electrodialysis processes. Low transport number reduces the efficiency of the desalting process.

Some of the important electrical and chemical properties of commercial anion exchange membranes and our membranes are summarized in Table V.

We sincerely acknowledge the keen interest and useful suggestions made by Prof. N. R. Kamath, Indian Institute of Technology, Bombay, during the course of this work.

1. Laxminarayanaiah, N., *Chem. Rev.*, 1965, **65**, 491.
2. Talpade, C. R., Ganu, G. M. and Joshi, K. M., *Indian Journal of Technology*, 1971, **9**, 325.
3. Scatchard, G. and Helfferich, F., *Discussion Faraday Soc.*, 1956, **21**, 70.
4. Winger, A. G., Ferguson, Kunin, *J. Phys. Chem.*, 1956, **60**, 556.
5. Wyllie, M. R. J. and Patnode, H. W., *Ibid.*, 1950, **54**, 204.
6. Pepper, K. W., Reichenberg, D. and Hale, D. K., *J. Chem. Soc.*, 1952, p. 3129.

GEOHYDROLOGICAL STUDY IN PARTS OF SHOLAPUR DISTRICT AND ITS BEARING ON THE FEASIBILITY OF TUBEWELLS IN THE DECCAN TRAP *

P. G. ADYALKAR AND V. V. S. MANI

Geological Survey of India, Nagpur

ABSTRACT

Systematic geohydrological studies in parts of Sholapur District of Maharashtra have brought to light a succession of massive and vesicular trap units between the elevations of 411·48 and 472·44 m above M.S.L. Here the traps show a gentle dip towards east. Based on the studies so far carried out, the authors discuss the feasibility of tubewells in the traps of this area. Taking particular advantage of the high permeability of the vesicular traps, the paper emphasizes the need of exploratory drilling in the area in the downdip direction of the trappean units, tapping the cumulative thickness of the vesicular units thereof.

INTRODUCTION

SYSTEMATIC groundwater studies in Akalkot *tahsil* of Sholapur District of Maharashtra were undertaken at the instance of the Government of Maharashtra to investigate the possibility of locating the water bearing zones at economic depths below the existing ones with scope for purposes of irrigation.

While investigating for groundwater geological mapping of the area was undertaken to delineate different units of the Deccan Trap. To collect adequate information on the occurrence, movement and development of groundwater in different trap units, large number of wells in them were examined. Yield tests were conducted on select irrigation wells to study the yield characteristics of the wells tapping different units. Samples of water were collected from select wells to study the chemical quality of groundwater in them.

LOCATION AND EXTENT

Akalkot *tahsil* lies in the south-eastern part of Sholapur District. An area of about 800 sq.km lying in parts of toposheet Nos. 56-C/3 and 7, and 47-0/15 was covered during the field season 1963–64.

PHYSIOGRAPHY AND RAINFALL

Located in the middle of the Deccan trap terrain the area examined forms the northern part of the Bhima basin. It is marked by its undulating relief ranging in elevation from 411·48 to 472·44 m (*i.e.*, 1350 to 1550 ft) above M.S.L. The general slope of the country is towards south. The region is typically characterised by the morphology of the Deccan trap flows. A glance at the geological map of the area will bring out the role of geology in the evolution of the morphology of the terrain. The massive hard basalt constitutes the high ground while the soft vesicular basalts form the depressions in the area (Fig. 1).

The Bhima form the chief drainage of the area with a tortuous course. It flows along the southern margin of the area. The numerous streams that drain the area are but the tributaries of the Bhima. The major tributaries are the Dhubdhabi and the Bori river.

The south-west monsoon contributes maximum rainfall annually between July and

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September, the average annual precipitation being 0·6 m.

5 mm in diameter, often lined with calcite and zeolites. Red bole is a ferruginous clayey

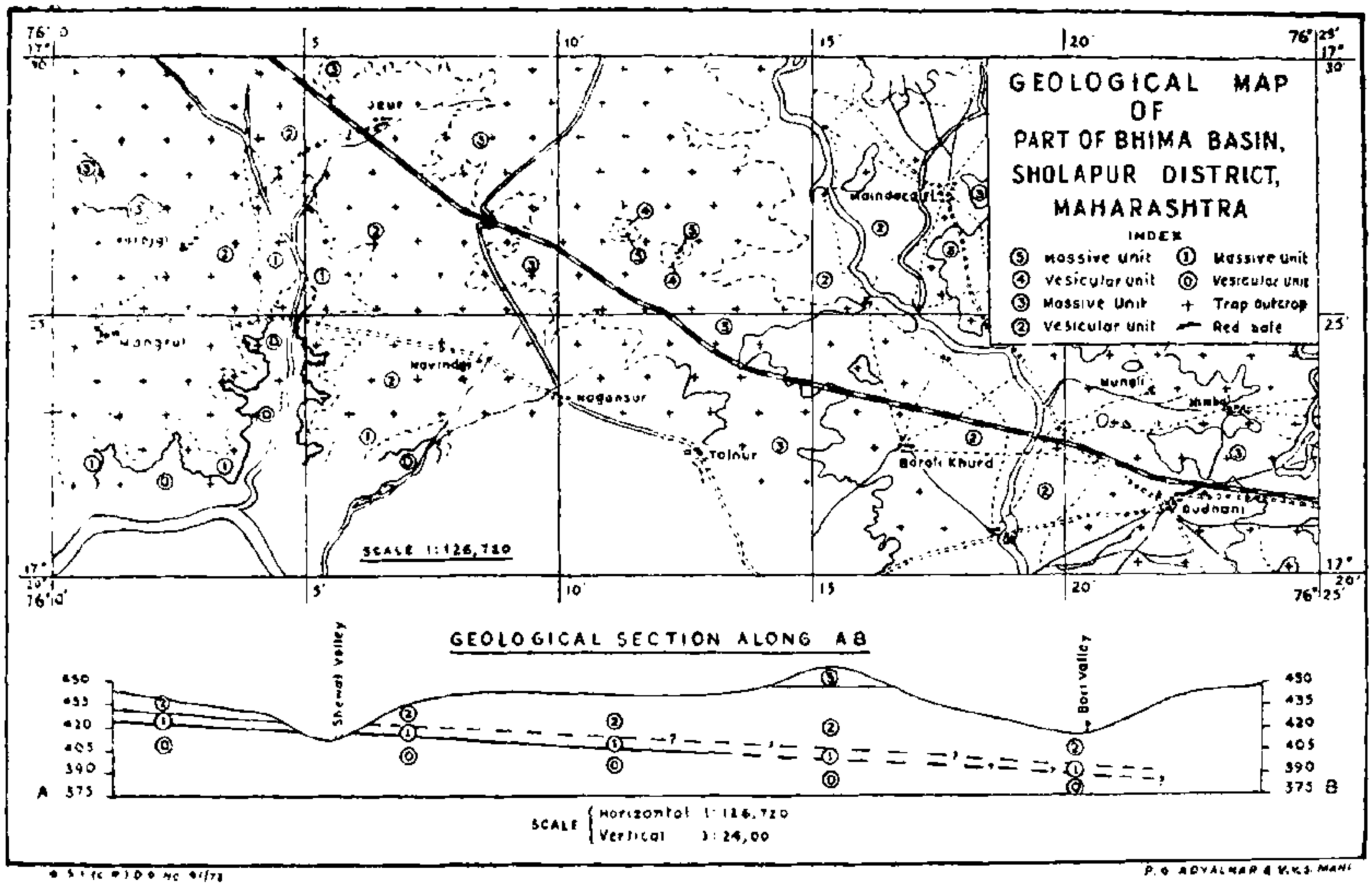

FIG. 1

Geological Setting

Basaltic lava flows of the Deccan Trap extending over 5,20,000 km^2 in the Central and Western parts of India constitute the main rock formations of the area. The traps in this part probably belong to the sequence of the middle traps, which together attain a thickness of about 1,000 metres in their thickest section elsewhere.

Geological mapping of the area investigated has brought to light, a succession of flows from 411·48 to 472·44 m (*i.e.*, from 1,350 to 1,550 ft.) above M.S.L. The flows are characterised by the prominent units of vesicular and massive basalt. No intertrappeans have so far been recognised nor any intrusive dykes in the area. The individual units of basalt attain a thickness of as much as 30 m, while the average is generally of the order of 20 metres.

The trap units can be classified into (*i*) the massive fine grained basalts, (*ii*) the vesicular basalts and (*iii*) the Red bole horizons. The term massive basalt has been generally applied to uniform, fine grained basalts. Vesicular basalts are characterised by vesicles of 4 to 5 mm in diameter, often lined with calcite and zeolites. Red bole is a ferruginous clayey material of brick red colour. The delineation of different units is based on their field characteristics.

Structurally the trap units exhibit a general horizontal disposition. However, closer study of the geological map of the area shows an easterly dip of the trappean units. The Red bole horizon occurs at an elevation of 426·72 m above M.S.L. in the Shewal valley (Fig. 1) (56–C/3 ; 76°05′) but further west it occurs at an elevation of 441·96 m above M.S.L. registering thereby a rise of about 15 m within a horizontal distance of 12·8 km. With its gently dipping nature the red bole horizon is missing further eastwards in the Bori valley at an elevation of 426·72 m above M.S.L. Geological Section along the line AB clearly brings out the inclined nature of the trappean units.

Black cotton soils, ranging in thickness from 0·3 to 2·5 m, cover different trap units met with in the area and *kankary* nodules are very common in them.

The following is the tentative succession of the trap units in the area ;

North of Karajgi in the West

Massive trap unit 3
——————— 472·44 m
Vesicular unit 2
——————— 449·58 m
Massive trap unit 1
——————— 441·96 m
Vesicular unit—0

Shewal Valley in the East

Vesicular unit 4
——————— 487·68 m above M.S.L.
Massive trap unit 3
——————— 457·20 m
Vesicular unit 2
——————— 434·34 m
Massive trap unit 1
——————— 426·72 m Red bole horizon
Vesicular unit 0

It is to be noted that the trap units are quite consistent in their behaviour over large areas of Akalkot *tahsil*. Spheroidal weathering is very characteristic in the massive units. In the case of vesicular units, the presence of empty vesicles and cavities filled with secondary minerals offer least resistance to mechanical weathering and give rise to porous soil with flakes of calcite and zeolite. The degree and extent of weathering undergone by the various vesicular units are highly variable. The depth of weathering in vesicular unit 2 varies from 6 to 9 m.

Groundwater Hydrology

Hydrological Properties of the Trappean Formations.—Prevalent rock types of Deccan traps in the area have an interesting feature with contrasting water bearing properties of different units constituting them. Massive units with their weathered zones and fracture porosities and the vesicular units with their minutely interconnected vesicles have both a decisive role to play in determining the groundwater possibilities of different parts of the area under consideration. The alternating massive and vesicular units have, therefore, an excellent similarity to that of alternating shales and sandstones of the Gondwanas on the one hand and the clays and sands of less consolidated sediments of recent age on the other.

Occurrence.—Groundwater occurs under water table condition in both the weathered and jointed zones of massive trap units and the vesicular units. These units locally show both lateral and vertical variation in the degree of weathering and porosity. This variation naturally plays a dominant role in the success or failure of the wells in the area.

In view of the excellent similarity existing between the alternating massive and vesicular units to that of shales and sandstones of the Gondwanas and clays and sands of the alluvium, the possibility of occurrence of groundwater under confined conditions has to be expected with almost impermeable to relatively less permeable massive members acting as confining units. In the Shewal valley (56C/3 ; 76° 05′) bores drilled at the bottom of the dug wells tap water from lower or bottom zones of unit '0' under confined condition ; and such bores locally range in depth from 3 to 5 metres. It has been observed that water from these bores rises about a metre over the well bottom. The piezometric surface of this confined zone lies at about 422 m (*i.e.*, approximately 1,385 ft.) above M.S.L. More data on the hydraulic characteristics of this zone are not available at this stage.

Analysis of Hydrological Data

Water table aquifer.—For quantitative assessment of the groundwater potential in any area, it is essential to have a knowledge of the aquifer characteristics of the aquifer units like transmissibility, specific capacity, etc. This is arrived at by analysing recuperation test data by suitable mathematical calculations.

As already stated, the vesicular units 0 and 2 are the more permeable aquifer units in the area. Recuperation tests on wells tapping them were conducted, and the aquifer characteristics were arrived at by the Theis recovery formula. From the recovery data of the tests, specific capacities of wells were calculated using Slichter's formula :

$$C = \frac{A}{t} \times 2303 \log_{10} \frac{S_1}{S_2}$$

Where 'C' is the specific capacity of the well expressed in litres per minute per metre of drawdown ;

t is the time in minutes since pumping stopped ;

S_1 is the total drawdown in metres ;

S_2 is the residual drawdown in metres after time 't' in minutes ; and

A is the cross-sectional area in sq. metres.

The results of test analysis are tabulated in Table I.

It could be seen that the vesicular trap units have good transmissibility and wells in them have often good yields. Thus along with geology, topography also plays an important role in contributing good yields in the tested wells.

TABLE I

Transmissibility and specific capacity values for vesicular trap units of the Shewal valley

Sl. No.	Location of the well	Specific capacity value (in lpm/m of draw down) for about 3 hours pumping period	'T' calculated by the Theis recovery method klpd/m	Aquifer
1	Kadabgaon ..	236	90·0	Unit 2
2	Dudhani ..	161	78·7	do.
3	Boroti ..	236	82·0	do.
4	Shewal ..	410	161·4	Unit 0

Confined Aquifer.—From the available data it appears that deeper zones in unit 0 are under confined condition, and are tapped by dug-*cum*-bore wells in the Shewal valley. The subsurface configuration of the terrain further downdip towards east, however, still remains to be worked out.

Possibility of Tubewells in the Deccan Trap.—The main purpose of the paper is to emphasize the need for systematic exploration of the Deccan Trap areas for development of the groundwater in them by tubewells penetrating the older vesicular units. Presently tubewells are not much utilised as means of development of groundwater in the trappean tracts. Further, after considerable work in parts of Nasik, Poona and Dhulia Districts of Maharashtra Deshpande (1949) had also ruled them out.

In contrast to his views, Vredenberg (1902) in his Memoir on the 'Recent Artesian Experiments in India remarked that the Deccan trap flows when considered as one mass are practically horizontal and have to be studied in that form. Detailed work in specific areas may bring to light the existence of gently dipping trap flows which may constitute artesian aquifers of a perfect nature though of limited extent. The officers of the well sinking department of the erstwhile Hyderabad State (Rao, 1947) also believed in the feasibility of borewells in such areas, where the cumulative thickness of the porous vesicular units is considerable. The authors, work in parts of Sholapur District of Maharashtra has revealed an easterly dip of the trappean units over a considerable part of the area, indicating a possibility of older porous units being exposed in their updip direction and thus enabling them to receive direct recharge from the precipitation. These could naturally be tapped by tubewells in their downdip direction. These theoretical considerations have been well illustrated in parts of Akalkot *tahsil* of Sholapur District as discussed in the present paper.

CONCLUSIONS

From the geohydrological studies so far carried out and the theoretical aspects discussed earlier, it can be inferred that the water in the deeper horizon of unit '0' in the Shewal valley (56-C/3 ; 76° 05′) is under confined condition. This horizon gets recharged by direct precipitation in its updip direction from the western part of the area, and is tapped by dug-*cum*-bore wells in the Shewal valley. Hence it is but natural to expect this horizon as well as older ones to extend beneath the areas occupied by the younger trap units further eastwards. The possibilities of developing groundwater by borewells tapping the older horizons in their downdip direction thus appear to be very bright.

These conclusions find confirmation in the Wallawalla area of Washington, U.S.A. According to Newcomb (1951)—"The water obtained by wells in basalt in the Wallawalla area comes from the zone of contact between one basalt flow and another. Though these interflow zones may be fairly extensive, their transmissibilities differ greatly from place to place. From areas of recharge, where the basalt is at or near the surface, rain water percolates downwards into the porous zones. The water in these porous zones moves by gravity down the dip of the basalt towards the centre of the basin, where the basalt aquifers contain water under considerable hydraulic head. Here water flows at the surface or stands but a few feet below the surface in wells tapping these aquifers".

Summing up, the authors wish to emphasize the need for such tubewells in the Deccan Trap, where the trappean units show dips, and where the cumulative thickness of the porous vesicular units as proved by yield tests is considerable. These tubewells could be safely depended upon for augmenting water supply in times of need and also in periods of draught. It is further suggested that geohydrological studies on similar lines in other Deccan Trap areas may also go a long way in developing the groundwater in them by such tubewells.

To conclude, the authors would like to quote the famous Geologist, Allen M. Bateman (with due apology for changing the two words) :

How can we know, we have not seen.
But we believe, the *traps* will yield.
Their water to the thirsty field.
And all the *plateau* turn green.

ACKNOWLEDGEMENT

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1. Deshpande, B. G., "A note on the rural water supply in Deccan Trap area in Mewasi Estates, West Khandesh District, Bombay Presidency," *Geol. Surv. Ind.*, 1949, Unpublished report.
2. Newcomb, R. C., *U.S.G.S. Open File Report*, 1951, p. 203.
3. Rao, D. V., *Manual of Groundwater and Well Sinking*, 1947, p. 291.
4. Vredenberg, E., "Recent artesian experiments in India," *Mem. Geol. Surv. Ind.*, 1902, Vol. 32, Pt. 1, p. 85.

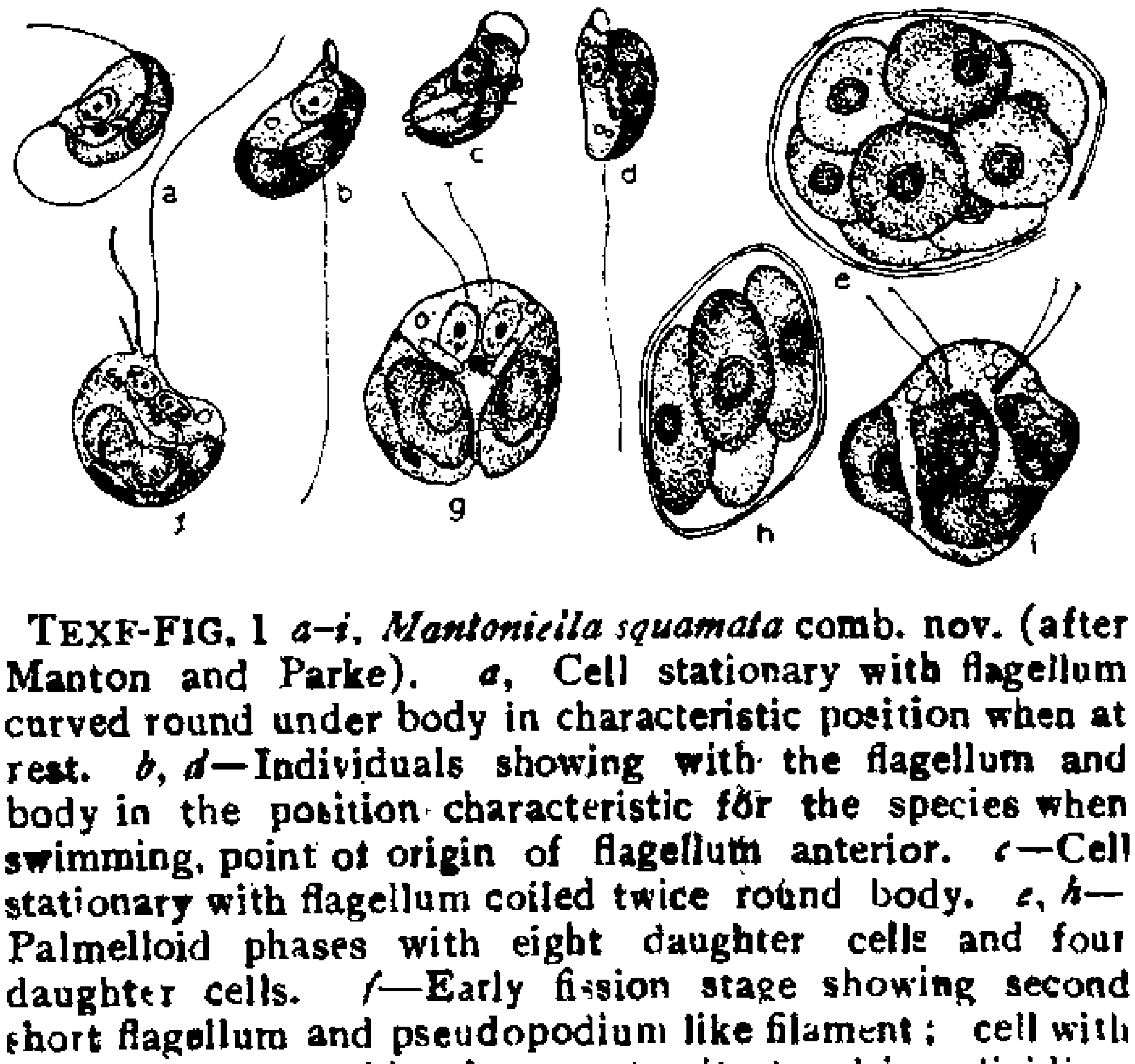
NOTES ON VOLVOCALES—I*

T. V. DESIKACHARY
University Botany Laboratory, Madras-5, India

SINCE the first discovery of a scale-bearing green flagellate, *Micromonas squamata*, by Manton and Parke[3], many more such species have been reported and this has led to new thoughts on the taxonomy of flagellated green algae in general. Many of these organisms are sometimes now placed in a distinct class, the Prasinophyceae (Christensen[2]).

In completing a forthcoming treatment of the Volvocales the writer had to necessarily go into the taxonomic status of these forms, whether they have to be accorded the rank of class, order, suborder, or family. Whatever be the status that may ultimately be given to them, it is clear that we can no longer put both scale-bearing and non-scale-bearing species in the same genus.

The genus *Micromonas* Manton and Parke was typified with *M. pusilla* (Butcher) Manton and Parke[3] which is a non-scale-bearing species. The second species, *M. squamata*, described by the same authors has scales (*see* Text-Fig. 1; Plate I, Figs. A, B), both body scales and flagellar scales being present. The nature of the flagellar insertion is also different and *M. squamata* must, therefore, be removed from *Micromonas* and placed in a new genus. The genus is being named after Prof. Irene Manton, in commemoration of her eminent contributions to our knowledge of the motile green algae.



TEXT-FIG. 1 *a–i*. *Mantoniella squamata* comb. nov. (after Manton and Parke). *a*, Cell stationary with flagellum curved round under body in characteristic position when at rest. *b*, *d*—Individuals showing with the flagellum and body in the position characteristic for the species when swimming, point of origin of flagellum anterior. *c*—Cell stationary with flagellum coiled twice round body. *e*, *h*—Palmelloid phases with eight daughter cells and four daughter cells. *f*—Early fission stage showing second short flagellum and pseudopodium like filament; cell with two nuclei, pyrenoid stigma and mitochondrion dividing. *g*—Fission stage showing chloroplast divided. *i*—Double fission with four daughter cells.

Mantoniella GEN. NOV.

Motile cells slightly compressed, small, cell wall absent, but covered with scales; uniflagellate, flagellum arising anteriorly and directed backwards during swimming; region of the body close to the point of origin of the flagellum showing metaboly; pseudopodia present; chloroplast present, single, appearing

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