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The 54th Chapter in the ancient Sanskrit literature, 'Brihat Samhita' (i.e. Master Collection) by Varahamihira (A.D. 505-587) deals with ground water exploration employing plants, termite mounds, soils, and rocks as hydrologic indicators. The treatment of this subject is multidisciplinary involving various branches of Earth sciences and life sciences (Prasad, 1977a, 1977b, 1977c, 1977d, 1977e, 1977f, 1977h) and nowhere in this work did Varahamihira advocate water divining and all the methods he employed have empirical bases. The descriptions are quite elaborate giving such details as: i) distance and direction of occurrence of aquifers with reference to the hydrologic indicators; ii) quality, quantity and direction of flow of water in aquifers; iii) subsurface geological units associated with aquifers; and iv) occurrence, in the sub-soil of certain cold-blooded animals such as fish, lizard, snake etc. referring "Aestivation" i.e. a state of dormancy commonly undergone by these animals under unfavourable conditions in arid and semi-arid regions.

With a view to find out the scientific basis for the observations made in this ancient Sanskrit Literature, a research project entitled "Geology of the Termite Soils", sponsored by the University Grants Commission, has been initiated. In pursuance of this, a geoscience study of the Chandragiri hill has been undertaken as part of the project investigations.

Chandragiri Hill

Chandragiri hill (Fig 1 and 3) is a conspicuous landmark near Chandragiri town in Chittoor District, Andhra Pradesh, forming part of the Survey of India toposheet No. 570/6. The area has great historical and archaeological significance because of the existence of two palatial monuments about 500 feet south of the hill, which is surrounded by an extensive fort wall (Fig. 1). The monuments are believed to be constructed by the famous Yadava king, Immedi Nara-
Simha Yedavaraya, by about 1000 A.D., and subsequently fortified by a Salva King, Narasimha Raya, between 1445-1486 A.D.

The hill rises to a height of 1841 ft. above MSL. The slope of the hill is somewhat gentle on the eastern side while on the western side it rises as a steep scarp.

The hill has a heterogenous composition consisting of medium to coarse-grained grey granite, porphyritic granite and migmatite. Caught-up patches of biotite schist and biotite-hornblende granulite occur in granite. (Fig. 7) The granitic rocks at several places have circular or oval-shaped pot holes varying from an inch to as much as 8 ft in diameter. These pot holes have been formed by the alteration and removal of the mafic constituents from the migmatites and or the caught-up patches. The rock types are extensively traversed by dolerite dykes varying in width from less than an inch to as much as 150 ft. The rocks are also traversed by numerous quartz, pegmatite, and epidote veins. Journaled in the rocks of the hill is a prominent feature. Two sets of joints occur of which, one trending N 70°E and the other trending N 20°E. At some parts of the hill, these two sets are widely spaced, and the growth of vegetation along these joints planes gives a sort of grid pattern. The distribution of joints pattern is most uneven on the hill. In addition to these two sets, sheet joming is also observed at certain places (Figs. 3 & 6).

3. Distribution of the Water Bodies on the Chandragiri Hill and in Its Vicinity.

The Chandragiri hill has very interesting features with respect to the quality and distribution of the water bodies which occur at different parts and at different elevations on the hill. They occur as ponds, springs, pot holes, and as seepages through the joints (Fig. 3). Around the hill, on the ground surface, water occurs as ponds and tanks and also in several dug wells. At the highest part (1841 above MSL) of the hill occurs a pond (20' x 12') which has been partitioned centrally by a brickwall; one part is known as “Pappu Satti” (dhal Pot) and the other as “Uppu Satti” (Salt pot) and these two bodies are famous for their distinctly differing water quality. At Akkalagudi which is situated at an elevation of about 1820 ft above MSL, a cave has developed in granite through which passes a water course which gets dried up during the summer months. From this place, at about 30' lower down on the slope, occurs a circular pond of 200 ft. diameter containing water in all seasons. At an elevation of 1500 ft. a dolerite dyke, trending N 60°W with a width of about 8'ft bifurcates into two branches - one trending S 20°W, while the other N 45°W. Near this joint bifurcation occurs a permanent water body as a nearly circular pond of about 30' diameter. In addition water occurs in several pot holes during rainy season. About 50 dug wells occur within one km. distance around the hill, with depths varying from 25-40 feet. In most of these wells the water table reaches the ground level during rainy season and gets dried up during summer season.

4. Water Quality

In order to summarise the salient features of the water quality in this area, 18 samples were collected from the water bodies on and around the Chandragiri hill and analysed for certain cations (Na+, K+, Ca++, and Mg++) and anions (Cl-, HCO3-, SO4-) as per the procedures of HEM (1959).
lata are shown diagrammatically by means of the bar graphs in terms of percentage equivalent million (epm). Variations in the quality of water may be attributed to the textural and mineralogical changes in the rock type and alteration products in the hill. Water play an important part in the formation of the soil on and along the hill. The neutral or basic ferromagnesian rocks, silicates are hydrolysed to quartzo-feldsparic rocks weathering olinitic soils. Well-drained soils from mafic rocks readily loose water along with bases. Poorly-drained soils are nominally kaolin-rich, with horizons of black, iron-rich compost forming the barrier impeding drainage on this side of the hill.

5. Termite Mound

Termite mounds occur at different parts of the hill. They are formed either along joints of the barren granite or on the soil mantle on the granite surface. The size of the termite mounds varies from 4 to 6 ft. in height and 4 to 7 ft. in width. The mounds on the soil mantle may assume a conical shape (Fig. 5) but those developed along the joint planes on the barren rock occur as nearly rectangular blocks (Fig. 4).

5.1. Physicochemical Properties of the Termite Soils:

Samples from twelve different mounds were collected from this area for laboratory studies. They were made moisture free and the physicochemical properties comprising colour, organic matter, pH and specific conductance were determined.

5.1.1. Colour

The colour of the soils was determined as suggested by Kornerup and Wanscher (1967) and it is expressed in terms of Methuen notation and Munsell notation.

The mounds developed on the barren rock are devoid of vegetation, and are brick red in colour while the mounds on the soil cover have yellowish brown in colour and have thick vegetation on and around the mound. Evidently the brick red on the first type is due to inorganically precipitated iron oxide while the...
colour of the second type is due to iron oxide and organic matter.

5.1.2 Organic matter

Organic matter in the termite soils was determined as suggested by Gross (1971). It ranges from 4.3% to 8.8%. Acidic soils have higher values of organic matter.

5.1.3 Soil pH

Soil pH was determined as per the procedure of the Indian Standards Institution (1973). When pH of the termite soils and of the surrounding soil is determined, an increase in the pH has been noted for various termite soils of Africa (Boyer, 1955, 1956, Kemp, 1955, Nye, 1955. Robinson, 1958, Sys, 1955, Watson, 1962, Wild, 1952) and for some termite soils of India (Gokhale, et al 1958, Sen, 1944, Shrikhande and Pathak, 1948). However there are cases wherein a decrease in the pH of the termite soil has been noted (Maldague, 1959, Pathak and Lehri, 1959). Stoops (1964) has observed very little difference in the pH of the termite soil and of the adjacent subsoil.

In the case of the termite mounds of the Chandragiri hill, both increase and decrease in pH with respect to that of the adjacent subsoil are noted, but certainly pH of the soils is lower than that of the rock on which they are developed. These variations seem to be related to the organic matter in the mounds and chemical quality of the circulating waters.

5.1.4 Specific conductance

Specific conductance for 12 samples was determined with the aid of conductivity bridge as per the procedure prescribed by the Indian Standards Institution (1966). It is significant to note that the specific conductance of the termite soils is consistently higher than that of their adjoining soils.

5.2 Textural Characteristics of the termite soils

The textural characteristics of the soils were determined on the samples made devoid of organic matter. Sand (2mm - $\gamma$10 mm), silt ($\u03bc m - 2 \times \gamma$50 mm), and clay (less than $2 \times \u03bc m$) components in the soils were determined following the standard methods of sieve analysis and pipette analysis (Krumben and Pettijohn, 1937). The standard statistical parameters comprising median, mean, standard deviation, skewness, and kurtosis were computed from the sieve analysis data based on the formulae of Folk and Ward (1957).

The construction material of the mounds are sandy particles of the subsurface soil carried in the jaws of the termites and cemented with a mixture of clay and saliva (Prasad, 1977p, p. 518). The maximum size of particles that can be transported and incorporated in structures is related to the size of the termite workers (Lee and Wood, 1971p, p.101). Textural characteristics of the termite soils have been studied by several earlier workers (Hesse, 1955; Nye, 1955, Harris, 1956, Maldague, 1959, stoops, 1964; Kemp, 1955, Watson, 1960; Joachim and Candiah, 1940; Pathak, and Lehri, 1959; Lee and Wood 1972 ;)

On the Chandragiri hill the construction material for the termite mounds are derived from the soil mantle on granite from the alteration material of granite from the joint planes. The details of the soil formation from granite have been discussed by Carrol (1970). According to Lee and Wood (1971, p.102) the termite
Usually select the clay and silt in preference to the sand sized. But it is significant to note that the mounds on the Chandragiri made up of "Sand" (Sheapard, 1960) have a significant clay and silt content, which silt and clay components are evident. Particle size analysis of sands in Africa (Hesse, 1955. Nye, 1956, Maldague, 1959, 1964) show that their textural characteristics are more or less similar to that of the subsoil. In this context the texture of the termite mound on the Chandragiri hill is that of granitic material occurring as tule on, or along the joint planes of granitic rocks constituting the hilly area. Further, the statistical parameters of the texture of the termite mound on the Chandragiri hill are more or less similar to the texture of the subsoil material used in the mound. Bouillon (1970) has demonstrated that free water in the soil at a depth of about 3 ft. and descended vertically down the side of a well to a depth of 10 ft. Raccliffe and Greaves (1940) have recorded the existence of a connection on the form of extensive network of subterranean galleries from below the termite mound to the moist subsoil. Bodot (1967) has found deep shafts penetrating to the water table below the termite mounds. Ghilarov (1962) has found the termite galleries from the nests about 5 ft below the ground surface to moist subsoil at a depth of 33 ft to 50 ft. Yakushev (1968) has pointed out that the termite galleries in Africa descend to the water table at a depth of 235 ft.

From the above discussion, it is evident that the termites on the Chandragiri hill use the water from the joints and other subterranean channels through their galleries to maintain high relative humidity in the mounds. From this it follows that the existence of ground water is an essential prerequisite for the existence of the termite mounds. Hence Varahamihira rightly pointed out that the termite mound is a hydrologic indicator.

6. Conclusions

1. Dramatic changes in the quality of water occurring at different parts of the Chandragiri hill are attributed to differences in the weathering environment.

2. Termite mounds are conspicuously developed through the joint planes in barren granitic rocks and on the soil mantle.
The construction material for these mounds are derived mostly from the sand sized particles of the altered granitic rocks.

3. The termite maintain requisite humidity in their mounds by transporting water from the subterranean regions. Thus the termite mounds serve ideally as hydrologic indicators.

4. Occurrence of ground water on the western and southern parts of the hill is revealed not only by a large number of dug wells but also by various morphological features of vegetation suggested by Varahamihira as hydrologic indicators.

7. Acknowledgements

Thanks are due to Dr. K.V. Suryanarayana, Professor and Head of the Department of Geology, for providing the necessary facilities to carry out this work.

Financial assistance of the University Grants Commission is highly acknowledged.

Table No. 1

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<th>Munsell Notation</th>
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<th>pH Terrestrial soil</th>
<th>Adjacent soil</th>
<th>Specific conductance in Mhos/cm² Rock</th>
<th>Specific conductance in Mhos/cm² Terrestrial soil</th>
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The values are in °C.
Table 2

Textural Characteristics

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References


**Explanation to figures**

Figure: 1:- Map showing the topography of the Chandragiri hill.
2:- Map showing the distribution of the water bodies and the termite mound on the Chandragiri hill.
Chemical quality of the waters is indicated by bar diagrams.
3:- A part of the Chandragiri hill showing sheet jointing with seepage of water.
4:- Termite mound on the hill, at a height of 850 ft. above MSL, through the widely spaced joint. Two sets of joints, emphasized by the growth of vegetation are also seen.
5:- The termite mound on the soil mantle developed on granite. The mound has developed against the barren surface of a huge granite boulder.
6:- The termite mound developed on a barren granite through a joint plane. The sheet jointing is prominently visible.
7:- Caught up patch in biotite-granite.