TABLE II

Free energy of formation of Fe_2O_3 in the temperature range 873–1300° K

Temp. °K	$\Delta G^{o}_{Fe_2O_3}$ Cals/gm mole (present work)	$\Delta G^{o}_{Fe_2O_3}$ Cals/gm mole (Ref. 8)	$\Delta G^{o}_{Fe_2O_3}$ Cals/gm mole (Ref. 7)
873*	−141,290 ± 140	..	..
900*	−139,590	−140,248	−138,900 ± 1500
923	−138,160	..	..
948	−136,650	..	−136,800†
973	−135,090	..	..
1000	−133,410	−134,363	−133,900
1073	−128,880	..	..
1100	−127,200	−128,461	−128,100
1173	−122,710	..	..
1200	−120,990	−122,540	−122,200
1273	−116,450	..	..
1300	−114,810	−116,616	−116,400

* Extrapolated, † Value at 950° K.

cals/gm mole) as against the larger uncertainty of ± 1500 cals/gm mole of Ref. 7 while the uncertainty in the values listed in Ref. 8 is not known.

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HYDROLOGIC BOUNDARY ANALYSIS IN BASALTIC AQUIFERS

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INTRODUCTION

DURING the course of systematic hydrogeological survey in the basaltic terrain of Maharashtra, the authors had an opportunity to conduct a number of aquifer performance tests on open wells piercing the basaltic water table aquifer. Analyses of these test results have brought to light certain interesting facts regarding boundary effects, which form the subject matter of this note.

HYDROGEOLOGIC SETTING

The lava flows of the Deccan basalt differwidely amongst themselves in respect of their ability to receive recharge as well as hold water in storage and later transmit it conveniently in the form of groundwater. The differences in the lava flows with regard to their productivity arise as a result of their inherent physical characteristics, such as their porosity and permeability. For example, when intercommunicating vesicles are distributed uniformly throughout the rock it has a tendency to increase its permeability. Similarly closely spaced inter-communicating joints in massive trap units contribute towards the fracture permeability. Another dominant factor is the degree of weathering and topographic setting. Weathering increases the porosity and permeability of a rock medium and topographic setting also affects the movement of groundwater. In short, the nature, size, number and distribution of vesicles along with the number and spacing of joints and the degree/extent of weathering control the productivity of the aquifer in the basaltic terrain.

Groundwater occurs under both water table and confined conditions in the Deccan lava flows. The near surface weathered and jointed zones of massive trap units along with vesicular units constitute the main water table aquifer that is being tapped presently. Hydraulic continuity does exist between the consecutive massive and vesicular units, weathered and jointed zones in the former being responsible for such continuity. Studies in the basaltic terrain of the U.S.A. (*viz.*, Snake river valley plain) have further confirmed this belief of continuity of the water table aquifer in an area, rather than there being separate or disconnected water table bodies in different consecutive units of flows. The saturated zone upto a depth of 15 to 20 metres can be considered to be the water table aquifer in the basaltic terrain.

Groundwater Hydraulics

Various formulae utilised for the study of groundwater hydraulics can be grouped under two heads :

(1) Drawdown methods, and

(2) Recovery methods.

Of these, the drawdown methods are not applicable in the present study of the problems due to following reasons :

1. The comparatively poorly permeable water table aquifers in the basaltic tracts are presently developed mainly by open wells operated with relatively high capacity pumps. Hence the drawdown curve which results therefrom does not fully register the hydraulic characteristics of the trappean aquifer. The discharge during the initial stages of drawdown in such wells is mainly from the well storage, and rarely from the instantaneous release of water from the aquifer. Hence the early readings in any test are too much vitiated to be used for the determination of aquifer characteristics.

2. Further, slow draining of the water bearing materials in the vicinity of the pumped well greatly affects permeability determinations by non-equilibrium formulae, as the specific yield factor enters in them. According to Wenzel (1942, pp. 110–111), "Non-equilibrium formulae when applied to the drawdown of the water table aquifers appear to give inconstant values, because of slow drainage of the water table aquifer".

Recovery Methods

The authors have accordingly applied the recovery method to analyse the pumping test data. The hydraulic theory of aquifer performance test precisely pictures the water level changes that occur during the recovery period as a result of an imaginary recharge well. If such a well injects water into the aquifer at the same rate as the real well pumps out, usual recovery curve results. Theis (1935) has devised a method to analyse mathematically such a curve. The most convenient procedure is to plot the residual drawdown Δs against t/t' on a semi-logarithmic co-ordinate paper. When the value of t' becomes sufficiently large, the observed data has a tendency to fit on a straight line. The slope of this line gives the value of the quantity $\log_{10} t/t'$ in the following equation :

$$T = \frac{264\ Q}{\Delta s} \log_{10} \frac{t}{t'} .$$

For convenience, the value of t/t' is usually chosen over one log cycle because its logarithm is unity, and then the above equation reduces to

$$T = \frac{264\ Q}{\Delta s} ,$$

where Δs is the change in the residual drawdown in feet per log cycle of time. The semi-log plots of Δs vs. t/t' for select wells are plotted in Fig. 1.

Hydrologic Boundaries

The development of formulae to compute the aquifer characteristics as discussed above are based on the fundamental assumption of infinite areal extent of the aquifer. In nature no aquifer is infinite in extent, though for practical purposes the above assumption does hold good. In certain specific cases, the aquifers have boundaries, which limit their extent. These boundaries are of two types :

(1) Positive or recharge boundaries, and

(2) Negative or impermeable boundaries.

A recharge boundary exists where the aquifer is in hydraulic contact with a perennial stream, while the impermeable boundary occurs where an aquifer terminates against an impermeable material. By the use of image theory it can be shown that an impermeable boundary resembles a groundwater divide. The significant feature of such a boundary is that no water crosses it.

The analysis of boundary effects is of prime importance in the study of aquifer yield, and identification of such boundaries from the inspection of aquifer test data is possible. For this Theis recovery graphs as shown in Fig. 1 can be considered in the present discussion.

When the aquifer conforms to the basic assumption of an ideal aquifer, the residual drawdown curve when extended leftwards should pass through the zero residual drawdown point when t/t' becomes unity. The ratio of t/t' thus approaches unity as the length of the recovery period is extended. After a long period of recovery, the water level throughout the aquifer tends to return to its original static water level with Δs approaching zero and t/t' becoming unity. Thus the residual drawdown curve should theoretically pass through the upper left-hand corner of the diagram, as in case of wells

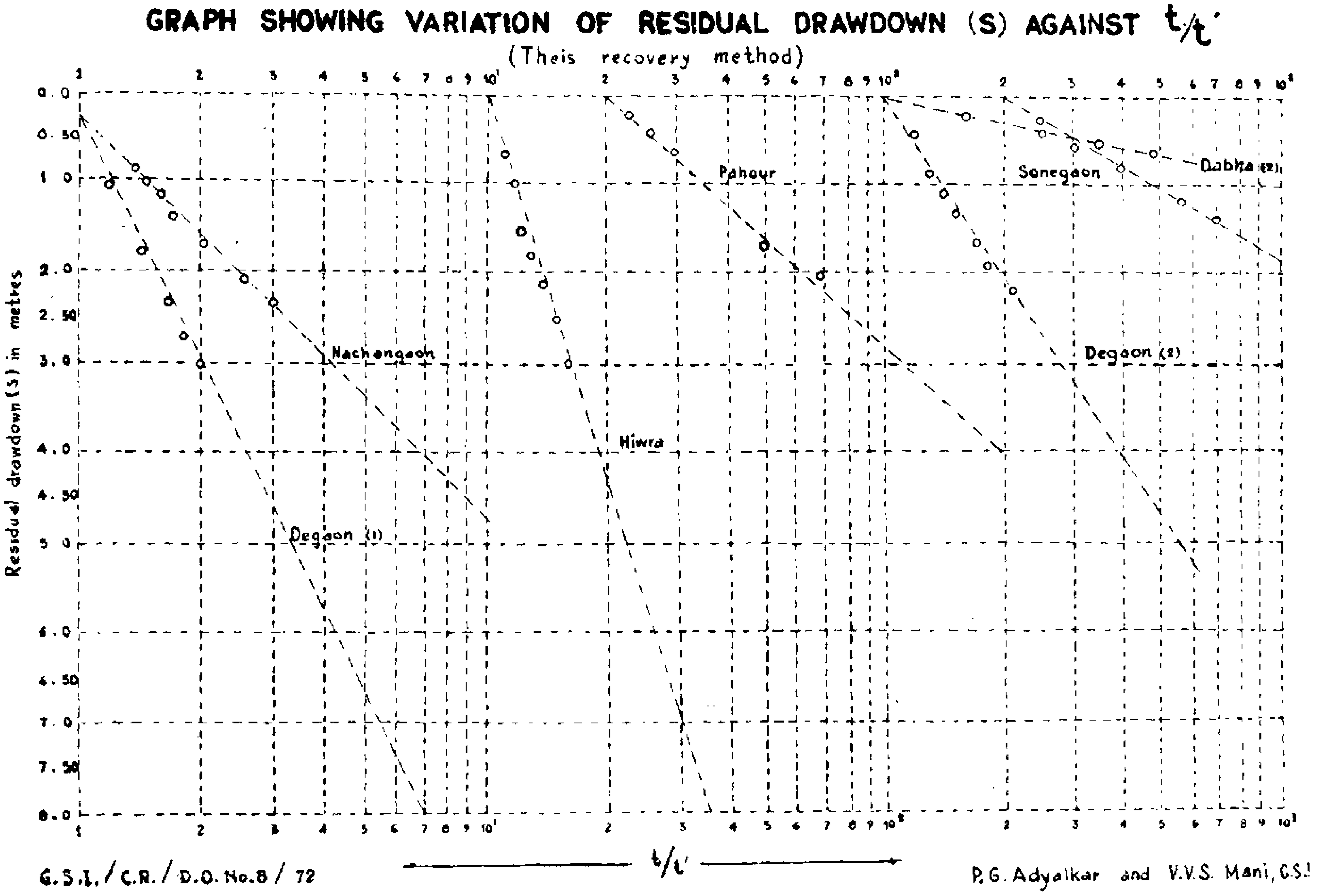

FIG. 1

located at Hiwra, Degaon (2) and Dabha (2) in the Wardha sub-basin of the Godavari main basin.

However, some graphs as shown in Fig. 1 do not pass through this point. When this happens, it is safe to conclude that the aquifer does not conform to the ideal assumed conditions with relative departures from the ideal condition. These departures are of two types, namely, that of the Positive boundary condition and the Negative boundary condition.

In the former case, the graphs show zero drawdown at a higher value of t/t'. Here recharge brings about full recovery of the water level to the original static water level during a relatively shorter recovery period much before t/t' approaches unity. Examples of such graphs are Sonegaon and Pahour. In the former case, the recharge effect is simulated by an increase in thickness of the producing aquifer, while in the latter case the well has the benefit of recharge from the adjacent surface tank.

A different condition is indicated when the curve extended to the left shows a residual drawdown of several centimetres even when t/t' approaches unity. This situation would occur in the case of an aquifer of limited extent with no recharge. Wells tested at Nachangaon and Degaon (1) show this effect. The effect would also be similar in the case of wells located in areas of groundwater divide.

CONCLUSIONS

The above illustrations clearly show that it is possible to recognise boundary effects in basaltic water table aquifers by the study of the straight line graphs as obtained by the Theis recovery method. However, actual distances to the boundaries cannot be determined as observation wells are very necessary for such computation. In the absence of the latter, the authors have not made any attempt at this stage to determine the distances of these boundaries.

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