



## WATER, SANITATION, ENVIRONMENT and DEVELOPMENT

### Groundwater in crystalline rocks and climatic conditions



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#### Abstract

The yield and quality of aquifers of the Precambrian crystalline basement rocks of the states of São Paulo (humid climate) Paraíba (semi-arid climate) in Brazil and southern Ghana (semi-humid climate) in West Africa were studied, using data on about 2000 wells. These aquifers are discontinuous in character with occurrence of water in fractured rock zones, lithological contacts and horizons of weathered rock masses. The average yield of wells in Paraíba is 2.16 m<sup>3</sup>/h and come mainly from fractured zones. In São Paulo and Ghana where water is obtained from both weathered mantle and fresh rock the yields are 15.70 m<sup>3</sup>/h and 4.25 m<sup>3</sup>/h respectively. The average total dissolved solids (TDS) of water in Paraíba wells is 4000 mg/l with 5% less than 500 mg/l, while in São Paulo and Ghana more than 90% of the waters have TDS less than 500 mg/l.

#### Introduction

The aim of this paper is to analyze the hydrogeological characteristics of crystalline basement rocks occurring under different climatic conditions: humid climate (São Paulo), semi-arid climate (Paraíba) all in Brazil and (semi-humid climate) Ghana in West Africa.

The State of São Paulo in Brazil covers an area of 246,898 km<sup>2</sup> in southeastern part of Brazil. It is situated between Long. 44° 19'W and 53° 08'W and Lat. 19° 46'S and 25° 16'S. Crystalline basement rocks occupy about 23% of the state.

The State of Paraíba is located between Long. 35° 30'W and 38° 00'W and Lat. 06° 05'S and 08° 00'S in the northeastern region of Brazil. Its area is 56,374 km<sup>2</sup>. The crystalline basement rocks also occupy about 97% of the area of the state.

The Republic of Ghana lies along the Gulf of Guinea, West Africa between Long. 03° 15'W and 01° 12'E and Lat. 04° 44'S and 11° 11'N. It covers an area of 238,537 km<sup>2</sup>. The area of the country underlain by crystalline rocks is approximately 54%.

#### Climate conditions

Precipitation is the main climatic element used in this study. In São Paulo the areas associated with crystalline basement rocks receive average precipitation ranging from

30 mm to 60 mm during dry months of the year. The mean annual precipitation is about 2000 mm, maximum annual is about 4000 mm.

The climate of Paraíba is the tropical semi-arid type where precipitation ranges from 300 mm to about 900 mm per annum. The total annual precipitation of the areas underlain by the crystalline rocks in Ghana lies between 1020 mm and 1800 mm. Here the climate is being described as tropical semi-humid.

#### Sources of data

Data used in this study were compiled from reports of the states governments' water supply organizations in Brazil and from Ghana Water and Sewerage Corporation in Ghana (ASOMANING 1992).

Information gathered from these data were categorized as follows:

- Geological information comprising lithology, type of overburden material, total thickness and saturated thickness of the weathered material, types of surface fractures, depth at which fractures were encountered in wells and the kinds of associated surface drainage.
- Technical data on wells included parameters such as, well depths, static water levels, dynamic water levels, yields and specific capacities.
- Chemical quality of the waters including constituents of the major elements (Na<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, HCO<sub>3</sub><sup>-</sup>), TDS, pH and EC.

For the purpose of brevity not all the informations are used in this paper.

#### Results and discussions

The descriptive statistics of the well data are presented as follows:

In São Paulo the average yield of water in 840 wells is 15.70 m<sup>3</sup>/h and fluctuates between a minimum of 0.15 m<sup>3</sup>/h and a maximum of 150.00 m<sup>3</sup>/h. The coefficient of variation is 114%. The mean of the static water level is 10.93 m and lies between 0.20 m and 50.00 m. The depth of the weathered mantle in São Paulo varies from 2.00 m to 88.00 m with a coefficient of variation of 58% and an average value of 42.47 m.

For 610 wells in Paraíba the mean yield is 2.16 m<sup>3</sup>/h, the minimum and maximum values being 0.06 m<sup>3</sup>/h and 13.09 m<sup>3</sup>/h respectively with a coefficient of variation of 98%. The average static water level is 5.00 m and varies between 0.00 m and 24.00 m, the coefficient of variation being 70.19%. The overburden is 2.42 m ranging from 0.00 to 12.00 m.

The mean yield of 560 wells examined in Ghana is 4.25 m<sup>3</sup>/h varying between a minimum of 0.18 m<sup>3</sup>/h and a maximum of 36.46 m<sup>3</sup>/h with a coefficient of variation of 75%. The static water level is between 0.1 m and 46.7 m the average of which is 8.2 m. The mean depth of weathering is 23.71 m and ranges between 1.00 m and 75.00 m.

The average TDS of water samples in Paraíba is 4,422.69 mg/l ranging from 203 mg/l to 27,850 mg/l. Only 20% has TDS less than 1000 mg/l and less than 5% less than 500 mg/l. In São Paulo groundwater in the crystalline rocks has average 170 mg/l of TDS with minimum and maximum values of 1.9 mg/l and 2,114.1 respectively in 400 samples. The value of the TDS of waters in Ghana's crystalline rocks lies between 54 mg/l and 2,160 mg/l for 240 samples with an average value of 366 mg/l.

In crystalline rocks groundwater occurs in fractured zones, lithological contacts and horizons of weathered rock masses. Climatic factors such as precipitation and temperature influence the depth of weathering and its zone of saturation which contributes water to the aquifer (PEDRO 1968, FANIRAN and JEJE 1983).

To demonstrate this, frequency distribution histograms of total depth of weathering and the thickness of the saturated weathered zone were made. In São Paulo and Ghana the histograms show approximately normal distribution (Fig 1 and Fig 2). Whereas in Paraíba (Fig 3) the histogram of the total depth of weathering is not normal with more than 80% of the depth of weathering being less than 5 m. The static water level is, in most cases, below the weathered (the overburden) zone.

The relationship between the total depth of weathering  $W_D$  and the thickness of saturated weathered zone  $S_T$  in the study areas are shown by a simple regression analysis making  $W_D$  the independent variable and  $S_T$  the dependent variable (Table 1).

The coefficient of regression R indicates the rate at which an increase in the weathering depth increases the thickness of the saturated zone and therefore recharge to the aquifer (OMORINBOLA 1982). R is highest (0.8826) in humid São Paulo and least (0.7766) in semi-arid Paraíba.

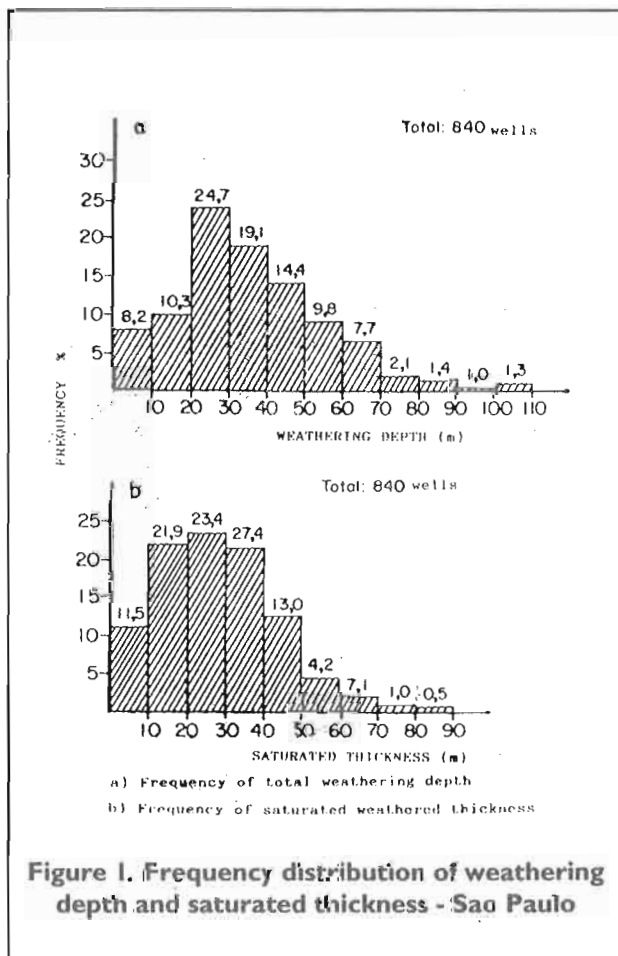
The regression equations are used to calculate the threshold depth of the zone of saturation as shown in the last column of Table 1. In the humid areas, São Paulo and Ghana, the threshold value is well within the weathered zone which results from precipitation but in semi-arid Paraíba this is below the average depth of the overburden which means that saturation is mainly in the fresh rock.

## Conclusion

It is concluded that climatic conditions influence the yield of aquifers in crystalline rock aquifers in tropical areas. Sufficient rainfall is needed for the formation of a weathered mantle to act as storage medium. Also recharge from precipitation improves the quality of such aquifers.

## References

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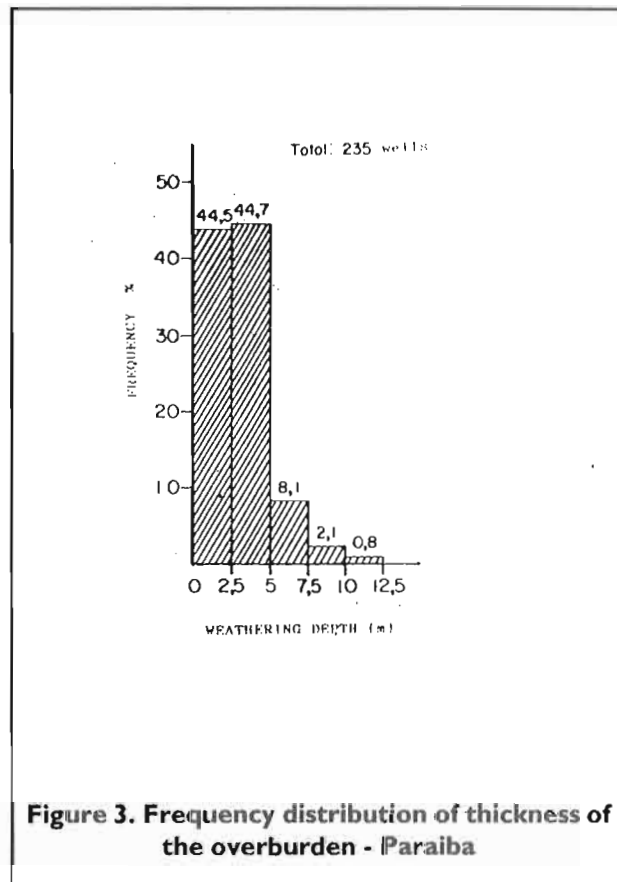
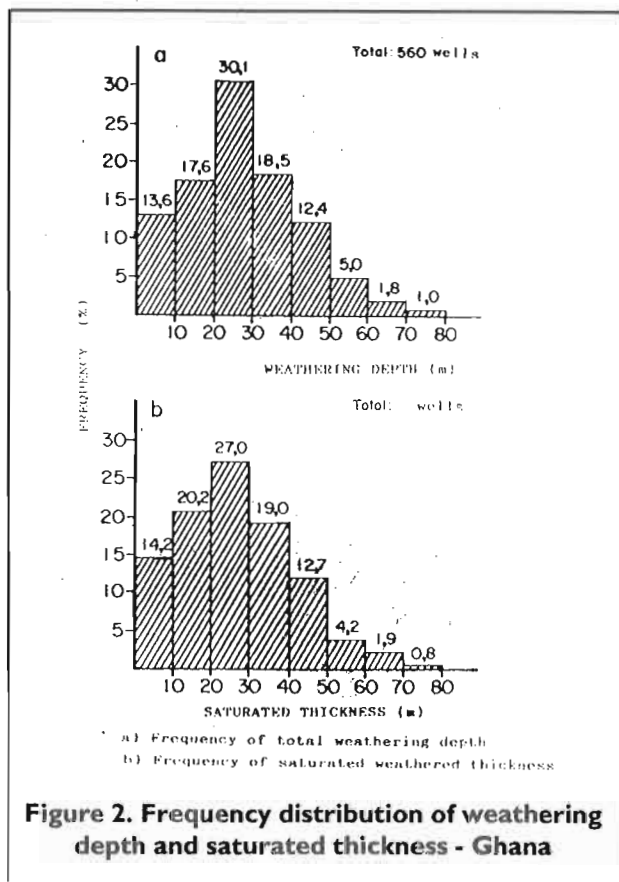


Figure 2. Frequency distribution of weathering depth and saturated thickness - Ghana

Figure 3. Frequency distribution of thickness of the overburden - Paraiba

Table I

Study area	Regression equation ( $S_T, W_D$ meters)	Coefficient of correlation R	Coefficient of determination $R^2 \times 100$	% Of total variance not explained by the regression model	Threshold limit for the formation of the saturated zone in the weathered zone (meters)
SAO PAULO	$S_T = 1.964 + 0.735W_D$	0.8607	74	26	2.67
PARAIBA	$S_T = 4.0145 + 0.767W_D$	0.7766	60	40	5.23
GHANA	$S_T = 2.995 + 1.021W_D$	0.8326	69	31	2.93