallons referred to in this report are imperial gallons.

The chemical analyses of water samples from seven of the boreholes indicate that the water is generally of usable quality for most domestic, municipal, and industrial purposes. The iron concentrations range from 0.3 to 4.2 mg/l (milligrams per liter). Concentrations of iron and manganese above 0.3 mg/l cause noticeable precipitation of iron oxides, when the water is allowed to stand. The pH is slightly acidic in five of the samples and may indicate slightly corrosive water. The chloride concentrations range from 30 to 195 mg/l. Nitrate concentrations in four of the wells indicate local pollution and a possible source for some of the chloride concentrations.

MIDDLE PRECAMBRIAN SUBPROVINCE

The Middle Precambrian subprovince is made up of rocks of the Birrimian Formation and associated instrusives. The Birrimian consists of a great thickness of isoclinally folded, metamorphosed sediments intercalated with metamorphosed tuff and lava. The tuff and lava are predominant in the upper part of the formation, whereas the sediments are predominant in the lower part. The entire sequence is intruded by batholithic masses of granite and gneiss, which in some areas have partly or completely granitized the Birrimian host rocks. The sediments, dominantly argillaceous, were metamorphosed to schist, slate, and phyllite with some interbedded graywacke. These rocks contain varying amounts of carbonaceous, ferrous, manganiferous, or calcareous material. The tuff and lava range from mafic to silicic composition, but the mafic types are most common. Many of the mafic lavas were extruded underwater. The base, and therefore the thickness, of the Birrimian is unknown, because the areas of deepest erosion reveal only the granitized roots of the complex.

The granites and gneisses associated with Birrimian rocks are of considerable importance in the water economy of Ghana, because they underlie extensive and usually well-populated areas. The granites and gneisses have similar hydrologic properties. They are not inherently permeable, but they do have a secondary permeability or porosity developed as a result of jointing, fracturing, and weathering. Where precipitation is high and weathering agents penetrate deeply along joint and fracture systems, the granites and gneisses commonly are eroded down to form comparatively low-lying areas. On the other hand, in the Northern Region, where the precipitation is less, and in some parts of of the forests zones of southern Ghana, the granites occur in massive, poorly jointed, rocky domes (inselbergs) that rise above the surrounding lowlands. Elsewhere, weathering may penetrate deeply along individual joint planes or zones of jointing, and in favorable areas weathered granite or gneiss may form permeable groundwater reservoirs. Major fault zones also offer favorable locations for ground-water storage. In the Wa district of the Upper Region, the regolith (zone of weathering) locally is as much as 450 feet thick, but in more eastern districts of the Upper Region the regolith generally is only about half as thick.

In the Wa granite of the Upper and Northern Regions (pl. 2), 328 boreholes have been drilled, and of these, 279 were considered successful. The yields obtained from successful boreholes averaged 1,200 gph (20 gpm) and ranged from 100 gph to 5,250 gph. The average depth of the boreholes in the Northern and Upper Regions (table 2) was about 115 feet. Boreholes tapping the Winneba granite of the Central Region appear to have somewhat lower yields. Of 25 boreholes drilled, only 17 were successful. The average yield for successful boreholes in this area was 90 gph (16 gpm). The wells in granite north of Kumasi in the Ashanti Region (table 2) had higher average yields than in either the Wa or Winneba granites. Nine of the 13 boreholes drilled were considered successful with an average yield of 2,073 gph (35 gpm).

The Birrimian slate, phyllite, schist, graywacke, tuff, and lava are generally strongly foliated and jointed, and where they crop out or lie near the surface, considerable water may percolate through the joints, fractures, or other partings. Boreholes tapping the lower part of Birrimian rocks in the Western, Central, and Ashanti Regions (table 2) have an average yield of about 2,800 gph (47 gpm). The average is based on 39 boreholes with a range in yield from 420 to 8,000 gph. The highest yields in this area occur in the Central Region where the average yield is 3,700 gph (62 gpm) for 14 boreholes. In the western part of the Brong-Ahafo Region (table 2), boreholes tapping the lower part of Birrimian rocks lying between the Ivory Coast border and the escarpment forming the southern limit of the Voltaian sedimentary basin have a slightly smaller average yield. The 18 successful boreholes in this area have an average yield of 2,638 gph (44 gpm). The yields in this group of boreholes ranged from 700 to 6,400 gph. In this area the boreholes with the highest average individual yields are located between Berekum (6) and Dormaa-Ahenkro (11), plate 2.

Boreholes tapping the upper part of Birrimian rocks in the Western Region from Enchi northeast to the Voltaian escarpment and from Axim northeast to Bogoso have an average yield of 2,787 pgh (47 gpm). The average yield was computed by using 12 successful boreholes, out of a total of 16 drilled, whose yield ranged from 200 to 4,330 gph. The areal distribution of boreholes in Upper Birrimian rocks is small, and the greatest concentration of high-yielding boreholes is in the Enchi and Bogoso areas. Boreholes tapping these rocks at Axim near the coast in the Western Region and at Buruata (31) in the Central Region have much lower yields (pl. 2).

The analyses of water from the boreholes tapping the Birrimian rocks and associated granites and gneisses indicate that the water is usable for most purposes. In some areas, temporary hardness exceeds 100 mg/l, and the iron and manganese concentrations are above 0.3 mg/l. These concentrations, however, are not high enough to require water treatment.

UPPER PRECAMBRIAN SUBPROVINCE

The Upper Precambrian subprovince includes, from oldest to youngest, the rocks of the Tarkwaian, Togo, and Buem Formations. The Tarkwaian rocks comprise slightly metamorphosed shallow-water sediments, chiefly sandstone, shale, and conglomerate, resting unconformably on and derived from the Birrimian. The rocks are eight to 10 thousand feet thick in the Tarkwa area. The Tarkwaian rocks have been intruded by thick laccoliths and sills of epidiorite and, like the Birrimian, have been folded along axes which run northeast to southwest. In some areas the rocks were folded and metamorphosed after the emplacement of the intrusives. The areas underlain by the Tarkwaian rocks are not as extensive as those underlain by the Birrimian rocks. The largest area lies in a band extending from Konongo to Tarkwa (pl. 2).

The Togo Formation consists of metamorphosed arenaceous and argillaceous sediments. The formation includes indurated sandstone, quartzite, quartz schist, shale, phyllite, sericite schist, talc mica schist and some limestone. These rocks are highly folded and form the chain of hills known as the Akwapim-Togo Ranges that extends northeast from the coast near Accra to the Togo border. The quartzites and related rocks commonly form hills, and the shale and phyllite are found in intervening valleys.

The Buem Formation consists of a thick sequence of shale, sandstone, and volcanic rocks with subordinate limestone, tillite, grit, and conglomerate. Rocks of the Buem Formation underlie a very considerable stretch of Ghana on the western side of the Akwapim-Togo Ranges, including the Kpandu, Jasikan, and Hohoe areas and the area northeast to the Togo frontier (pl. 2). The basal beds of this formation are mainly shale overlain by sandstone. Overlying the sandstone is conglomerate and tillite interbedded with shale. Rocks of volcanic origin form the upper part of the Buem and include lava, tuff, and agglomerate interbedded with shale, limestone, and sandstone.

The three units of the Upper Precambrian subprovince—the Tarkwaian, Togo and Buem—are lithologically similar and have similar water-bearing properties. The rocks themselves are largely impervious but contain openings along joint, bedding, and cleavage planes. Where these openings are extensive, good supplies of ground water can be developed from boreholes. Springs frequently occur along the flanks of hills where quartzites are in contact with argillaceous rocks of the valleys, such as in the Akwapim-Togo Ranges. The weathering of the quartzites yields an unconsolidated alluvium of sand and quartzite fragments, which form veneers over the rocks of the valley plains.

Good supplies of ground water are obtained from shallow wells in this alluvium. Generally, the Upper Precambrian rocks have relatively good potential for ground-water development with the most favorable areas for development in the valleys, where the rocks are highly fractured.

In the Volta Region (table 2), of the 58 boreholes drilled in Buem and Togo rocks, 51 were considered successful. The average yield from these boreholes was about 2,000 gph (35 gpm), and yields ranged from 200 to 7,000 gph. The average depth of the boreholes is about 185 feet. Of 14 boreholes drilled in the Ho area, 10 were considered successful with an average yield of 2,040 gph (35 gpm) and a range from 160 to 5,400 gph. In this area the boreholes average 200 feet deep. The higher yielding boreholes in this area are believed to tap large fracture systems or fault zones.

Chemical analyses of water from 53 boreholes in the Volta Region indicate that the water is generally usable for most purposes. The total hardness among these analyses averages 190 mg/l and is mostly temporary hardness. The hardness concentrations range from 31 to 1,867 mg/l. Chloride concentrations average about 16 mg/l, but there were two boreholes with concentrations greater than 250 mg/l. Iron and manganese concentrations were mostly in the general range of 0.3 to 2 mg/l, but concentrations as high as 40 mg/l are reported in a few cases.

VOLTAIAN PROVINCE

The Voltaian province is underlain by rocks of the Voltaian Formation, which is of probable Cambrian to Silurian age. The formation underlies approximately 35 percent of the country and extends northeast beyond the borders of Ghana almost to the Niger River. It underlies the central and eastern part of the Northern Region, the central and eastern part of the Brong-Ahafo Region, and the northeastern parts of the Ashanti and Eastern Regions. These rocks occur in a large sedimentary basin and form the most extensive sedimentary sequence in Ghana.

The northern, western, and the southern limits of the Voltaian Formation in Ghana are marked by escarpments, which slope down to bordering lower terain of Precambrian rocks. On the east, however, the Voltaian-Precambrian contact is in low-lying country and is much less conspicuous. The Voltaian Formation consists of interbedded mudstone, sandstone, arkose, conglomerate, and some limestone. The rocks are mainly flat lying or gently dipping, except near the eastern margin of the basin adjacent to the contact with the Precambrian rocks, where the lower members of the formation are gently folded. Junner (1946) proposed the following classification or division of the Voltaian Formation based on its lithology:

Upper Voltaian:	
V_3b	Upper massive sandstone.
V_3a	Thin-bedded sandstone.
Lower Voltaian:	
V_2b	Obosum beds; red and chocolate-colored arkosic mudstone and shale with limestone and conglomerate.
V_2a	Oti beds; yellow-weathering green mudstone, arkosic conglomerate and sandstone.
V_1	Basal quartz sandstone.

It is difficult, however, to map such a flat-bedded sequence of sedimentary rocks in a country of low relief, especially in the absence of adequate topographic maps. The best geologic sections are obtained from exposures of the Voltaian in the escarpment slopes, on three sides of the Voltaian sedimentary basin, and from a few boreholes in the central part of the basin. These boreholes indicate a great lateral variation in lithology in the basin. The Voltaian Formation has a maximum exposed thickness of about 1,300 feet in the rim of the sedimentary basin. The deepest known borehole, at Tamale in the northern part of the sedimentary basin, ended in Voltaian rocks at a depth of about 2,300 feet.

The Voltaian rocks are generally well consolidated and are not inherently permeable. A possible exception, however, may occur in the plains area near the Sene River and in a long belt between Kete-Krachi and Sang where the strata may possibly be permeable. Here, the sandstone, quartzite, and arkose are well jointed and, upon weathering, produce permeable surficial materials. The massive sandstones found in the western and southern escarpments tend to have widely spaced, open joints, whereas the thin-bedded sandstones and arkoses have permeability developed on a large number of bedding planes and joints. Near the western and southern escarpments, the sandstone and overlying material store considerable amounts of ground water, which discharges in springs along joints and bedding planes at many localities. These springs maintain many permanent streams, which rise in the sandstone hills. Junner (1946) reported such a spring near Abudom between Nkoranza and Kintampo with a measured flow in 1916 of 1 mgd (million gallons per day).

Shale crops out in the central part of the Voltaian sedimentary basin, except for a few isolated areas where sandstone crops out, as those near Tamale. In this part of the basin, the relief is low, and the shale lies at shallow depth and is generally capped by a few feet of laterite. In the wet season, large areas are covered by shallow ephemeral lakes or ponds, which become dry during the dry season. The lack of springs on permanent tributary streams indicates the absence of shallow ground water. Artesian conditions might, however, be anticipated if the permeable arkosic sandstone cropping out around the upland rim of the basin forms a continuous bed extending beneath the shale cover of the low-lying center of the basin. The majority of the boreholes thus far drilled in the Voltaian basin are relatively shallow, and the presence or absence of artesian conditions has not been demonstrated.

In the Northern Region (table 2), 39 boreholes of which 28 were considered successful, have been drilled in the Voltaian Formation. The boreholes had an average yield of about 800 gph (13 gpm). The average depth of these boreholes is 350 feet. Complete chemical analyses of water samples from seven of these boreholes are available from the Tamale, Damongo, Salaga, and Gambaga areas. The water from these areas had an average total dissolved-solids concentration of about 1,100 mg/l.

Saline water in the northern part of the Voltaian sedimentary basin appears to be fairly extensive and may markedly limit the future ground-water development of this area. In the Tamale and Daboya area, salt beds are known to crop out, and water from some boreholes in these areas has high chloride concentration. At Tamale, chloride concentrations up to 1,560 mg/l have been noted in water samples from shallow boreholes. Salt water has also been reported in the deeper boreholes at Daboya and Tamale. In a borehole at Daboya, salt water was found at a depth of 850 feet. In 1964, a borehole put down at Makongo near Yeji found salt water at 175 feet.

The boreholes in the Voltaian sandstone in the Kete Krachi area in the Volta Region (table 2) have much higher yields than boreholes in the explored northern areas of the Voltaian Formation. The average yield obtained from 12 boreholes in Kete Krachi area was 1,950 gph (33 gpm) with a range in yield from 180 to 3,640 gph and an average depth of about 185 feet. In this area some of the boreholes flow indicating artesian conditions at shallow depth. Along the southern escarpment of the basin between Wenshi in the Brong-Ahafo Region and Anyaboni in the Eastern Region, 33 successful boreholes tapping the Voltaian sandstone have an average yield of about 1,900 gph (30 gpm) with a range in yield from 75 to 6,840 gph.

Several deep exploratory boreholes to sample the full thickness of the Voltaian sediments in the central part of the basin are needed to evaluate potential artesian aquifers and possible mineral wealth.

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COASTAL BLOCK FAULT PROVINCE

The Coastal Block Fault province is underlain by rocks of the Accraian and Sekondian Formations of Devonian age and the Amisian Formation of Jurassic age. The rocks have been subjected to a postdepositional igneous activity and major block faulting. The faults strike in several directions and divide the rocks into a mosaic of fault blocks. The Devonian rocks underlie Accra, Takoradi, and Sekondi and crop out along the coast between Sekondi and Cape Coast. The rocks at Accra (Accraian Formation) include sandstone, grit, and shale, whereas the Sekondian Formation near Sekondi and Takoradi consists mainly of sandstone and shale with conglomerate, pebble beds, grit, and mudstone. The rocks of both formations lie unconformably over a complex of granite, gneiss, and schist of Precambrian age. Fossils found in sandstone and shale near Takoradi show the Sekondian Formation to be of Devonian age. Here the total section is at least 4,300 feet thick. Boreholes that tap these rocks have yields that average about 866 gph (15 gpm).

The Amisian Formation of probable Late Jurassic age is composed of poorly sorted, semiconsolidated sedimentary rocks—largely pebbly and bouldery shale and sandstone deposited in a fresh-water environment. The formation occurs in down-faulted blocks in Precambrian rocks, which are also faulted. This formation crops out near the mouth of the Ochi (Amisa) River.

COASTAL PLAIN PROVINCE

In the Western Region from near Esiama to the Ivory Coast frontier (pl. 2), southwestern Ghana, Cretaceous to lower Tertiary sedimentary rocks of the Coastal Plain province extend inland 5 to 15 miles from the shore. The sedimentary sequence includes a thick section of alternating sand and clay with occasional thin beds of gravel and fossiliferous limestone. Except for the limestone members, outcrops are rare. Junner (1940) described a line of outcrops of fossiliferous limestone that can be traced in a west-northwest direction from the beach at Kangan to the frontier. Because of their oil potential, the limestone horizons were described in some detail by Mitchell (1960). Seepage of oil and gas have been reported at several places along the coast near Bonyeri, Techinta, Tobo, and Nauli. The Nauli limestone horizon contains five individual beds of limestone that average only a few feet thick and that are intercalated with clay. The uppermost limestone bed is most persistent and can be followed almost continuously along the strike from west of Kangan to Edu. The variations in the dip of these limestone horizons indicate warping and flexuring of the sediments. At Bonyeri, an oil prospect borehole was drilled to a depth of approximately 8,200 feet. The upper 376 feet of this hole penetrated thick beds of unconsolidated sand separated by relatively thin layers of white, yellow, red and black clay, and the Nauli limestone horizon was reported to be present between depths of 396 and 476 feet.

Ground-water supplies from boreholes in the Cretaceous to lower Tertiary sediments between Esiama and Half Assini (table 3) are obtained largely from the upper 300 feet of the section. Thirty-one out of 34 boreholes which were considered successful have an average yield of about 2,800 gph (46 gpm). Such yields are relatively low considering that unconsolidated, coarse, water-bearing sand predominates in the upper part of the Cretaceous to lower Tertiary section. Much higher yields should be available from properly constructed and developed boreholes. In the zone adjacent to the shoreline, however, overdevelopment could lead to sea-water encroachment in the aquifers.

Chemical analyses of water samples from 15 of the boreholes in the Cretaceous to lower Tertiary sediments in the Western Region suggest that the water from these aquifers is usable for most purposes. Chloride concentrations in this area normally range between 10 and 25 mg/l; however, in the area between Beyin and Anochi, concentrations of chloride are somewhat higher. Periodic sampling of water from boreholes in this area should detect any increase in chloride content that might indicate sea-water encroachment.

The coastal belt of Togo and Dahomey and the Keta District of southeastern Ghana are also underlain by Cretaceous to lower Tertiary consolidated and semiconsolidated marine sediments. In this area, these sediments are covered by younger continental deposits. Somewhat inland in Togo and Dahomey, erosion has removed the younger deposits and exposed the marine sequence. The Cretaceous to lower Tertiary sediments, where covered by younger sediments in Ghana, are known from borehole samples. The borehole (depth 134 feet) closest to the Ghanian frontier, where the stratigraphic sequence is well established, is at Togblékové, about 10 miles north of Lomé, the capital of Togo. In this borehole, a fossiliferous blue marl was found at 85 feet and a bed of phosphatic limestone, at 126 feet; below 128 feet, fossils in a limestone indicate a Paleocene age.

In Togo and Dahomey, numerous exploration boreholes for water, phosphate, and oil have established a detailed stratigraphic section for the coastal plain sediments. Slansky (1959) gave the following composite section in ascending order:

1. The Upper Cretaceous (Maestrichtian), which is about 650 feet thick, is largely unfossiliferous sand overlain by interbedded coal, clay, and marl.

2. The top of the Maestrichtian is marked by a fossiliferous horizon.
3. The Paleocene (Montian and Thanetian), about 150 feet thick, consists of beds of fossiliferous sandy limestone which conformably overlie the Maestrichtian.
4. The Eocene (Ypresian) includes interbedded marls, limestones, and nummulites, which are overlain by a phosphatic facies dated as Eocene (Lutetian) by microforaminifera. This marine sequence is overlain by sandy and clayey beds at the base and "terre di barre" at the top. The thickness of the Eocene reaches a maximum of 325 feet.

The stratigraphic sequence in southeastern Ghana has not been worked out in as much detail, but the subsurface section is similar in most respects to the section described by Slansky in Togo and Dahomey. In the Keta area of southeastern Ghana, two limestone horizons have been traced in the subsurface. The upper limestone is probably equivalent to the limestones found in boreholes further inland at Anyako, Ehi, Fenyi Yokoe, and across the Togo frontier at Togblékové. West of Keta, however, in boreholes at Anloga, Anyanui, and Ada, the limestone horizons were apparently not found, even at depths of 2,000 feet. A study of borehole logs along the coast from Aflao to Ada suggests possible structural complications in the upper limestone. These boreholes, however, need to be logged by a gamma-ray logger to identify key marker beds, which could be used to determine accurately the structural trends in the area.

The limestone aquifers in the Keta area probably represent a single hydrologic unit recharged from intake areas at higher altitude further inland. Figure 2 is a map of the Keta area showing locations of boreholes, approximate altitude of water level (in feet above sea level in the limestone aquifers), and the concentration of chloride in water from the aquifers. Although the data are incomplete, several features stand out, which may be significant and may warrant further consideration. Two recharge areas are indicated: one is centered at Avenopedu-Agbodrafo on the west and the other, at Dzodze-Ehi on the east. These recharge areas are separated by an area of negative head (artesian head below sea level) from Wuti to Afife. The artesian head in both the upper and lower limestones along the coast from Aflao to Keta appears to be about 8 feet above sea level. The extensive distribution of water of high chloride concentration in the Keta area is particularly noteworthy. In the Wuti-Afife area of negative fresh-water head, the chloride concentrations are also high. Flooding by brackish or salty water in this area may have permitted contamination by vertical percolation into the underlying limestone aquifers. Southwest of Keta toward Ada, the chloride concentrations in the ground water are ex-

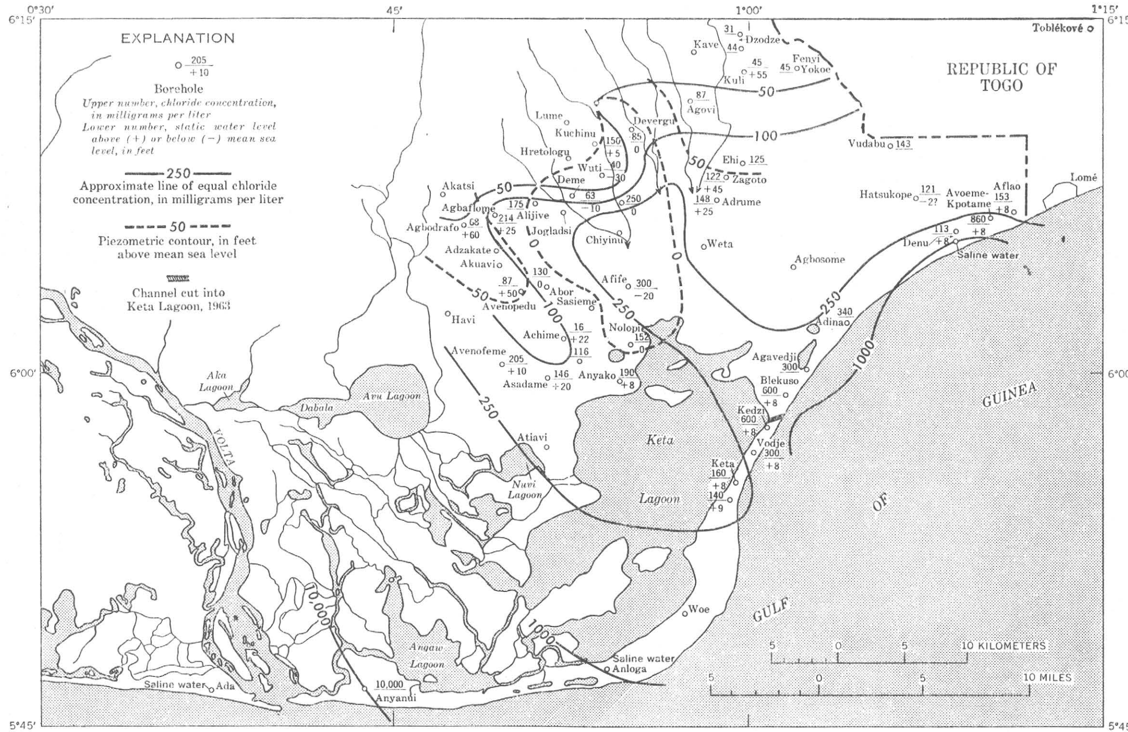

FIGURE 2.—Borehole locations, chloride concentration, and artesian head in aquifers of the Keta area. Base from AMS 1:250,000 series, G503, from map of Land and Survey Department, Ghana, 1942. Hydrology by H. E. Gill, U.S. Geological Survey, 1964.

ceedingly high—approaching the concentration of sea water. In this area, however, a continuously permeable section may be in direct connection with sea water, even though the limestones were not reported in the stratigraphic section.

Because of the wide distribution of high-chloride concentrations in the ground water, further study of the Keta area is needed to establish in some detail the hydrogeologic framework. Periodic sampling of boreholes to measure significant changes in chloride concentration with time should have a high priority, particularly, if extensive ground-water development is undertaken in the Keta area.

Records of 43 boreholes in the Keta area (table 3) indicate that the average yield of wells is 2,919 gph (48 gpm). Boreholes tapping limestone aquifers along the coast from Aflao to Keta and inland around Anyako had average yields of 4,744 gph (80 gpm), and the yields ranged from 1,000 to 12,000 gph. Properly screened and developed boreholes in the Keta area would probably yield much greater quantities of water.

Chemical analyses from water in the 43 boreholes indicate that the ground water in the Keta areas is generally of usable quality. The average total of dissolved solids from the water sampled is about 1,000 mg/l, and the hardness, averaging 250 mg/l, is of the temporary type. Iron concentrations are generally less than 1 mg/l and range from 0.2 to 9 mg/l. The pH of the water is generally slightly alkaline.

Unconformably overlying the Cretaceous to lower Tertiary marine sediments, in many places along the coast, are unconsolidated continental deposits of red limonitic, sandy, pebbly clay with a basal quartz gravel of probable Miocene to Pliocene age. These deposits cover most of the Cretaceous and lower Tertiary sediments in the Keta district of southeastern Ghana and much of the Cretaceous in the Half Assini area of the Western Region. The deposits are as much as 100 feet thick in some places but thin to a featheredge away from the coast and are hydraulically connected with the Cretaceous to lower Tertiary sediments in the higher, more inland areas.

ALLUVIAL PROVINCE

Surficial deposits of Quaternary age are generally not thick or areally extensive in Ghana. Locally, however, relatively thick deposits of permeable water-bearing alluvium are present in the valleys of the larger streams, such as the Volta River and its tributaries. Extensive but relatively thin alluvial deposits also occur on the delta of the Volta River in southeast Ghana (pl. 2).

Although the alluvial deposits have not yet been developed to any significant extent for water supply, they have considerable potential. In particular, the alluvial deposits—where permeable, relatively thick, and located adjacent to perennial streams—offer desirable locations for shallow, vertical, or horizontal wells, which can induce river recharge and supply moderate to large water supplies for municipal, irrigation, or industrial purposes.

PRESENT USE OF GROUND WATER

Current (1964) ground-water development in Ghana includes a large but uncounted number of hand-dug domestic wells and approximately 700 successful boreholes drilled for public and village water supply. Virtually all the boreholes were drilled by the Water Supplies Division, partly with departmental drilling equipment and partly under private contract.

In 1964 the Water Supplies Division in Ghana was operating 19 water-supply installations that obtain water entirely or in part from boreholes. These supplies are metered, and quarterly reports are filed with the Chief Engineer at Kumasi. The average pumpage from each of these 19 installations was approximately 1 mgd during 1963. In order to arrive at an estimate of the total ground-water use in Ghana from borehole sources, it was necessary to assume that the successful boreholes were probably being used to their total tested capacity for about 12 hours a day. The estimated ground-water use for each hydrologic unit was calculated by using the average yield times the total number of successful boreholes times 12 hours of daylight operation.

The estimated total ground-water withdrawal from boreholes in Ghana during 1963 was approximately 11 mgd. Table 1 shows the estimated ground-water pumpage by geohydrologic province, geologic unit, and geographic area or political subdivision in gallons per day.

TABLE 1.—*Estimated pumpage for 1963 from borehole sources*

Geohydrologic province or subprovince	Geologic unit	Geographic area or political subdivision	Approximate pumpage (gpd)
Lower Precambrian	Dahomeyan	Accra Plains	124,000
Coastal Plain	Cretaceous to lower Tertiary.	Half Assini area	1,058,000
Middle Precambrian	Upper Birrimian	Western and Central Regions.	401,000
Coastal Block Fault	Devonian	Central Region	31,000
Middle Precambrian	Lower Birrimian	Western and Central Regions.	1,272,000
Precambrian	Granite	Northern and Upper Regions.	4,024,000
Voltaian	Voltaian	do	298,000
Precambrian	Togo and Buem	Volta Region	1,301,000
Voltaian	Voltaian	do	281,000
Precambrian	Dahomeyan and Buem	Ho area	245,000
Middle Precambrian	Lower Birrimian	Brong-Ahafo Region	190,000
Precambrian	Granite	Ashanti Region	224,000
Coastal Plain	Cretaceous to lower Tertiary.	Keta area	1,506,000
Precambrian	Granite	Central Region	87,000
Total			11,042,000

GROUND-WATER PROBLEMS

In many parts of Ghana it is difficult to obtain large or even adequate ground-water supplies because of the wide distribution of crystalline-type rocks in the Precambrian province. These rocks contain only small quantities of water in fractures and faults. In many places, however, deep weathering has produced a permeable horizon that is of varying thickness and that caps the unweathered crystalline rock. Where this horizon lies in the zone of saturation, the probabilities for completion of successful boreholes are greatly enhanced. On the other hand, weathering may yield clayey products that fill the fractures and faults in the unweathered rock and reduce their permeability and water-storing potential. In areas where crystalline rocks occur, it may be possible to improve siting, and thereby to obtain larger yields from boreholes, through careful and detailed study of existing borehole records, joint and fault patterns in the rocks, and their relationship to the topography and surface drainage. In general, topographically low areas in the crystalline rocks are more favorable for siting boreholes because they commonly indicate zones of jointing of fracturing. Also, the relationship of borehole yields to rock types would merit careful study in the Precambrian province.

The present yields obtained from boreholes in the sandstones and shales of the Voltaian province are also relatively small (1 to 50 gpm). Owing to consolidation and cementation, much of the primary pore space in these rocks has been destroyed, and water occurs chiefly in the secondary fractures developed along joints and bedding planes of the rocks. The generally stable mineral composition of the rocks of this province permits little development of secondary permeability that might result from dissolution or decomposition of the intergranular cementing material. The generally impervious character of the near-surface unweathered rocks allows only minimum opportunity for infiltration and recharge to ground water. The water problem in the Voltaian province is also complicated, at least in the north-central part of the Voltaian sedimentary basin, by the presence of highly mineralized water in the rocks. This appears to be a rather widespread condition, as indicated by the salty water obtained from boreholes at Daboya, Tamale, and Makongo. On the other hand, exploratory drilling to date (1964) in the Voltaian province has not proved conclusively the presence or absence of possible artesian aquifers at depth. Several deep (2,000 feet or more) boreholes, perhaps located on an east-west line betwen Wenchi and Kete Krachi, would be desirable to explore for artesian aquifers in the central part of the Voltaian sedimentary basin. Moreover, where ground-water supplies in substantial quantity are needed in this province, attention should be given to the feasibility of development of shallow ground water in the alluvial fill materials adjacent to perennial streams, from where river infiltration can be used for recharge.

Aquifers in the semiconsolidated or unconsolidated Cretaceous and Tertiary sediments of the Coastal Plain province in the southeastern and southwestern coastal areas of Ghana have the potential for yielding moderate (50 to 200 gpm) to large (200 to 500 gpm) supplies of water from properly constructed and developed boreholes. The presence brackish or salty water, however, in a few of the existing boreholes in both these areas is indicative of potential salt-water encroachment problems, and care should be exercised in the full development of these aquifers.

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TABLES 2, 3

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*

[Borehole numbers are by the Division of Water Supplies at Kumasi]

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Ashanti Region							
Akumadan	1	A40	Voltaian sandstone	505	705	50	495
Nkinkaso	2	A38	Voltaian sandstone-granite contact.	203	800	69	195
Do	3	A37	do	240	800	58	234
Do	4	A39	do	200	1330	42	145
Abofour	5	A34	Lower Birrimian phyllite-granite contact.	250	2400	70	220
Do	6	A35	do	275	1200	75	265
Do	7	A36A	do	400	1030	75	395
Ejura	8	A2	Voltaian sandstone	332	650	92	320
Do	9	A3	do	350	660	10	105
Do	10	A9	do	573	1500	34	80
Kumasi	11	A1	Lower Birrimian phyllite and schist.	140	420	30	33
Efiduasi Asokori	12	AC8	Weathered granite	250	2140	[1] +3	55
Efiduasi-Asokori	13	AC10	do	150	2030	4	53
Asokori-Efiduasi	14	AC11	do	250	1250	5	130
Do	15	AC12	do	250	2610	4	78
Do	16	AC14	do	197	4240	5	40
Do	17	AC15	do	250	680	10	235
Agogo	18	A5A	Voltaian sandstone	800	1600	49	200
Do	19	A5	do	355	544	48	146
Do	20	A6	do	720	1500	16	320
Do	21	A8	do	613	700	120	540
Sekodumase (inundated 1965).	22	A53	Voltaian shale and mudstone	300	6000	35	120
Edubia	23	A47	Lower Birrimian phyllite	250	3420	55	132
Do	24	A48	do	252	2400	95	175
Obuasi	25	A52	Lower Birrimian phyllite	250	2000	25	180
Akrokeri	26	A51	do	300	1130	65	250
Brong-Ahafo Region							
Banda	1	B15	Contact Tarkwaian quartzite and Upper Birrimian phyllite.	165	870	12	161
Nsawkaw	2	BA1	Lower Birrimian phyllite	205	2850	19	171
Do	3	BA2	do	200	870	11	181
Sekwa	4	BA3A	do	185	990	11	170
Do	5	BA4	do	260	1780	28	216
Berekum	6	BA7	do	320	6400	15	76
Do	7	BA8	do	290	4880	45	45(?)
Awiam	8	BA18	do	370	2570	90	180
Do	9	BA19	do	400	3060	50	150
Wamfie	10	A28	do	209	2400	50	165
Dormaa-Ahenkro	11	A24	do	163	5300	10	50
Do	12	A27	do	234	5160	5	125
Do	13	BA20	do	360	3060	60	195
Do	14	BA21	do	325	1180	40	275
Mim Mohu	15	A22A	do	212	1200	18	90
Do	16	A26	do	118	700	40	103
Sunyani	17	A14	do	152	1300	13	142
Do	18	A29	do	300	1300	45	250
Do	19	A30	do	246	2500	80	120
Wenchi	20	A15	Voltaian sandstone	325	1600	66	187
Do	21	A17	do	131	6000	60	78
Do	22	A21	do	210	600	31	145
Do	23	A23	do	200	2000	50	102
Do	24	BA22	do	250	5870	0	190
Do	25	BA23	do	220	6000	0	50
Techiman	26	A46	Granite	250	1000	98	244
Do	27	BA-11A	do	210	2400	64	150
Do	28	BA13	do	252	2700	95	130
Do	29	BA14	do	253	4000	59	135

[1] + indicates feet above land surface.

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
			Brong-Ahafo Region—Continued				
Bungasi	30	BA9A	Contact Tarkwaian quartzite and Upper Birrimian phyllite.	250	110	43	247
Do	31	BA10	do	170	200	15	170
Do	32	BA12	do	250	2170	50	140
Do	33	BA15	do	210	110	35	200
Do	34	BA16	do	265	1260	50	255
Do	35	BA17	do	300	850	50	285
Atebubu	36	A10	Voltaian shale and mudstone	234	1060	22	
Do	37	A11	do	180	300	21	
			Central Region				
Maudaso	1	C9	Lower Birrimian phyllite	250	4560	45	120
Diaso	2	C6	Lower Birrimian-granite contact.	216	4880	46	80
Do	3	C7	do	301	3660	77	120
Agona	4	C5	Lower Birrimian phyllite	250	3100	50	95
Oboasi	5	C3	do	350	3100	77	160
Nkwantanum	6	C10	do	290	4240	42	198
Jamang	7	W94	do	400	1430	60	259
Ayanfuri	8	C1	do	185	3100	19	120
Dunkwa	9	W11	do	250	6000	5	45
Do	10	W12	do	250	2400	45	180
Do	11	W14	do	200	1710	5	165
Do	12	W15	do	180	1800	26	35
Do	13	W16	do	250	4800	40	150
Do	14	W18	do	155	8000	0	30
Asin Nyankumasi and Foso.	15	C14	Granite	200	1130	20	50
Dominasi	16	C2	do	290	8090	18	103
Kisi	17	W26	do	250	1200	4	230
Domenasi	18	W52	Granite-Sekondian sandstone and shale contact.	90	100	30	85
Komenda	19	W8	Sekondian sandstone and shale	250	1200	54	64
Do	20	W30	do	285	200	68	
Atransi	21	W42	Granite	81	180	27	
Do	22	W44	do	133	200	25	120
Dawurampong	23	W36	do	164	230	69	
Do	24	W39	do	136	140	69	
Asafo	25	W62	Sekondian sandstone and shale	108	1600	5	44
Swedru	26	W22	do	325	600	1	5
Do	27	W31	do	407	350	38	58
Do	28	W41	do	300	120	60	
Do	29	W47	do	250	1200	2	176
Do	30	W56	do	382	400	5	275
Buruata	31	W59	Upper Birrimian phyllite	240	120	15	183
Obutu	32	W45	Granite	51	600		
Do	33	W51	do	138	480	12	125
Adzintam	34	W55	do	155	220	105	130
Senya Beraku	35	W37	Togo quartzite	193	130	64	
Do	36	W43	do	143	400	49	142
			Eastern Region				
Pepiasi	1	E5	Voltaian sandstone	715	575	245	370
Do	2	E7	do	345	350	52	268
Abetifi	3	E3	do	145	3000	13	58
Do	4	E4	do	420	75	89	
Do	5	E6	do	165	6840	32	55
Kwahu Tafo	6	E8	do	522	2000	18	165
Do	7	E64	do	110	1970	0	42
Aduamoa	8	E9	do	400	1300	30	202
Mpraeso	9	E1	do	104	3000	23	62
Asakraka	10	E10	do	625	550	221	515

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Eastern Region—Continued							
Bepong	11	E12	Voltaian sandstone	400	1600	26	95
Nkawkaw	12	E16	Upper Birrimian phyllite	383	650	45	158
Nkawkaw	13	E17	Upper Birrimian phyllite	280	1200	44	171
Ntronang	14	E43	Tarkwaian quartzite, phyllite and schist.	200	1600	38	81
Do	15	E44	do	200	2400	27	56
Anyaboni	16	E72	Voltaian sandstone	250	310	25	
Kade	17	E49	Lower Birrimian phyllite and schist.	350	3600	50	124
Do	18	E51	do	300	4000	71	149
Kade Town	19	E54	do	210	3060	19	80
Do	20	E56	do	200	2570	9	64
Aboabo	21	E29	do	235	2700	53	120
Do	22	E33	do	250	2400	39	160
Do	23	E35	do	250	3200	31	69
Do	24	E18	do	250	1700	40	120
Oda	25	E23	Lower Birrimian phyllite and schist.	250	5500	60	91
Do	26	E32	do	250	3000		144
Akim Oda Sawmill	27	E41	do	250	6000	8	100
Adim Swedru	28	E24	do	200	2700	6	55
Do	29	E26	do	200	2400	20	100
Do	30	E28	do	127	2700	2	34
Ewisa	31	E30	do	225	1200	65	145
Akim Ewisa	32	E31	do	205	1330	50	126
Asene	33	E25	do	200	2200	7	115
Do	34	E27	do	200	4800	23	23(?)
Manso	35	E35	Granite-Lower Birrimian phyllite contact.	253	1500	34	150
Do	36	E37	do	141	600	23	100
Manso	37	E38	Granite-Lower Birrimian phyllite contact.	255	930	51	195
Akroso	38	E36	Granite	260	480	3	160
Do	39	E39	do	230	400	36	230
Suhum	40	E42	do	105	2000	15	58
Do	41	E42A	do	138	1570	14	83
Do	42	E46A	do	203	6000	3	100
Do	43	E48	do	200	600	25	182
Do	44	E50	do	209	1360		200
Do	45	E52	do	190	500	19	138
Do	46	E53	do	245	3100	0	135
Adaiso	47	E61	do	250	300	10	234
Do	48	E63	do	250	1200	13	234
Do	49	E66	do	300	2700	34	150
Do	50	E68	do	175	2490	20	136
Akpoman	51	AP18	Dahomeyan hornblende-biotite gneiss.	100	120	30	
Abokobi	52	AP17	do	180	800	64	105
Teiman	53	AP14	do	409	750	63	
Ayimensa	54	AP16	do	350	550	96	
Accra Ashoman	55	AP3-BA	Dahomeyan hornblende-biotite gneiss at contact with Togo quartzite.	236	1640	7	80
Saduasi	56	AP9	do	246	1000	49	58
Dodowa	57	AP1	do	259	2500	18	30
Nungwa	58	AP86	Dahomeyan gneiss	176	750	4	34
Agomeda	59	AP7	do	399	1600	132	245
Northern Region							
Kulmaso	1	MW36	Granite gneiss	72	870	13	64
Kalba	2	NW37	do	90	250	8	82
Kunfosi	3	NW41	Mica schist and pegmatite	125	310	20	111
Ypala	4	NW44	Mica schist and gneiss	75	40	18	72
Sawla	5	N42	Granite gneiss and schist	185	1050	70	165
Do	6	N41	do	210	800	70	185

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Northern Region—Continued							
Zantigi	7	N80	Granite gneiss	102	3600	18	65
Bale	8	N77	do	55	2170	12	39
Mandara	9	N78	do	61	300	23	59
Mankuma	10	N72	do	85	250	22	82
Bogoda	11	N71	do	95	1460	42	75
Bole	12	N38	do	230	1200	25	185
Bole	13	N39	Granite gneiss and mica schist	212	2000	40	160
Lampurga	14	N75	do	90	2600	32	75
Seripe	15	N81	Lower Birrimian mica schist-granite contact.	82	740	49	79
Sakpa	16	N82	Lower Birrimian phyllite	150	3600	39	60
Wagawaga	17	N85	Lower Birrimian phyllite-granite contact.	101	400	42	68
Maluwe	18	N84	Lower Birrimian phyllite	101	250	36	95
Tinga	19	N87	do	70	105	45	65
Banda Nkwanta	20	N91	Upper Birrimian phyllite	137	1969	27	65
Jema	21	N92	Tarkwaian quartzite and phyllite.	143	1137	30	76
Tasirima	22	N93	do	201	144	28	170
Carpenter	23	N94	Lower Birrimian phyllite	150	540	38	79
Jogboi	24	N95	do	152	1429	31	60
Larabanga	25	N43	Voltaian sandstone	330	20	70	
Damongo	26	N34	do	500	780	85	480
Do	27	N47	do	125	300	7	
Do	28	N48	do	150	75	60	
Do	29	N2	do	157	600	70	156
Do	30	N3	do	110	150	6	
Do	31	N4	do	302	926	81	
Do	32	N16	do	195	800	3	
Do	33	N17	do	310	800		
Do	34	N24	do	300	1100	4	275
Do	35	N25	do	307	375	15	
Do	36	N26	do	274	2000	51	82
Do	37	N27	do	300	1100	25	145
Do	38	N28	do	513	660	140	439
Do	39	N33	do	630	300	20	585
Daboya	40		do	876	[2] SA		
Singa	41	N50	Voltaian shale and sandstone	200	7580	25	70
Walewale	42	N49	do	710	[3] IA		
Gambaga	43	N46	Voltaian sandstone	1164	487	150	850
Tamale	44	N9	Voltaian shale and sandstone	402	379	12	
Do	45	N10	do	142	100	23	
Do	46	N11	do	287	264	13	
Do	47	N12	do	210	120	40	
Do	48	N13	do	274	900	60	
Do	49	N14	do	285	200	65	
Do	50	N29	do	513	660	140	439
Do	51		do	2380	[2] SA		
Salaga	52	N1	do	450	100		
Do	53	N15	do	607	1000	20	
Do	54	N30	do	960	400	18	650
Do	55	N31	do	632	400	12	615
Makongo	56		do	175	[2] SA		
Upper Region							
Hamele	1	NL10	Granite	150	1600	18	102
Kokolugu	2	NL22	do	143	1400	6	50
Nandom	3	NL33	Upper Birrimian phyllite	180	2400	30	40
Do	4	NL34	do	180	2500	15	36
Hapa	5	NL39	Upper Birrimian schist and graywacke.	140	3360	23	34

[2] SA, saline water found and hole abandoned.
[3] IA, yield inadequate and hole abandoned.

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Upper Region—Continued							
Bangwon	6	NL6	Upper Birrimian phyllite	104	650	34	98
Billaw	7	NL41	Upper Birrimian graywacke	127	1500	10	116
Lambussie	8	NL38	Upper Birrimian graywacke-granite contact.	110	2000	5	41
Gwo	9	NL47	do	140	450	13	128
Tome	10	NL46	Upper Birrimian phyllite	200	660	20	163
Topari	11	NL20	Granite gneiss	120	920	3	106
Chebagga	12	NL42	Granite	160	2500	13	120
Samoa	13	NL44	do	141	1200	12	137
Hamoro	14	NT4	Gneiss	120	200	67	110
Fatchio	15	NT5	do	76	400	20	72
Kare Mission	16	NL8	do	176	1430	35	169
Kare	17	NL2	do	143	1780	18	138
Zini	18	NT10	Granite	100	2000	14	75
Lawra	19	NL31	Lower Birrimian phyllite and graywacke.	340	3600	20	320
Do	20	NL23	do	302	1440	10	240
Do	21	NL24	do	350	2400	17	127
Kalsara	22	NL29	Upper Birrimian phyllite	201	1440	20	170
Duri	23	NL27	do	160	640	21	148
Kusala	24	NL43	do	114	690	19	100
Zambor	25	NL13	do	130	1370	12	109
Donweni	26	NL9	do	108	870	74	101
Tiza	27	NL1	Upper Birrimian mica schist-granite contact.	140	460	2	134
Bo	28	NL37	Gneiss	140	650	16	125
Ulu	29	NL7	Granite	103	200	20	93
Han	30	NL4	Gneiss	94	460	32	82
Tolibiri	31	NL17	Lower Birrimian mica schist and gneiss.	109	960	21	100
Burufu	32	NL26	Lower Birrimian schist	200	1800	3	30
Babile	33	NL28	Granite gneiss	100	660	9	85
Babile Agriculture	34	NL21	do	115	1920	16	83
Tugu	35	NL30	Lower Birrimain schist	180	325	17	168
Jirapa	36	NL14	Upper Birrimian schist-gneiss contact.	142	2400		22
Jirapa	37	N23	do	118	1200	26	----------
Gbari	38	NL36	Granite	103	165	21	83
Sabuli	39	NL5	do	75	225	26	74
Yagha	40	NL35	Upper Birrimian phyllite	190	2000	3	140
Nadawli	41	NW21	do	120	310	54	120
Busie	42	NW17	Granite	91	200	18	84
Fian	43	NW10	do	120	1000	52	63
Wogu	44	NW20	do	273	114	25	157
Issa	45	NW15	do	180	114	4	153
Kujopere	46	NW8	do	109	700	13	----------
Nator	47	NW25	Lower Birrimian phyllite	160	2170	14	68
Tappo	48	NW24	Upper Birrimian phyllite	180	2390	8	58
Naro	49	NW13	Granite	120	199	7	110
Gwo II	50	NW35	Upper Birrimian phyllite	130	1430	25	125
Charia	51	NW27	Granite	170	685	48	120
Kaleo	52	NW11	do	120	320	59	80
Jang	53	NW26	do	130	1595	22	75
Pirisi	54	NW16	do	105	2170	20	94
Nakora	55	NW12	do	161	1300	31	110
Wa	56	N18	do	100	800	46	----------
Do	57	N21	do	262	1000	7	----------
Do	58	N22	do	114	1200	50	----------
Do	59	N60A	do	314	2000	19	267
Do	60	N61	do	115	2000	20	111
Do	61	N62	do	162	1500	20	115
Do	62	N63	do	250	2610	5	196
Do	63	N65	do	60	600	3	38
Do	64	N66	do	171	870	13	164
Do	65	N67	do	95	3100	9	63
Do	66	N68	do	121	1780	21	106
Do	67	N69	do	82	550	9	73
Do	68	NW2	do	160	1900	0	145

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Upper Region—Continued							
Kandiau	69	NW28	Granite	70	200	6	35
Kunfabela	70	NW38	do	76	250	27	69
Tanina	71	NW32	do	65	1780	20	50
Busa	72	NW30	do	80	1130	15	65
Boli	73	NW39	do	78	1440	19	77
Manwie	74	NW33	Upper Birrimian mica schist	65	188	10	55
Loggo	75	NW43	Granite	92	310	13	85
Guropisi	76	NW34	do	63	550	11	53
Bulinga	77	NW31A	do	75	325	24	72
Gwolu	78	NT8	do	131	690	25	124
Bellu	79	NT12	do	120	2400	25	114
Kuntulo	80	NT21	do	119	1700	30	100
Dasima	81	NT13	do	91	2400	10	37
Djarwia	82	NT27	do	91	1800	21	30
Kapulima	83	NT29	do	63	1400	19	39
Sorabella	84	NT20	do	105	650	20	93
Tumu R. H	85	NT1	do	130	3000	13	29
Tumu Court	86	NT6	do	88	600	14	72
Tumu Middle School.	87	NT3	do	82	2400	11	21
Tumu P.O	88	NT11	do	100	3000	8	28
Lilixia	89	NT31	do	87	700	5	5(?)
Sekai	90	NT33	do	108	1200	5	20
Bujan	91	NT30	do	83	700	19	49
Nabugobeli	92	NT26	do	116	240	20	99
Pien	93	NT17	do	110	500	20	100
Walembeli	94	NT16	do	106	360	15	90
Beehembeli	95	NT28	do	110	500	32	46
Nabolo	96	NT24	do	110	2400	31	78
Funsi	97	NW4	do	98	80	10	65
Ketiu	98	NN7	do	100	480	22	26
Do	99	NN9	do	94	1400	23	80
Chana	100	NN11	do	85	1800	25	87
Do	101	NN15	do	97	300	16	81
Gwenia	102	NN19	do	85	960	15	70
Doninga	103	NN26	do	114	225	11	81
Sinyensi	104	NN23	do	91	1080	25	80
Bidema	105	NN20	do	95	720	20	82
Kanjarka	106	NN32	do	85	800	10	75
Sandema	107	NN5	do	127	700	9	17
Do	108	NN10	do	90	2400	42	60
Do	109	NN14	do	97	1000	11	91
Wiaga	110	NN17	do	75	2400	12	65
Do	111	NN18	do	80	880	15	70
Fumbisi	112	NN30	Upper Birrimian phyllite	84	750	10	74
Do	113	NN24	do	90	600	10	82
Kadema	114	NN22	do	66	1200	10	61
Na	115	NN31	do	94	360	12	85
Paga	116	N106	Granite	152	2610	9	100
Do	117	N107	do	121	2170	20	110
Do	118	NN39	do	70	2800	12	42
Natumgo	119	NN35	do	86	2000	10	25
Mirigu	120	NN3	do	91	450	10	82
Navrongo Agr. Station.	121	N109	do	200	1130	35	150
Navrongo	122	NN2	do	156	600	21	146
Do	123	NN28	do	163	720	15	70
Doba	124	N105	do	115	4880	1	74
Do	125	NN8	do	78	3200	15	28
Do	126	NN45	do	81	2000	10	57
Do	127	NN46	do	56	1500	20	98
Kandiga	128	NN44	do	72	240	10	64
Sherigu	129	NZ27	do	68	2500	31	64
Zoko	130	NZ15	do	67	1600	18	50
Sambolugu	131	NZ16	do	115	900	15	107
Fiogu	132	NZ13	do	62	480	5	57
Soboko	133	NZ12	do	79	1500	4	75
Bongo	134	NZ9	do	112	650	5	98

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
			Upper Region—Continued				
Yorogo	135	NZ2	Granite-Tarkwaian quartzite contact	499	710	14	380
Do	136	NZ5	do	85	950	3	60
Bolgatanga	137	N40	Granodiorite	317	400	17	
Do	138	N96	do	300	650	18	300
Do	139	N97	do	250	1130	20	250
Do	140	N98B	do	133	650	13	133
Do	141	N99	do	139	2400	11	120
Do	142	N100	do	157	2409	39	145
Do	143	N102	do	255	1130	13	175
Do	144	NZ10	do	198	1030	15	186
Winkogo	145	NZ24	Granite	85	600	21	63
Yarigabisi	146	NZ17	do	136	2620	8	131
Do	147	NZ19	do	190	1700	18	170
Zuarungu	148	N101	do	222	3130	5	140
Do	149	NZ1	do	102	1400	29	97
Do	150	NZ3	do	104	2800	12	63
Zuarungu School	151	NZ7	do	83	920	12	75
Tongo	152	NZ22	do	67	1000	13	62
Adaboya	153	NZ18	do	95	520	10	30
Kumbosugu	154	NZ14	Lower Birrimian phyllite and graywacke	120	360	27	118
Nangodi	155	NZ8	Upper Birrimian phyllite and graywacke	150	800	6	140
Pelungo	156	NZ25	do	115	1300	17	82
Shiega	157	NZ20	Upper Birrimian phyllite and graywocke.	61	800	18	59
Datoko	158	NZ26	Granite	116	400	10	70
Widenaba	159	NB30	Upper Birrimian phyllite	65	1200	14	59
Teshi	160	NB17	do	51	2000	10	47
Sapeliga	161	NB16	do	117	2400	16	104
Zebila	162	NB5	do	120	1510	32	115
Tili	163	NB6	Granite	81	1600	29	60
Tanga	164	NB4	do	132	1400	24	125
Kapalisako	165	NB15	do	85	700	32	
Binaba	166	NB7	do	85	1800	28	80
Do	167	N103	do	151	1130	25	145
Do	168	N104	do	145	650	18	136
Kusinaba	169	NB10A	do	115	2400	15	101
Apodabogo	170	NB13	do	150	700	38	
Bulunga	171	NB41	do	80	1550	22	75
Zongori	172	NB8	Voltaian sandstone	150	750	28	42
Bazua	173	NB14	Granite	71	1000	33	
Sogodi	174	NB42	do	60	200	9	54
Zawse	175	NB18	do	101	200	35	90
Bawku	176	N36	do	220	1000	5	
Do	177	N51	do	173	5250	9	90
Do	178	N52	do	250	1400	6	225
Do	179	N53	do	142	1800	3	142
Do	180	N54	do	180	1350	13	180
Bawku	181	N56	do	156	2700	9	60
Do	182	N57	do	180	2160	16	170
Do	183	NB2	do	300	500	6	150
Do	184	NB3	do	260	1300	3	90
Do	185	NB9A	do	102	600	10	102
Bawku Hospital	186	NB21	do	80	1000	12	72
Misiga	187	NB1	do	116	700	10	75
Pusiga	188	NB32	do	125	260	25	124
Bimpielega	189	NB20	do	71	600	47	65
Pulimakon	190	NB23	do	76	1350	32	70
Najigu	191	NB19	do	98	550	18	91
Manga	192	NB12	do	126	400	15	126
Zabgu	193	NB44	do	70	1200	10	60
Buguri	194	NB34	do	122	1200	46	114
Bulpielesi	195	NB22	do	105	480	36	98
Binduri	196	NB11	do	112	2400	22	100
Do	197	N58	do	180	675	27	168
Kado-Voko	198	NB47	do	70	660	21	60

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
			Upper Region—Continued				
Voko	199	NB29	Granite	101	460	26	92
Natkuliga	200	NB48	do	63	500	13	33
Kagbiri	201	NB28	do	101	200	30	77
Garu	202	NB27	do	101	1020	25	96
Wuriyanga	203	NB24	do	90	2300	24	78
Kugri	204	NB36	do	112	620	21	108
Zawngo	205	NB35	do	129	1,000	28	120
Danvonga	206	NB38	do	131	240	20	104
Sinibaga	207	NB25	do	163	210	38	157
Woricombo	208	NB46	Voltaian sandstone	97	1,660	21	80
			Volta Region				
Banda School	1	T38	Voltaian sandstone and shale	170	2,390	29	
Chindiri	2	TC2	do	109	2,620	14	
Buafori	3	TC1	do	156	2,620	22	
Mamata (inundated 1965).	4	T23	Voltaian siltstone and shale	100	3,100	19	
Kpetsu	5	T39	Voltainan sandstone and shale	155	180		
Apesokubi	6	TJ8	Buem shale	272	830	45	
Asafo	7	TJ21	do	123	2,810	11	
Kedjebi	8	TJ14	Buem shale and quartzite	250	2,620	29	
Do	9	TJ9	do	250	2,810	23	
Do	10	TJ5	Buem quartzite	340	3,060	26	
Worawora	11	T5	do	220	350		
Do	12	TJ1	Buem shale	250	2,440	3	
Do	13	TJ12	do	212	3010	10	
Do	14		do	250	200		
Nsuta	15	TJ17	do	220	3010	22	
Tapa Amanya	16	TJ6	Buem conglomerate and shale	130	2500	[1]+1	
Kudje	17	TJ15	Buem shale	150	1140	20	
Aka	18	TJ13	do	150	2440	15	
Guaman	19	TJ18	do	200	2810	7	
Atonko	20	T19	Buem quartzite	200	1430	23	
Okadjarkrom	21	TJ7	Buem shale		3010	20	
Jasikan	22	TJ11	Buem shale and sandstone	360	2800	47	
Do	23	TJ22	do	120	830	5	
Amanforo	24	TJ20	Buem shale	162	2810	55	
Borada	25	TJ19	do	200	2810	18	
Ayoma	26	T16	Togo schist	400	800	28	
Baglo	27	T17	Togo schist and quartzite	200	2000	89	
Wurupong	28	TP27	Buem shale	170	2440	10	
Ntumeda	29	TP19	Buem sandstone and conglomerate.	100	2400	3	
Kpeme	30	TP22	Buem shale and conglomerate	120	2500	13	
Ahenkro	31	TP24	Buem shale	145	2800	6	
Golokuati	32	TP18	Buem sandstone and shale	200	650	31	
Kpandu	33	T15	Buem mudstone	201	7000	0	
Agbome	34	TP21	Togo shale	150	2200	7	
Dafo	35	TP23	do	200	2600	7	
Duga	36	TP26	do	230	2500	17	
Deme	37	T34	Togo quartz schist	335	2150	101	
Do	38	T37	do	380	3370	93	
Wusuta Dzigbe	39	TP25	Buem conglomerate	100	2160	[1]+2	
Afeyi	40	TP13	Buem quartzite and sandstone	223	1510	37	
Tokome	41	TP16	Buem shale and quartzite	133	1200	12	
Anfoega Akukome	42	TP12	do	184	2500	0	
Beme	43	TP15	Buem quartzite	70	320	3	
Akleme	44	TP11	Buem shale and quartzite	240	2100	9	
Todome	45	TP14	Togo quartzite	100	2300	7	
Do	46	T21	Togo mica-schist and quartz-micoa-schist.	400	2500	35	
Do	47	T26	Togo quartz-sericite-schist	480	2400	44	
Do	48	T29	Dahomeyan acid gneiss	167	800	22	
Do	49	T30	Togo quartz-sericite schist	295	2000	103	
Do	50	T32	do	253	1140	105	

[1] + indicates feet above land surface.

TABLE 2.—*Records of selected boreholes in the Precambrian, Voltaian, and Coastal Block Fault geohydrologic provinces of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)
Western Region							
Yakasi	1	W85	Upper Birrimian phyllite	250	3660	9	28
Enchi	2	W77	do	90	1200	10	83
Do	3	W78	do	250	4050	9	20
Do	4	W81	do	250	4330	6	14
Do	5	W84	do	70	3660	2	58
Do	6	W87	do	250	2960	8	22
Adaka	7	W88	Lower Birrimian phyllite	160	1880	11	45
Achimfu	8	W89	do	200	1128	4	90
Ajum	9	W35	Lower Birrimian phyllite and schist.	240	2000	35	65
Dunkwa	10	W91	do	160	1600	11	80
Do	11	W92	do	155	1430	13	90
Bremang	12	W17	Lower Birrimian phyllite	300	1200	10	231
Esankran Bremang	13	W95	do	215	1150	29	65
Asankwangwa	14	W10	Lower Birrimian phyllite and schist.	250	7000	22	96
Do	15	W9	do	250	3000	8	35
Achichire	16	W96	do	150	1130	12	95
Hiawa	17	W97	do	175	2610	25	100
Akropong	18	W90	do	135	5610	5	60
Do	19	W104	do	235	4330	30	160
Japa	20	W106	do	204	1500		69
Bawdia	21	W98	do	155	2610	7	23
Bogoso	22	W99	Upper Birrimian phyllite	143	4245	3	65
Do	23	W101A	do	140	3660	14	90
Do	24	W102	do	139	1880	18	128
Aboso	25	W109	Tarkwaian quartzite and phyllite.	250	4245	27	150
Tarkwa	26	W105	do	183	2610	14	120
Manso	27	W103	Granite-Upper Birrimian phyllite contact.	250	4330	16	95
Nkrofro	57	W20	Lower Birrimian phyllite	260	800	10	
Do	58	W25	do	203	2200	12	92
Asanta	60	W34	Upper Birrimian phyllite	198	1600	15	185
Axim	61	W24	do	226	200	21	220

TABLE 3.—*Records of selected boreholes in the Coastal Plain geohydrologic province of Ghana*

[Borehole numbers are by the Division of Water Supplies at Kumasi]

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)	Remarks
Volta Region—Keta-Anlo District								
Dzodze	51	K5	Cretaceous and lower tertiary marine sandstone and shale.	148	1600	106		Chloride, 31 mg/l.
Kuli	52	TK1	do	266	1040	93	220	Chloride, 45 mg/l.
Fenyi Yokoe	53	K3	do	250	1800	104		Do.
Todzi	54	TK19	do	287	200	129	222	Chloride, 85 mg/l.
Devergu	55	K14	Tertiary red continental sand and sandy clay.	185	530	101	140	Chloride, 63 mg/l.
Kuchinu	56	TK7	do	173	3000	115	150	Chloride, 150 mg/l.
Atijive	57	TK11	do	219	320	125	180	Chloride, 175 mg/l.
Wuti	58	TK13	do	244	2700	85	110	Chloride, 40 mg/l.
Do	59	K12	do	274	2200	84	96	
Deme	60	TK16	do	302	3000	60		Chloride, 63 mg/l.
Agbaflome	61	TK2	do	147	500	108	130	Chloride, 214 mg/l.
Jogladsi	62	K15	do	330	80			
Chiyinu	63	K37	Cretaceous and Tertiary limestone.	120	3940	44	50	
Avenopedu	64	TK22	Cretaceous and Tertiary shale.	349	500	70	70	Chloride, 87 mg/l.
Abor	65	K11	Tertiary red continental sandstone.	114	950	84		Chloride, 130 mg/l.
Do	66	K35	Cretaceous and Tertiary limestone.	283	2360	80	105	
Afife	67	K19	do	285	2620	58	135	
Achime	68	K40	do	254	5040	28	32	Chloride, 16 mg/l.
Sasieme	69	K38	do	357	2900	30	100	
Nogopo	70	K35	do	683	7000	17	24	Chloride, 140 mg/l.
Avenofeme	71	K33	do	312	3000	38	75	Chloride, 205 mg/l.
Tsiame	72	K34	do	414	4700	18	80	
Atiavi	73	K32A	do	775	2500	10	30	Chloride, 190 mg/l.
Anyako	74	K18	do	640	12000	3	130	Do.
Abolave-Nopoli	75	K31	do	502	7880	15	33	Chloride, 152 mg/l.
Weta	76	K30	do	398	3940	52	75	
Adrume	77	TK12	do	235	3000	53	81	Chloride, 148 mg/l.
Zagoto	78	TK9	do	255	3000	55	102	Chloride, 122 mg/l.
Kliko	79	K44	do	605	5200	26	47	Chloride, 120 mg/l.
Kpoglo	80	K46	do	292	3300	84	94	Do.
Hatsukope	81	K29	do	685	5100	52	60	Chloride, 121 mg/l.
Aflao	82	K41	do	950				Chloride, 153 mg/l.
Avoeme-Kpotameo	83	K42	do	975				Chloride, 860 mg/l.
Denu	84	K20	do	1000	3500	0	85	Chloride, 113 mg/l.

TABLE 3.—*Records of selected boreholes in the Coastal Plain geohydrologic province of Ghana*—Continued

Location	Serial No.	Bore-hole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land surface)	Remarks
Volta Region—Keta-Anlo District—Continued								
Denu	85	K49	Cretaceous and Tertiary limestone.	869	3380			Abandoned, salt water.
Adina	86	K27	do	459	7580	6	25	
Blekuso	87	K28	do	544	4000	3	73	Chloride, 600 mg/l.
Kedzi	88	K17	do	1000	3000	0	98	Chloride, 660 mg/l.
Vodje	89	K26	do	524	4100	2	60	Chloride, 300 mg/l.
Keta	90	TK1B	Cretaceous and Tertiary sandstone.	478	1000	9	15	Chloride, 140 mg/l.
Do	91	K25	Cretaceous and Tertiary limestone.	710				Chloride, 160 mg/l.
Anloga	92	K39	Cretaceous and Tertiary sandstone and shale.	2000				Abandoned, salt water; limestone not encountered.
Anyanui	93	K22	do	820				Abandoned, salt water; chloride, 10,000 mg/l. No limestone encountered.
Ada	94		do	1500				Salt water. No limestone encountered. Gray-green shale at a depth of 620 to 1270 feet. Glauconitic sand, 1270 to 1500 feet.
Western Region								
Half Assini	28	W3	Cretaceous to Holocene unconsolidated sand.	144	2780	8	8(?)	
Do	29	W49	do	260	3200	6	9	
Do	30	W71	do	195	4880	8	30	8-inch slotted pipe at a depth of 140 to 150 feet.
Techinta	31	W2	do	260	2000	123	130	
Ndumswaso	32	W53	do	265	2000	153	154	
Bonyeri	33	W5	do	192	8000	13	13(?)	
Do	34	W108	do	250	4880	60	185	
Alawuri	35	W61	do	205	2390	120	169	
Tikwabo I	36	W40	do	165	1850	40	128	
Alenda	39	W48	do	260	1500	181	182	
Nuba	40	W67	do	451	870	162	440	
Tikwabo I	37	W72	do	230	2390	41	142	

TABLE 3.—*Records of selected boreholes in the Coastal Plain geohydrologic province of Ghana*—Continued

Location	Serial No.	Borehole	Water-bearing formation or geologic setting	Depth (feet below land surface)	Yield (gph)	Static water level (feet below land surface)	Pumping water level (feet below land) surface	Remarks
Western Region—Continued								
Tikwabo I	38	W82	Cretaceous to Holocene unconsolidated sand.	164	1,270	75	105	Abandoned.
Beyin	41	W63	do	230	2,610	12	36	Abandoned. Chloride, 110 mg/l.
Kaboku	42	W69A	do	385	1,509	8	43	
Atuabo	43	W66	do	253	4,240	12	70	
Do	44	W73	do	320	1,130	8	277	
Anochi	45	W75	do	230	3,100	13	95	
Eikwe	46	W60	do	166	5,240	16	28	
Aiyinasi	47	W27	do	138	400	45	80	
Do	48	W32	do	250	340	45	248	
Do	49	W38	do	243	1,500	37	----------	
Do	50	W57	do	200	3,430	13	184	
Beku	51	W76	do	254	2,540	11	----------	8-inch slotted pipe at a depth of 175 to 211 feet.
Ngaliachi	52	W79	do	207	6390	21	70	
Do	53	W80	do	214	2610	15	110	8-inch slotted pipe at a depth of 152 to 190 feet.
Esiama	54	W6	do	163	6000	70	70(°)	
Do	55	W68	do	139	1590	10	132	
Do	56	W70	do	110	1430	6	96	
Kikam	59	W7	do	155	4180	67	68	

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