INFLUENCE OF BEDROCKS ON HYDRAULIC CHARACTERISTICS OF WEATHERED BASEMENT AQUIFERS: *A Case Study from SW-Nigeria*

BY

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PRESENTATION OUTLINE

- Background Information
- Weathered Basement Aquifer
  - GW-Occurrences
  - Hydraulic Characterization
- Aims and Objectives
- Study Area
- Methods
- Results and Discussion
  - Measured Parameters
  - Evaluated Parameters
  - Statistical Correlation
- Summary and Conclusions

BACKGROUND

- There have been increasing interests in GW resources throughout the world.
- The interests are as a results of:

  (a) Increasing GW development for public and domestic uses.

  (b) Increasing GW demands for agricultural and industrial activities in developing world.

  (c) Emerging threat of climate change impacts on GW.

- Hence, the need for detail understanding of hydraulic and recharge characteristics of aquifers especially in basement terrains.

BACKGROUND INFORMATION (Cont'd.)

- Basement Complex terrain aquifers have been known to exhibit complexity in terms of:
  - Spatial variations in GW occurrences and recharge.
  - Spatial variations in depth of weathering profiles
  - Spatial and vertical variations in hydraulic properties.

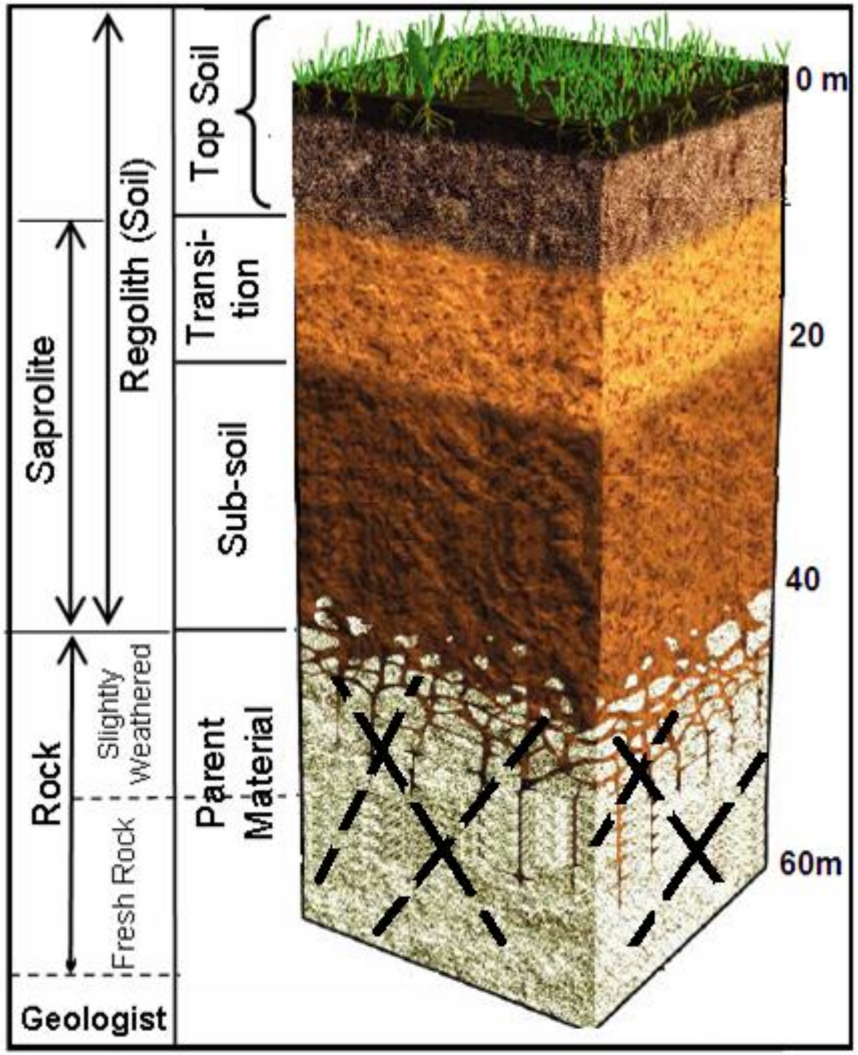
    (Chilton and Foster, 1995; Kellett, 2004).

- About 50% of the Nigeria like many other parts of SSA, is characterized by Basement Complex rocks.
- However, detail understanding of the hydraulic characteristics of the basement aquifers are lacking.

WEATHERED LITHO-PROFILE

Generally, the components of weathered basement litho-profile are:

- Weathered regolith with variable hydraulics subject to the clay content.
- Slightly weathered and/or partly fractured saprock unit.
- Fractured or poorly fractured fresh rock bedrock units.
- Quartz and pegmatite veins in an otherwise non-water bearing weathered regolith.



GW IN BASEMENT TERRAIN

Combinations of the different components of the weathered profile usually dictate the nature and potentials of GW in the basement terrains as follows:

a) Highly decomposed bedrock unit forming thick weathered regolith, underlain by fractured / unfractured bedrock unit.

b) Thin/shallow weathered regolith underlain by fractured saprock unit, with pegmatite / quartz veins.

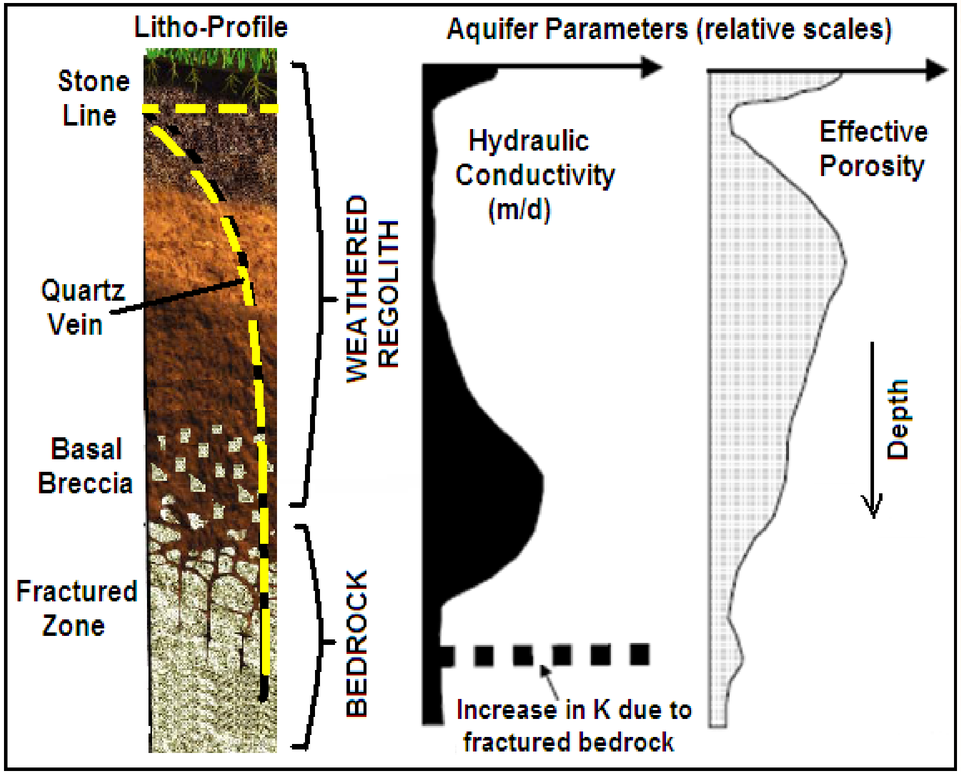
c) Shallow weathered regolith underlain by fresh un-fractured bedrock unit.

- The first two conditions are commonly encountered and usually sustain wells with moderate to high yields.
- Hence, the need to assess the implications of such hydraulic varied weathered units with respect to GW recharge.

HYDRAULIC CHARACTERIZATION

- There are extensive studies on hydraulic characterization of basement aquifers.

- However, complexity of basement rock units pose challenges to such hydraulic characterization.



Hydraulic Properties with depth in Basement aquifers (Based on Chilton and Foster, 1995)

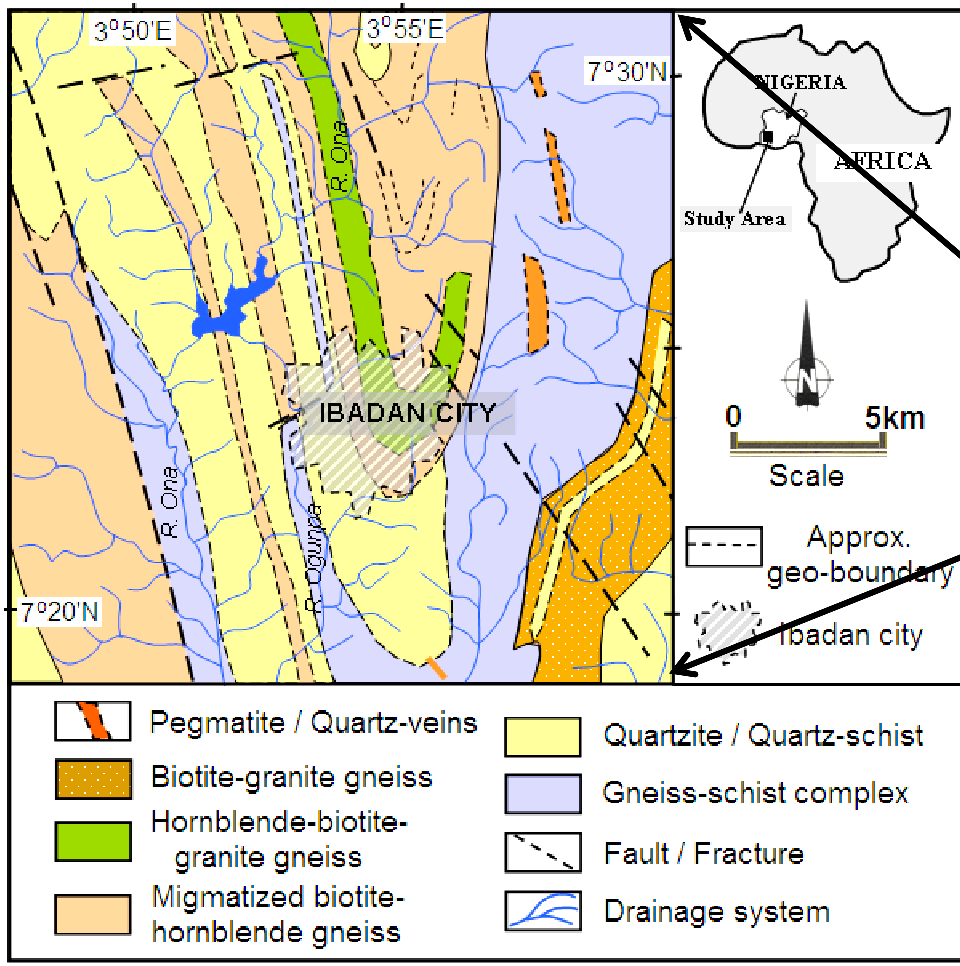
- Hence, a direct generalization regarding hydraulic properties and GW recharge potentials potential are not possible (Gustafson and Krásný, 1994).

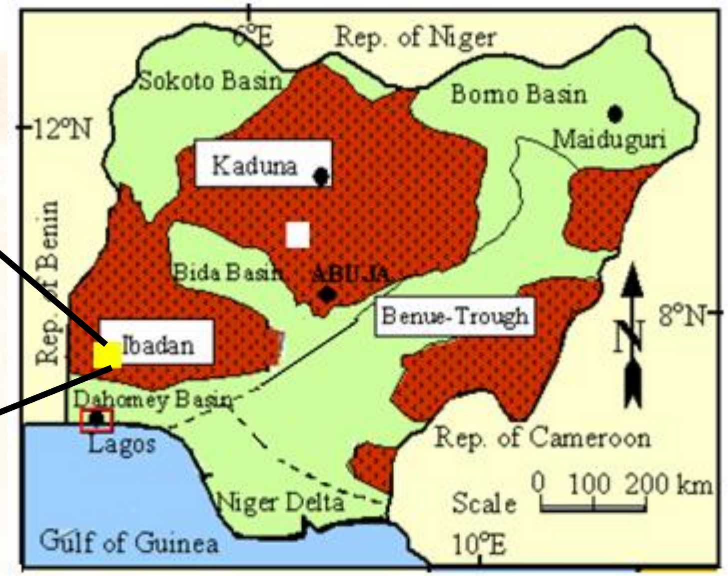
OBJECTIVES

Based on the above background, this study focused on the weathered basement (regolith) aquifers of parts of SW-Nigeria with the objective of:

- Assessment of **bedrock types** and related **geological control on the hydraulic characters** of the weathered basement aquifer.
- Evaluation of **impacts of the hydraulic properties on the on the groundwater recharge potentials** of the bedrocks units.
- Highlight **the influence of hydraulic characteristics on the overall groundwater occurrence / develop-ment** in weathered basement terrain.

STUDY AREA





Location: Between long. 03°49’00”E and 03°59’00”E and between lat. 07°22’00”N and 07°28’00”N

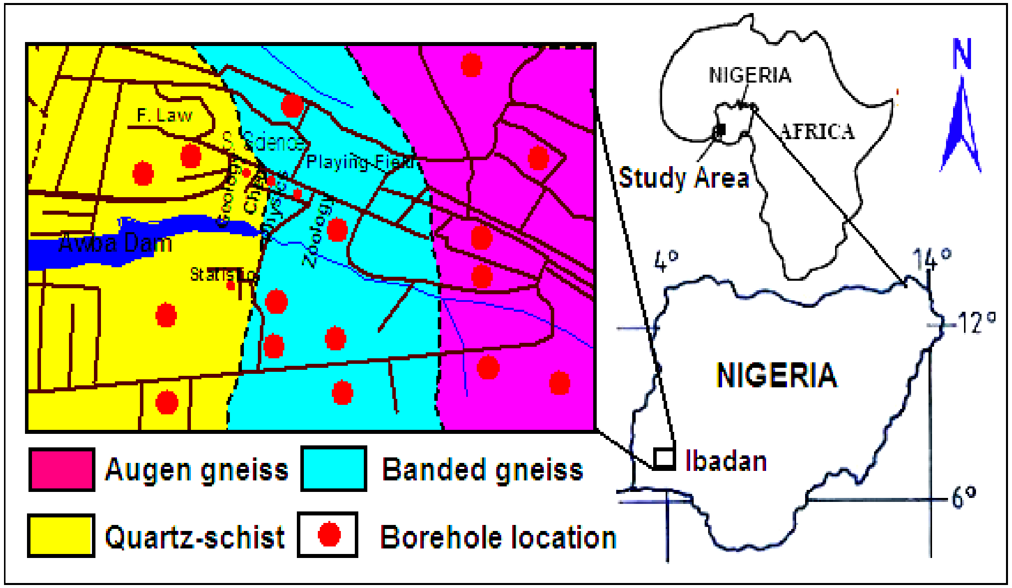
Ibadan Metropolis:

- **Situation:** SW - Nigeria (largest pre-colonial city in Nigeria)
- **Population:** About 1.76 million.
- **Pop. density:** 3,250 persons/km^2

METHODS: Study Catchment

- **Drainage systems:** Dendritic patterns, unmodified stream channels with a southerly flow direction.

- **Topography:** undulating terrain with quartzite ridges/ inselbergs of gneiss and adjoining plains/valleys.



Location map of tested water wells

- **Geology:** Precambrian Basement Complex, composed of quartzites, granite-gneisses and migmatite and intruded pegmatites, quartz veins, aplites and dolerite dykes.

- **Hydrology:** Wet season (March – October) with Av. annual rainfall of about 1,250mm and Dry season (Nov – Feb).

METHODS: Field Procedures / Data

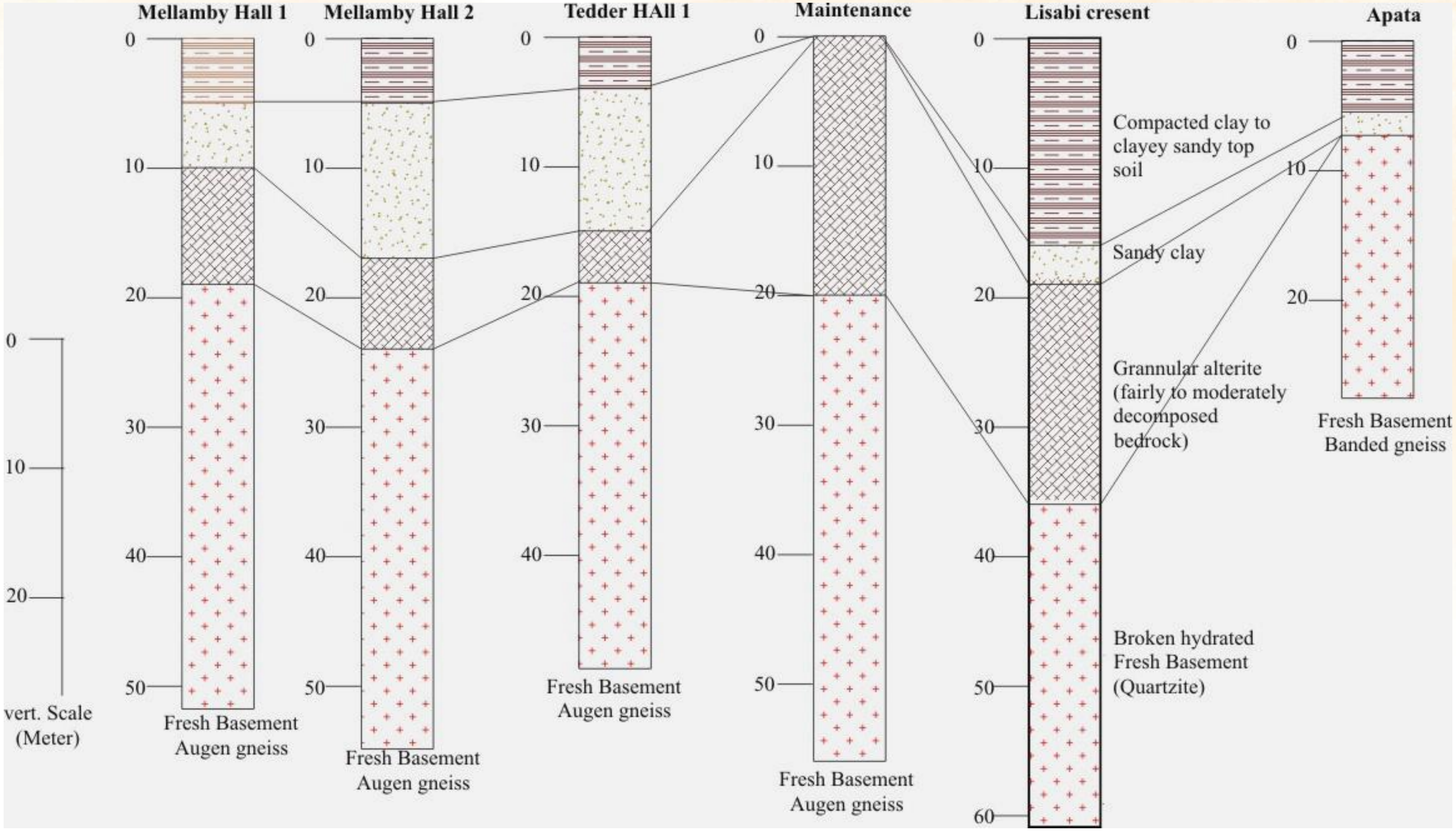
- A total of **<u>21 boreholes</u>** drilled into the **quartz-schist, banded gneiss, and augen gneiss bedrock settings** were pump tested in the study area.

- The procedure involved:

  a) **Single well tests** and analyses (at constant discharge rate for both drawdown and recovery measurements) using standards procedures.

  b) **Data Analyses** and interpretation of pumping test data using Cooper-Jacob (1946) time-drawdown method.

METHODS: Representative Logs



Representative litho-logs of well in the different bedrock settings.

METHODS: Estimated Hydraulic Parameters

Transmissivity (m^2/d)

$$T = \frac{2.3Q}{4\pi}\frac{1}{\Delta s}$$

Hydraulic Conductivity (m/d)

$$K = T / B$$

Specific Capacity (Sc) = $\frac{Q}{s}(m^3/d/m)$

where,

T	=	aquifer transmissivity (L^2/T),
Q	=	the constant discharge rate (L^3/T),
Δs	=	drawdown / log cycle (L),
B	=	saturated (or total aquifer) thickness

Other data evaluation involved statistical correlation of the aquifer hydraulic and well parameters.

RESULTS: Measured Data

Results of measured well the different bedrock settings

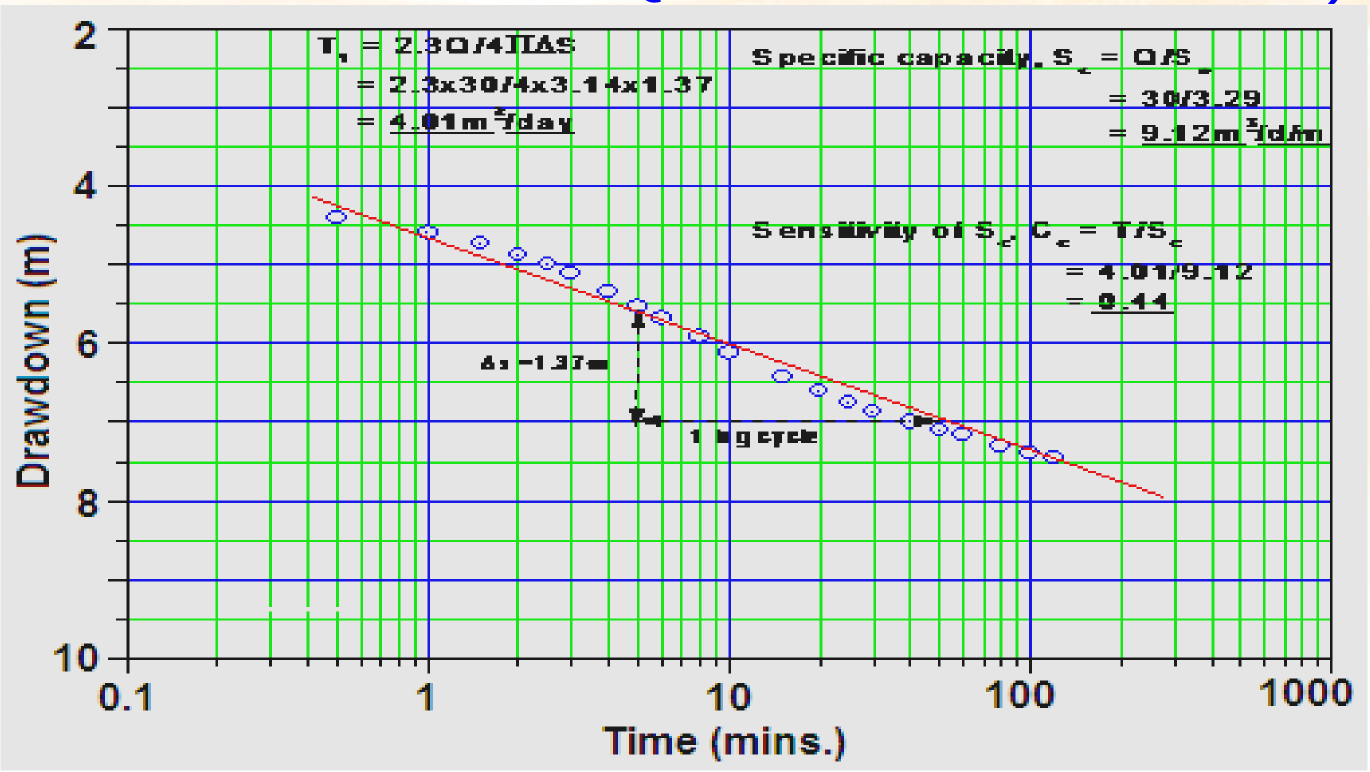
Parameters	Banded gneiss (N = 6)			Augen gneiss (N = 13)			Quartzite (N = 5)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Well depth (m)	21.6	60.0	36.2	12.1	68.0	47.7	60.0	87.0	66.4
Depth WL (m)	0.94	5.9	3.4	0.75	11.2	4.67	3.07	11.3	6.1
Drawdown (m)	2.2	26.4	13.7	3.3	29.4	11.3	15.1	34.7	28.9
Sat. Thick. (m)	16.4	54.9	30.7	8.02	62.8	42.2	48.7	81.6	62.7
Yield (m^3/d)	31.0	88.6	55.9	30.0	138.2	88.7	62.8	86.4	75.4

- The depth of wells (boreholes) range from 12.12 – 68m (mean 47.7m) for augen gneiss, 21.6 – 60m (mean 36.2m) for banded gneiss and 60 – 87m (mean 66.4m) for schistose quartzite setting.
- **The variability in well depths signifies the geologic control and differences in the extent of weathering.**

RESULTS : Measured Data

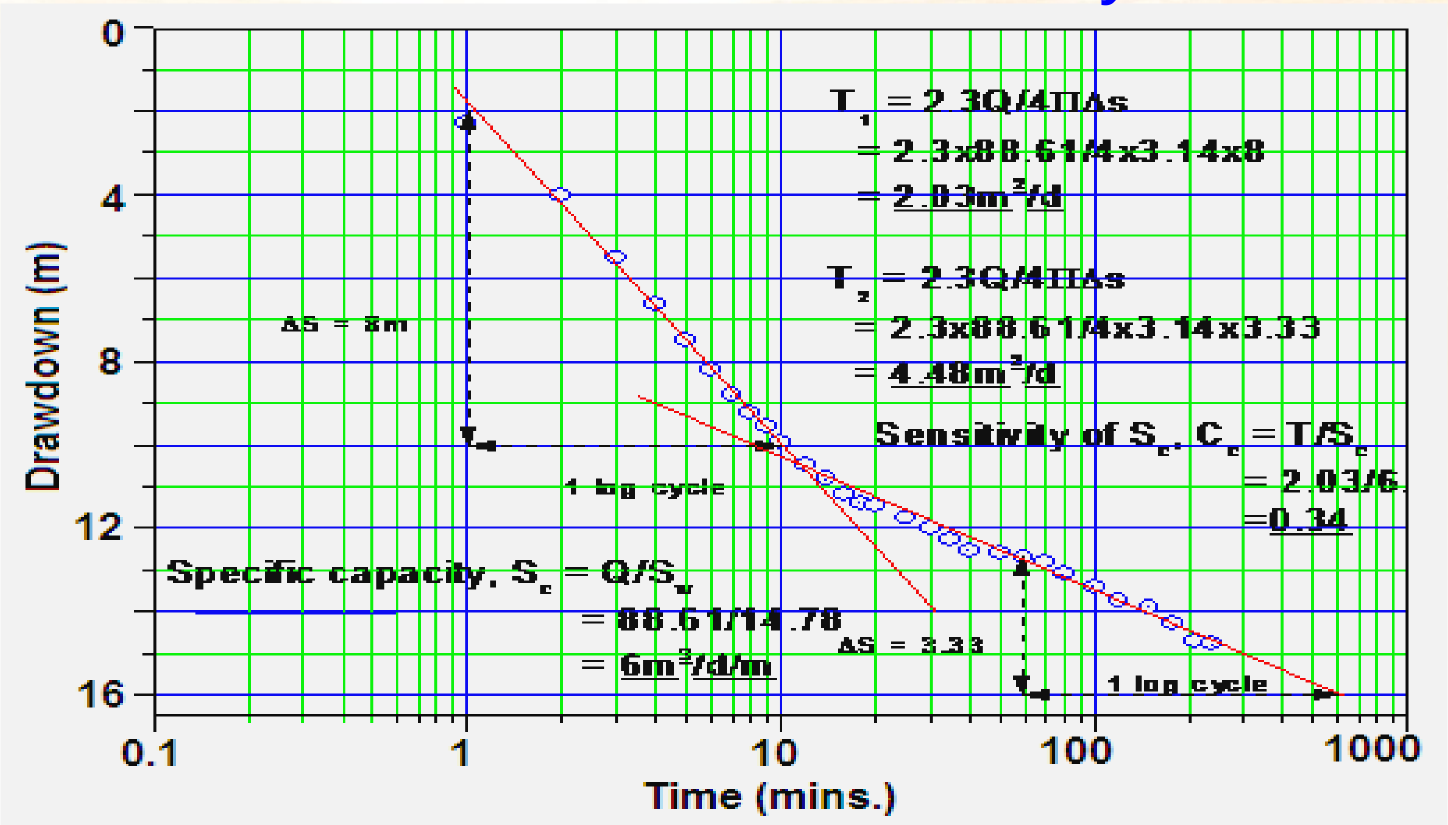
- Depths to WL in the boreholes vary widely from <1m to more than 10m but generally less than 15m below surface in the different geologic settings.
- **Shallow WL is an indication of enhance infiltration and recharge of the weathered regolith aquifer.**
- This apparently **facilitates the development of hand-dug wells and shallow boreholes** for domestic water supply in the study area.
- Saturated thickness in the boreholes shows a wide variation of 8.02m (in gneiss) to 81.58m (in the quartz schist setting).
- **Higher sat. thickness in quartz-schist setting is an indication of dependency on the extent of weathered regolith and topography.**

Time-Drawdown Plots: Scenario 1 (Normal / Quasi-ideal Condition)



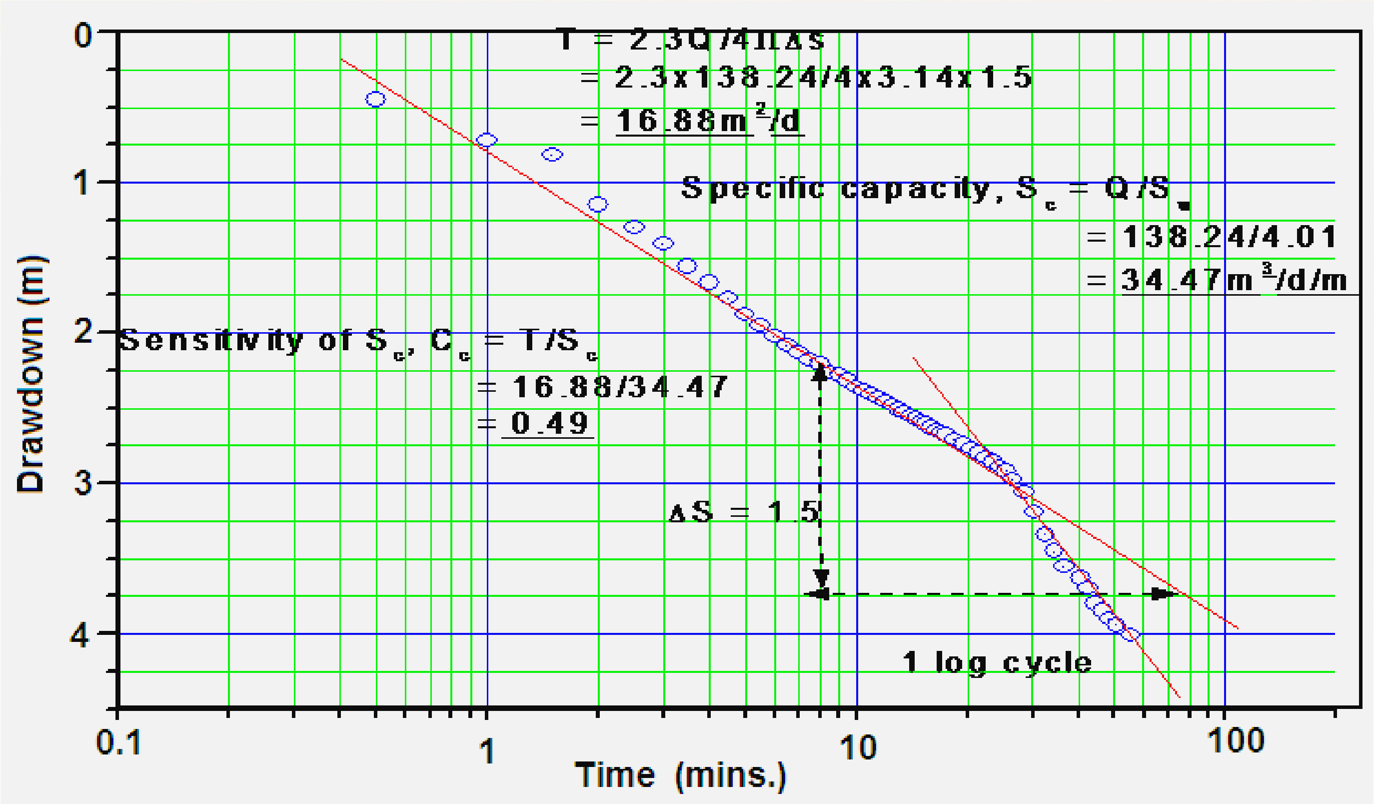
- The first aquifer response scenario represents a situation where discharge rate is proportional to in-flow into the well.
- It is commonly observed under augen and granite gneiss settings.

Time-Drawdown Plots: Scenario 2 (Recharge boundary Condition)



- The second type of aquifer response curve is indicative of presence of transmissive fracture system within the bedrock units
- This is a clear indication of recharge boundary effect and is found all the 3 bedrock settings, especially the quartz-schist setting

Time-Drawdown Plots: Scenario 3 (Impermeable boundary Condition)



- The last response scenario is indicative of an impermeable boundary condition.
- This typifies bedrocks with moderately thick weathered regolith but with very limited or no fracturing at depths.

RESULTS: Evaluated Data

Evaluated parameters for the different bedrock settings

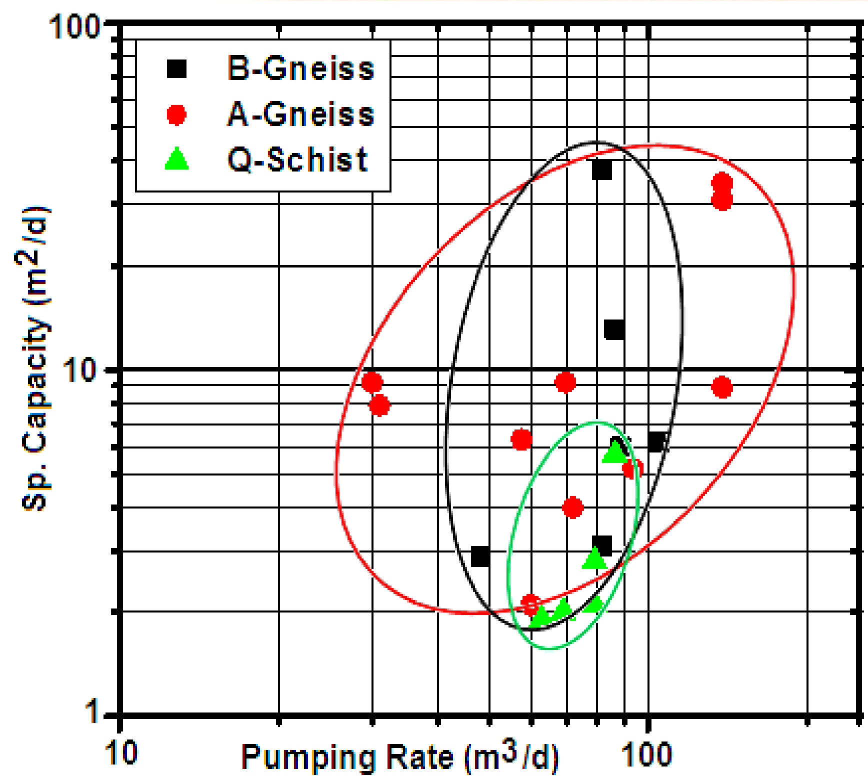
Parameters	Banded gneiss (N = 6)			Augen gneiss (N = 13)			Quartzite (N = 5)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Sp. Capacity (m^2/d)	2.92	7.9	5.6	1.25	37.8	13.0	1.86	17.5	5.23
Transmissivity (m^2/d)	1.10	4.16	2.8	0.76	27.2	7.25	0.41	10.6	2.71
Sensitivity, Cc	0.24	2.0	0.7	0.25	0.7	0.43	0.17	0.42	0.28
Hydraulic Conduct.(m/d)	0.07	0.15	0.1	0.02	0.5	0.2	0.01	0.18	0.05

- K-values as estimated from Transmissivity and saturated thickness revealed values of **0.01 – 0.18m/d** for banded gneiss and quartz-schist compared to **0.2-0.5m/d** for augen gneiss.
- T ranges from **0.76-27.16m^2/d** in augen gneiss, **1.1 – 4.2m^2/d** in banded gneiss and **0.41 – 10.6m^2/d** in the quartz-schist.

RESULTS: Evaluated Data

- The observed T and K imply that quartz-schist and banded gneiss settings have lower GW-recharge and discharge potential when compared to the augen gneiss.

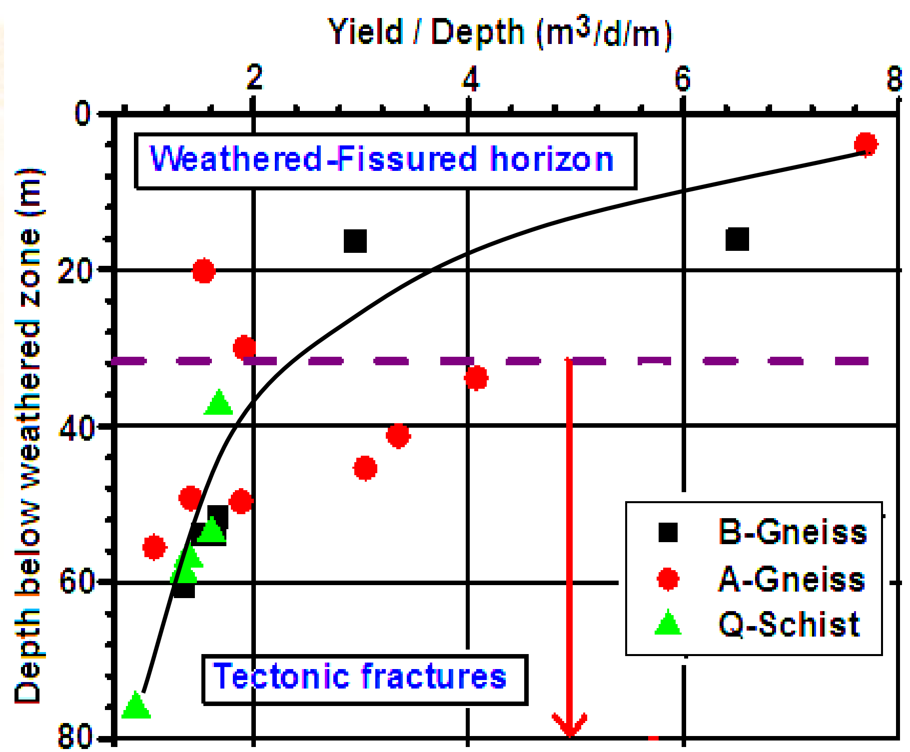
- Specific capacity range from **1.3 – 37.8m²/d** for Augen gneiss and **2.9 – 7.9m²/d** for Banded gneiss and **1.86 – 17.5m²/d** for Quartz-schist settings.



Specific capacity (m²/day) versus Discharge revealed lower values for quartz schist with yield of 62-84m³ per day, suggesting influence of deep weathering.

RESULTS: Evaluated Data

Decrease in specific yield with borehole depth suggests greater roles of hydraulic parameters rather than that of the borehole in such a weathered basement aquifer.



However, the yield in quartz-schist is apparently fracture controlled with limited vertical drainage within the weathered regolith.

RESULTS: Statistical Correlations

Bedrock	Parameters	Pearson's Product Moment (R)		
		Q	SC	T
All borehole	Sat. thickness	0.24	0.04	0.10
	Borehole depth	0.26	0.02	0.07
Banded gneiss	Sat. thickness	0.20	0.35	0.36
	Borehole depth	0.18	0.36	0.37
Augen gneiss	Sat. thickness	0.38	0.16	0.24
	Borehole depth	0.47	0.15	0.24
Quartz-schist	Sat. thickness	**-0.14**	**-0.26**	**-0.26**
	Borehole depth	**-0.34**	**-0.32**	**-0.32**

- The negative correlation for quartz-schist test can be attributed to fact that the aquifer performance is more or less a function of **the transmissive fractured bedrock** rather than the **sat. thickness and/or the well depth alone.**

SUMMARY AND CONCLUSIONS

- Assessment of the degree of interrelationship among the aquifer parameters revealed poor positive correlation

  a) between yield and regolith thickness (R=0.26)
  b) between yield and saturated thickness (R=0.29)
  c) between T and regolith thickness (R=0.06)
  d) between T and saturated thickness (R=0.15)

- The implication is that the basement aquifers performance is more or less a function of the hydraulic characteristics rather than the **saturated thickness and/or the well depth alone.**

CONCLUSIONS

- There is the general tendency to link aquifer potentials in terms infiltration and groundwater recharge

  a) to nature of bedrock mineralogy, and structural features
  b) thickness of weathered regolith and saturated thickness.

- **BUT not all hydraulic and aquifer parameters exhibited significant impact on the productivity of weathered basement aquifers. Nonetheless, it can be inferred that:**

  a) bedrock type and geologic structure influence regolith aquifer recharge and yield positively,
  b) regolith thickness and saturated thickness are shown to have little significant influence.
  c) Hydraulic indices (T, K, and Sp. Capacity) are important controlling factors.


END OF PRESENTATION
THANKS FOR YOUR ATTENTION
AND
LISTENING PLEASURE.
Ibadan, Nigeria