THE
INDIAN GEOGRAPHICAL JOURNAL

Formerly

THE JOURNAL OF THE MADRAS GEOGRAPHICAL ASSOCIATION

Vol. XXX JAN — MARCH and APRIL — JUNE 1955 Nos. 1 & 2

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SOME NOTES ON THE REPRESENTATION OF THE DENSITY OF RURAL HABITATIONS

EDGAR KANT

The first attempts on cartographical representation of the density of urban habitations have been made by the author in the study of Tartu, in 1926.[1] Our recent efforts have been devoted to finding a relative method capable of representing cartographically the density of rural habitations.

The first map of the density of rural habitations is, as far as we know, professor STEN DE GEER's map of the housing density (*karta over boningshusens tathet*) on the island of Gottland. This work, however, has not been published.[2] For a long time after preparation of his map, STEN DE GEER has been trying to ascertain the relative merits of the representation of the density of population and of habitations.

"As a factor contributing towards the geographical landscape, habitations are unquestionably more important than inhabitants; though, on the other hand, inhabitants mean more economically and are significant as active agents, changing the aspect of the landscape including the habitations. But both habitations and inhabitants are closely related genetically and practically; so that, considered in the large, the two factors tend to show the same distributing relation." [3]

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[1] EDG. KANT; Tartu. Linn kui umbrus ja organism.
Resume en francais: Tartu. Etude d'un Environnement et Organisme Urbain. Tartu (Dorpat), 1926, map XIII, p. 221. The absolute method is applied in the supplement, see plans 1 and 7/XV.

[2] Befolkningens fordelning i Sverige. Beskrivning till karta i skalan 1:500,000 av STEN DE GEER, Stockholm, 1919, p. 20.

[3] STEN DE GEER, A Map of the Distribution of Population in Sweden: Method of Preparation and General Results. *The Geogr. Review*. Vol. XII, 1922, p. 74.

In reality, the density of habitations and the density of populatio... not a unique measure, nor uniform, for the number of inhabitants per h... is variable.[4] The two ways of representation do not express exactly ... same phenomenon, the map of the population having a rather demograp... or sociographical value, the map of habitations, on the contrary, having a ra... purely geographical value.

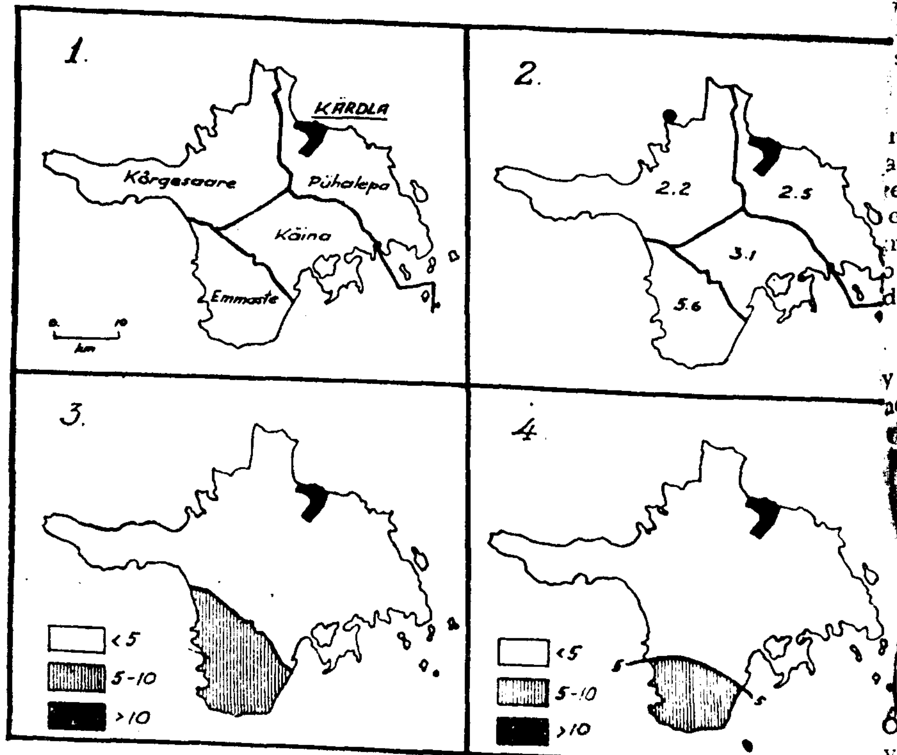

Fig. 1. The rural communities of the island Hiiumaa (Dago), Estonia.
Fig. 2. The numerical density of rural habitations per administrative di... (community).
Fig. 3. The density of rural habitations (per sq. km) according to the method of Mlle M. Lefevre, per commune.
Fig. 4. The density of rural habitations according to the isarithmical meth...

The double aspect of the problems concerning the density of popu... and habitations was already known to Mlle MARGUERITE LEFE... when she said that "concerning Belgium, the quantitative maps of habit... do not make superfluous the maps of population : these two maps ar... necessarily copies of one another."[5]

As to the ways of representing the static facts of rural habitatio... maps and cartograms we can, in general, classify them in two groups : absolute and the relative methods, according to their nature, the form... about the distribution and the absolute location of the habitations, the ... is about the relative density on the surface of the earth.

[4] See example in EDG. KANT, Quelques problemes concernant la represen... de la densite des habitations rurales. Exemples pris en Estonie. *Lund Studi... Geography*, Ser. B, No. 2, 1950, p. 6.

[5] M.A. LEFEVRE, La densite des maisons rurales en Belgique. *Annal...* *Geographie*, Vol. XXXII, 1923, p. 398.

In the past, numerous researches have proposed various methods, but ... limit ourselves to more recent proposals as to the relative maps, i.e., the ...s of the density of habitations.

Before all, MARGUERITE LEFEVRE, a Belgian geographer at the ...ersity of Louvain, has established a fundamental cartographical type,[6] ... the communities as a basis for calculation. For every community, the ... and the number of houses being given by the census, LEFEVRE has ...lated the density of habitations per square kilometer. In her calculations ...as only kept account of the houses in the real sense (*maisons proprement* ...), i.e. of those serving effectively as abodes. For her map, at the same ... picturesque and solid, LEFEVRE has chosen a scale of colours from very ... yellow to dark-brown. The tints are spread over the whole area of the ... districts, no reduction being made to allow for wooded or uncultivated ...s.

A similar type of map has been published later by FRIEDRICH LEYDEN, ...rman geographer, for Belgium, Luxemburg and the Netherlands.[7] The ...ipal interest of LEYDEN's map lies in the fact that it has made possible ...ose comparison between three countries. At a comparison between ...EVRE's and LEYDEN's map, the importance of the choice of colours in ...esenting the densities is noticeable. As to LEYDEN's map of the density ...ouses (*Hauserdichte*) it may be regretted that not a different scale of ...rs was chosen. It would have seemed logical, that when a density B is ... between two densities, A and C, it has to be represented by a colour or ...tone tint lying between those indicating A and C.

A second type of maps of the density of habitations is favoured ...cially by Polish geographers. The principal representatives of this ...ol are W. DESZCZKA[8], IGNACY ALBERT[9] and MIECZYSLAW IEŚMAN.[10]

The work of IEŚMAN, for instance, pays attention to the density of ...lings (*gestośc zabudowania*) at Volhynia. The principal part of this work ...ists of three maps : (1) a map of the density of buildings 1921 ; (2) a ... of the density of buildings 1931 ; (3) a map of the changes of number of ...lings from 1921 to 1931. IEŚMAN's maps have been constructed by means ...n isarithmic method by interpolation between the centres of gravity ...e rural districts ; he does not use colours, but shading.

[6] M.A. LEFEVRE, L'Habitat rural en Belgique. Etude de Geographie humaine ..., 1926, chapter III, pp. 99-157 and map II in colours.

[7] F. LEYDEN, Die Volksdichte in Belgien, Luxemburg und den Niederlanden in Verteilung nach den einzelnen Gemeinden und in ihren Beziehungen zur Wohndichte zur Hauserdichte in den drei Staaten. *Petermanns Geogr. Mitteil.*, Erg.-H. 204, 1929 ...et II in colours, scale 1:925,000).

[8] W. DESZCZKA, Repartition des maisons rurales en Pologne. *Pam. Zj. Sow. ...gr. i Geogr. w Poznaniu w 1927 r., Sekcja V* ; IDEM, Rozmieszczenie domow oraz ...ose i rozmieszczenie osiedli w Polsce. *Kwart. Statyst., t.* VIII, 1931 r.

[9] I. ALBERT, Z geografji osiedli wiejskich w dorzeczu Sanu. *Prace geograficzne ...awane przez prof. E. Romera (Travaux geogr. publ. sous la direction de E. Romer)*, ... 1934, fig. 7-12.

[10] M. IESMAN, Gesstosc zabudowania wojewodztwa Wolynskiego. *Prace wykonane ...akladzie Geograficznym Uniwersytetu Wilenskiego (Travaux executes a l' Inst. de ...r. de l' Univ. de Vilno)*, No. 1, 1936, fig. 1, 2, 4.

The Polish maps of density are sometimes drawn by means of a mixed method,[11] territorial and isarithmical. The communities of highest and lowest density are assumed to be homogenous within the administrative boundaries; in the communities of intermediary density, the average for each community has been attributed to the centre of its territory and the isarithmes have been drawn by interpolation between these points. By this interpolation method,[12] a picture fairly close to reality is given of the density, in every case more plastic than would have been possible to obtain with the same statistical materials based on the administrative boundaries.

The maps of density, drawn with the aid of the isarithmes have, in the course of the last twenty-five years met with criticism of various nature, some of it well founded, but some completely unjust. This has been expressed most acutely by FR. LEYDEN[13] at an evening party for geographers in Berlin. According to LEYDEN the method of isarithmes can, in the most favourable case, mitigate only the harsh contrasts of density, but, according to his principles, it is not fit for representing the full originality of the sudden differences of the density.

The retouching of the sharp differences on many maps drawn by the aid of the isarithmes does not depend, in our opinion, upon any erroneous principle of this method but rather upon the size of administrative units which have been used, and upon the intervals at which the isarithmes have been drawn.[14]

Having enumerated and characterized the principal relative density methods which are based on the administrative units, we are now going into the problem in its entirety in drawing the attention to the maps of the density of habitations derived from the absolute maps. Instead of applying the method of isarithmes on data emanating from administrative territories it is possible to make maps of density, based on large scale dot maps.

During the second World War I.A. BARNES and A. H. ROBINSON[15] have proposed a different method for the representation of the density of dispersed rural population. This method starts from a dot map, on which

[11] See example in M. ZDOBNICKA, Metoda izarytmiczna w grafice statystycznej. *Pokosie Geograficzne*, Lwow-Warszawa 1925; M. DOBROWOISKA, Metody Kartograficzne w badaniach osadniczych. *Pam. IV. Pow. zj. Hist. Pol. w* Poznaniu, Lwow 1925; F. UHORCZAK, Metoda izarytmiczna w mapach statystycznych. *Polski Przeglad Kartograficzny* 1930; E. RUHLE, Uzycie ziemi i rozmieszenie ludnosci na Zachodniem Polesiu. *Wiad. Suzby Geogr., No.* 3, 1930.

[12] This method originates from a Lieutenant of the Danish Navy, NIELS FR. RAVN, and was called the method of isarithmes by E. ROMER, according to a proposal by FESK, an Austrian mathematician. For details consult *Statistisk Tabelvaerk. Ny Raekke, Tolvte Bind, Anden Afdelning, indeholddende Tabeller over Folkemaengder i Kongeriket Danmark.* Utg.af det Statistiske Bureau. Kjobenhavn 1857, p. XVI (Two maps in colours); E. ROMER, Geograficzno-Statystyczny Atlas Polski (Atlas de Geographie Statistique de Pologne), Warszawa-Krakow 1916, tabl. VII; H. HASSINGER, Neue Methoden der Darstellung der Volksdichte auf Karten. *Kartogr. zeitschrift*, VI 1917, No. 3-4, p. 64.

[13] FR. LEYDEN, Die Darstellung der Volksdichte auf Karten. Vortrag auf dem Berliner Kartographenabend am 12. Marz 1930. *Geogr. Anzeiger*, XXXI, 1930, No. 12, pp. 375-382.

[14] See further EDG. KANT, Reflexions touchant les problemes de etude des rapports reciproques de l'homme et de la Terre et les modes de representation sur les cartes de peuplement. *Annales Acad. Scient. Estonicae*, I, 1940.

[15] I. A. BARNES and A. H. ROBINSON, A new method for the representation of dispersed rural population. *The Geogr. Review*, Vol. XXX, 1940, No. 1, pp. 134-1

every dot represents a farm house. If A indicates the total area and n the number of farmhouses, A/n indicates the average area that belongs to a farmhouse. In representing this area by a hexagon, the distance D of a farm from its six neighbours, is equal to twice the height of equilateral triangle obtained by linking the corners of the hexagon to its centre. The area of the hexagon

$$A\,n = \tfrac{1}{2}\sqrt{3}\,D^2$$

consequently

$$D = \sqrt{\frac{2A}{n\sqrt{3}}} = 1{\cdot}11\sqrt{\frac{A}{n}}\,. \qquad (1)$$

Obviously unknown to BARNES and ROBINSON, a Swedish statistician, E. SIDENBLADH[16] used exactly the same formula sixty years earlier for the representation of population densities.

Starting from the dot maps or topographical sheets, one can draw the relative maps in two ways. The density of habitations (d) is the ratio of two quantities—C and A—the number of habitations (C) belonging to a given area (A),

$$d = C/A.$$

In order not to change the basis of the calculation, we have to keep one of them (A or C) constant. In keeping the base area A constant, we count the number of habitations that fall on any given area A, and later we obtain d by reducing these data as per unit area. On the other hand, keeping C constant, we can determine on the map the surface A, under a given number of habitations (c) and then dividing C by A, we get the number of elements that belong to unit area.[17]

The simplest but at the same time the most accurate way of determining d is to take C equal to unity (habitation, farmhouse or house respectively). In this case it is natural to regard on a large-scale topographic sheet or on a dot map, one dot (i.e. one habitation or one farmhouse respectively) as a surface, equal to a square with a side that is equal to the distance between two dots. If we mark this distance by letter X, we get for the area $A = X^2$ and

$$d = 1/X^2.$$

If X is measured on the map, we have to adapt it to the scale of the map or to change the coefficient of the formula. Using the formula.

$$x = \frac{1}{M}\sqrt{\frac{A}{d}} \qquad (2)$$

where X is the (relative) interval between the dots (i.e. between two habitations or settlements), 1/M is the scale of the map, A is the basic unit of the

[16] See E. SIDENBLADH, Folkmangdstatheten och Medelegovidden i Sverige. *Statistisk Tidskrift*, 1880, Nr. 2, and T. HAGERSTRAND, Innovations-forloppet ur korologisk synpunkt. *Meddelanden fran Lunds Universitets Geografiska Institution, Avhandlingar* XXV, 1953, p. 45.

[17] This is the way how an Estonian mathematician A. KARSNA has worked out a map of isolimnarithmes of Estonia. See H. RIIKOJA and A. KARSNA, Jarvede levimisest Eestis. Summary: On the Distribution of Lakes in Estonia. *Tartu ulikooli juures oleva Loodusuurijate Seltsi Aruanded*, XLII, 1935, Nr. 3-4.

area (say, a square kilometer), d is the number of the habitations on this very unit of area (i.e. the density of habitations), then it is possible to transform the topographic map or the dot map into a relative map of habitations.[18]

Starting from the topographic maps[19] of the island Hiiumaa (Dago), Estonia, we have produced a dot map of the location of rural habitations (in fig. 5). Fig. 6 shows, in comparison, a relative map, using formula (2). On this the shading gives a picture of the variation of density of the rural habitations in relation to the general area.

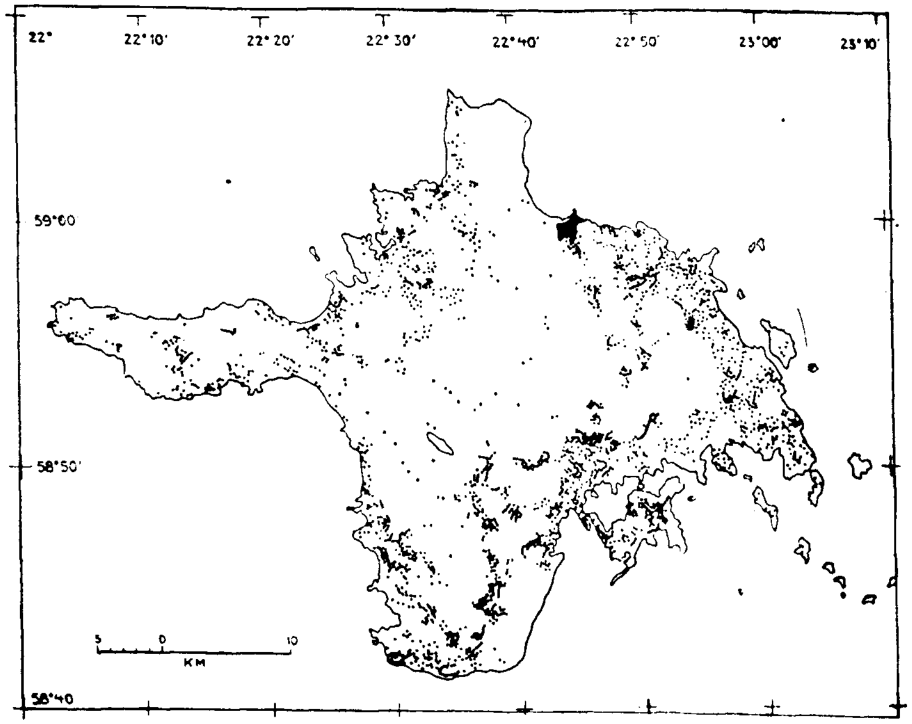

Fig. 5. *Distribution of rural habitations of the island Hiiumaa (Dago), Estonia, by the dot method.* Every dot corresponds to one habitation. The population occupies the coastal rim as the most suitable terrain. The areas in the interior where the high water table causes swampy grounds and forests, constitute the least productive part of the island and are almost unhabitated or sparsely populated.

The detailed examination of the observable facts found on the maps figs. 5 and 6 does not fall in the scope of the present study.

[18] Theoretically this formula has many analogies with the one that the Swedish cartographer G. A. BACKHOFF proposed for the intensity scales on the maps of the distribution of the population drawn with the aid of the dot method (*enhetsprickkartor*) where n=1 and S=1/M.—See G. A. BACKHOFF. Forslag till intensitetsskalor for folktatshets-kartor, konstruerade enligt den absoluta prickmetoden. *Globen*, V, 1926. No. 4. pp. 25-28.

[19] Our cartogram of Hiiumaa was produced from an Estonian General Staff map (scale 1:200,000) : *Eesti topograafiline ulevaatekaart* 1:200,000. Tallinn 1938, sheets 11-21. 21-22.

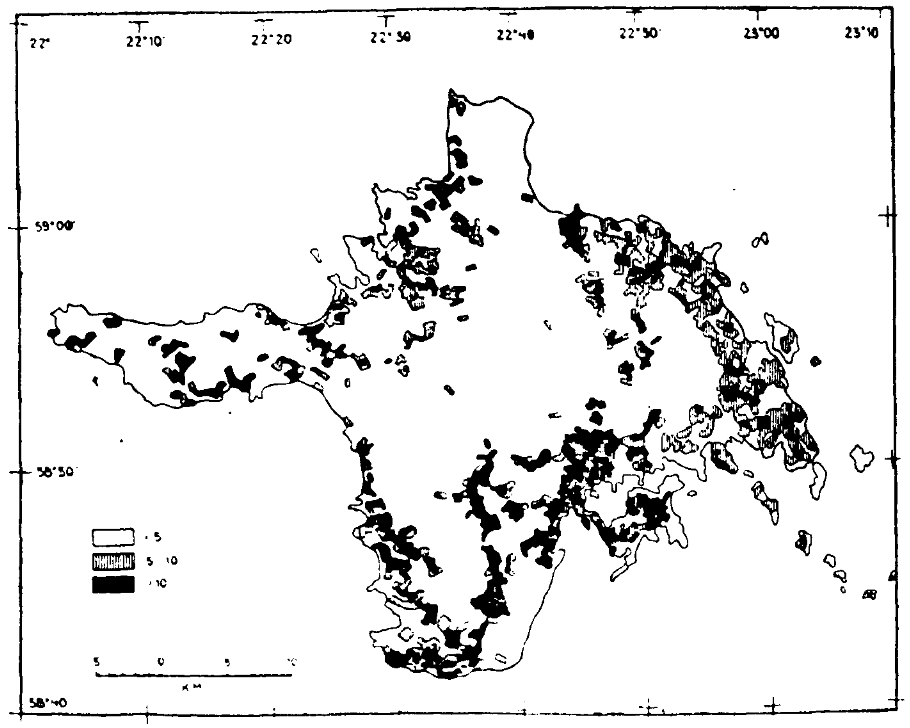

Fig. 6. *Density of rural habitations per sq. km. on the island Hiiumaa (Dago), Estonia, presented according to the relative method using formula (2).* The areas of high densities (darker shading) attract immediate attention. It may be considered that a density of more than 10 represents the area of compact villages; a density less than 5 seems to correspond to the areas of isolated farms. The intermediary values (5—10 habitations per sq. km.) correspond to dispersed settlements or such as the roadside villages.

CONCLUSIONS

Let us, however, formulate some short observations in order to be able to estimate better the practical results to which the applying of the method may bring us.

In comparison with formula (2), the formula of SIDENBLADH-BARNES-ROBINSON (1) gives a more levelled cartographical picture of the density of rural habitations, respectively farmhouses.

Comparing the relative maps of the density of habitations, as drawn by using formula (2) with the map-nomograms, proposed by A. KARSNA and H. RIIKOJA, we find that the former is superior in a more exact presentation of the local conditions, whereas the latter gives the average density for a certain territory, having, in their turn, the advantage of unform precision over the whole map.

Relative maps, based on either the topographic charts or the dot maps, seem to be the most exact representations of geographical interdependencies. Starting from a conventional dot value they make possible the presentation of any shade of detail as well as a large measure of generalization.

The maps of the density of rural habitations which we obtain by this means are, indubitably, a good basis for explaining the existing relations between the human being and the physiographical and ecological factors.

The studies of the geography of settlements in general, and particularly the studies on the density of rural habitations constitute an important part of human geography, for they lay stress upon the essential phenomena which take place in a cultural landscape. They allow us to outline the more or less homogeneous regional units within the limits of a country.

These studies can be of practical value in a variety of applications. For example in question of readjustment of boundaries of administrative divisions, of the siting of public offices, of the building of lines of communications, traffic organisation, electricity grid, in short, in any matter where it is necessary to know the density and grouping of rural habitations.

And finally, be it mentioned in passing that with certain photographic techniques it is possible to convert any absolute dot map directly into corresponding relative density map. We hope to return to these technical questions of cartography on another occasion.

A TWO YEARS' OBSERVATION OF THE ERRAKUPPAM RESERVOIR, MADRAS

By

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A. INTRODUCTION

In the catchment area of the Red Hills reservoir, which is the source of the Madras City Water Supply, there are 141 minor irrigation tanks or reservoirs considerably smaller than the Almati reservoir within an area of 140 Square Miles (Madeley 1914). All of them are formed by damming a depression at its lowest place. Rain water is collected during the two monsoons and the water thus stored is let out for irrigating some adjacent paddy fields depending upon depth and the water-spread. They differ from the Red Hills reservoir in several respects: (*a*) they are much smaller in area and depth, (*b*) completely dry up during summer months, (*c*) not connected to any river system, (*d*) depend only upon rainfall in its own catchment area, which invariably contains no cultivable land. Iyengar (1938) has stated that so far no attempt has been made to investigate the correlation that exists between the nature of their environment and biota. The limnology of one such minor irrigation reservoir of this area which has not been investigated before was studied. It is called Errakuppam reservoir and was studied once a month for two years and four months (September 1940 to December 1942) and the data thus gathered form the basis of this paper.

B. LOCATION, SHAPE, SIZE AND DEPTH

The Errakuppam reservoir constructed about 25 years ago, is situated on a gentle slope in the arid laterite waste lands lying between Sholavaram and Red Hills reservoirs. It is a semi-circular self-contained piece of water, deriving the whole of its water supply from rains falling on the adjacent, somewhat highly elevated little mounds of laterite, during the south-west and north-east monsoon seasons. At its lowest end, an earthen bund of laterite has been constructed to store the rain water thus collected, so that it can be used for irrigating some acres of paddy fields lying below the bund, which runs from east to west, the slope being from south to north. The earthen bund is about 500 feet long which can be considered as the maximum length of the pool, whose maximum breadth is about 100 feet. It is deeper at the western end and shallower at the eastern end. It holds about 50,000 cubic feet of water at its full tank level. Its maximum depth is about 5′—6″ at the deepest place where an outlet is situated for irrigating paddy fields lying below and south of the bund. So, it is nothing but a big rain water pool, which runs dry for a few months every year in the hot weather.

The basin of the pool lies on laterite soil, which is covered with a fine deposit of about 3″ of brownish detritus consisting of finely divided ferric oxide.

C. METEOROLOGY

(TABLE I)

(a) *Rainfall*: The investigation was started in September, 1940 and ended in December, 1942. When it was started, the maximum level of 5′—6″ was recorded at the outlet which was the deepest place. From June, 1940 to September, 1940, which covers the south-west monsoon season 11.57″ of rainfall were recorded (Table I) and from October to December, 1940 (north-east monsoon season) 34.91″ were recorded. At the same time, as the pool was being filled up, water was also let out for irrigation. So, the depth of water recorded on 20th December, 1940, was only 2′—4″. The total fall. for 1940 was 52.72″, which was slightly above the normal of 52″.

In January and February, 1941, as the rainfall was poor being 0.08″ and 0.25″ respectively, there was no rise in level; and as water was also let out for irrigation and due to evaporation, the tank became dry towards the close of February, 1941. There was no rainfall in March, 0.49″ in April and "Nil" in May, 1941; so the pool was completely dry during the summer (March to May, 1941). It was in June, 1941, that 4.32″ of rainfall were recorded and consequently there was a depth of 0.1″ of water. Increasing amounts of rainfall during each of the next three months of the south-west monsoon period (July to September, 1941) resulted in the gradual increase in level in the reservoir. Only half the maximum depth was reached by the end of the south-west monsoon when a total of 15.00″ was recorded. But during the next north-east monsoon period the total precipitation was greater than during the former period. 12.46″, 16.54″ and 8.73″ were recorded for October, November and December, 1941 respectively. The full reservoir level was reached early in October, 1941, which was more or less maintained on account of heavy rainfall during November and December. The total rainfall for 1941 was 57.97″ which was slightly above the normal annual precipitation of 52.72″.

But there was no rainfall in the cold weather of 1942 (January and February) and as the stored water was gradually let out for irrigation and also on account of evaporation, the reservoir ran dry again in March, 1942. A few days prior to the collection of water samples in April, 1942, a fall of 1.37″ was recorded and a pool of reddish coloured stagnant water was formed. Even this water had evaporated and there was no water on the day of sample collections in May,-1942.

Again in June, 1942, a few days before sample collection there was a fall of 1.89″ and a pool of water had collected near the outlet, which was examined. The rainfall during the south-west monsoon was comparatively lower being 2.18″, 3.80″ and 3.68″ respectively for July, August and September, 1942. The total fall for this season was 11.55″ as against 19.32″ for the same season in the previous year. Naturally, the level of water during the south-west monsoon season of 1942 was far lower than in 1941.

Similar partial drought conditions continued in October and November, 1942 when 3.53″ and 2.61″ of fall respectively were recorded. It was only in December, 1942 that 12.94″ of fall was recorded which resulted in the sudden rise in level from 0′—1″ to 4.0 feet.

Summing up, the year 1940 was a normal one when 52.72″ of fall was recorded; and the reservoir had sufficient water for nearly 9 months; 1941 was a little better than 1940 when 57.97″ of fall were recorded, and the reservoir maintained more water than in the previous year for 9 months; 1942 was a partial drought year when only 32.00″ were recorded; and the tank was almost dry for the major portion of the year.

(b) *Temperature*: The mean, maximum and minimum temperatures and the total monthly rainfall are compared below for the three years.

YEARS	Maximum				Minimum			
	Rainfall (inches)		Temperature (°F)		Rainfall (inches)		Temperature (°F)	
	Month	Amount	Month	Amount	Month	Amount	Month	Amount
1940	Nov.	19.01	May	87.6	Jan., Feb. & March	Nil	Jan.	74.4
1941	Nov.	16.64	June	99.1	March	Nil	Dec.	82.9
1942	Dec.	12.94	June	99.2	Jan., Feb. & March	Nil	Dec.	82.1

In 1940 the temperature range was from 74.4°F in January to 87.6°F in May; in 1941 it was from 82.9°F in December to 99.1°F in June and in 1942 it was from 82.1°F in December to 99.2°F in June. 1940 was a normal year in respect of both rainfall and temperature; 1941 had a higher rainfall and temperature, and 1942 had a lower rainfall but higher temperature.

D. METHODS

The methods followed were the same as those described by Ganapati (1943).

E. PHYSICAL CONDITIONS

(TABLES II *a* & *b*)

(i) *Colour of water*: It was deep reddish in colour almost throughout the period of investigation. On a few occasions it had the colour of tea and milk mixture. This showed that the reservoir contained an abundance of inorganic suspended matter of iron compounds.

(ii) *Turbidity* was also very low, as measured by a Seechi's disc at the deepest place. It varied within 6.5 cm. So, it was highly turbid throughout the period of investigation, indicating the presence of a large amount of suspended matter.

(iii) *Temperature of water*: The temperature of water varied from a minimum of 26.3°C in December to a maximum of 31.0° in September in the last four months of 1940: from a minimum of 25.8°C in November to a maximum of 30.4°C in August for 1941; and from a minimum of 25.4°C in

January to a maximum of 32.6°C in September for 1942. Temperature determinations were made between 9-00 and 9-30 a.m. in 1940; 9-45 and 12-15 p.m. in 1941; and between 11-00 and 12-45 p.m. in 1942.

The temperature depended upon the time of collection, the season and the depth of water in the reservoir. For example, the lowest temperature of water was 25.8°C in November, 1941, when the reservoir had maximum water level, although recording was done after midday and the maximum temperature of 30.4°C was found on 30-8-1941 when the depth of water was only 0'-4". Again in 1942, highest temperature of 32.6°C was reached on 26th September, 1942 at 12-30 p.m. when the water level was 0'-2" and the lowest temperature of 25.4°C was reached on 26th January 1942 at 11-15 a.m. when the water level was 3' 3".

F. CHEMICAL CONDITIONS

(TABLES II *a* & *b*)

(i) *Dissolved oxygen:* In the last four months of 1940, it varied between 4.770 cc/1 in September and 5.246 cc/1 in October and the percentage of saturation varied between 81.0 in December and 92.8 in October.

In 1941, the oxygen content varied from a minimum of 4.697 cc/1 in July to a maximum of 5.613 cc/1 in November. The figures for the percentage of saturation varied from a minimum of 81.7 in July to a maximum of 99.1 in January.

In 1942, the oxygen content varied from a minimum of 3.513 cc/1 on 28th April, 1942 to a maximum of 5.746 cc/1 on 24th December and the percentage of saturation between 74.3 in October and 98.4 in December.

Other noteworthy features were: (*a*) the water was not supersaturated with oxygen at any time during the period of investigation and (*b*) the oxygen content also was fairly high at all seasons. The former appeared to be due to the absence of an abundance of phytoplankton, which was evident from the reddish colour of the water. This was also, due probably to the initial presence in water of ferrous iron salts immediately after the rains which in becoming ferric removed a portion of the dissolved oxygen and the persistent presence of ferric compounds in suspension at all seasons corroborated this finding.

(ii) *Hydrogen Ion Concentration (pH):*

The variations in p.H. were as follows:—

(*a*) from 6.8 to 7.1 in 1940; (*b*) from 6.9 to 7.7. in 1941; and (*c*) from 7.0 to 7.7 in 1942. Since the pH of the water did not rise above 8.0 it would appear that the photosynthetic activity also was minimal in the reservoir (Atkins and Harris, 1924).

(iii) *Free* CO_2:

This was always present and varied from 0.110 to 0.132 in 1940: from 0.121 in January, 1941 to 0.260 parts in October, 1941: and from 0.066 in November and December to 0.198 parts per 100,000 in January in 1942.

Its presence at all seasons indicated that they were not completely utilized by plant organisms, which were present in relatively small numbers. The pH of the water did not rise above 8.0 at any time for the same reason, as already stated.

(iv) *Carbonates* (CO_3) *and Bicarbonates* (HCO_3):

Carbonates were not detected at any time, manifestly due to the absence of appreciable photosynthetic activity: and aquatic vegetation was practically absent.

The bicarbonates varied from a minimum of 0.945 parts on 22nd November to 1.159 parts on 20th December in 1940; from a minimum of 1.159 parts on the 29th November to a maximum of 3.05 parts on 27th June in 1941; and from a minimum of 1.067 parts on 24th December to a maximum of 3.66 parts on the 27th November in 1942.

Thus they were generally high when the level of water was low and *vice versa.* The content of bicarbonates was therefore manifestly, derived from the salts in the bottom sediments, when the level was very low and wind action was strong. No correlation could be noted between the bicarbonates and the presence of plant or animal organisms in the water.

(v) *Chlorides:*

They varied from a minimum of 1.5 parts on 22nd November to 4.8 parts on 30th September in 1940: from a minimum of 1.3 parts on 30th August to a maximum of 4.90 parts on 25th February in 1941; and from 1,2 parts on 31st July to a maximum of 3.4 parts on 20th February in 1942.

The increase was due to the concentration when the reservoir level went down. But after drying up, the effects of the first rainfall did not help to increase the amount. Further, there was no possibility for any sewage or other organic contamination, which could effect an increase in the dissolved chlorides.

(vi) *Lime (CaO):*

The values as calculated according to Morton (1931) from the data for bicarbonates follow the same graph as for bicarbonates. The lime content varied from a minimum of 0.43 parts on 22nd November to a maximum of 0.53 parts on 20th December in 1940; from a minimum of 0.53 parts on 29th November to a maximum of 1.20 parts on the 27th June in 1941; and from a minimum of 0.49 parts on 24th December to 1.68 parts on 27th November in 1942. It will be noted that the content of lime in the reservoir was generally very low.

(vii) *Total Solids:*

The figures for the total solids varied from a minimum of 9.8 parts on 22nd November to a maximum of 21.9 parts on 30th September in 1940; from a minimum of 12.8 parts on 22nd December to a maximum of 26.8 parts on 27th June in 1941; and from a minimum of 14.4 parts on the 26th January to a maximum of 91.0 parts per 100,000 on 23rd October in 1942.

They were high generally when the level was low, due to concentration and low when the level increased effecting a dilution of the solids.

(viii) *Organic substances and their decomposition products:*

(a) *Oxidisable organic matter (Tidy's 4 hours' test).*—This was found to vary from a minimum of 0.068 parts on 22nd November to 0.088 parts on 30th September in 1940; from a minimum of 0.040 on 29th November to a maximum of 0.139 parts on 24th January in 1941; and from a minimum of 0.060 on 24th December to a maximum of 0.279 parts per 100,000 on 31st August in 1942.

The records show that the figures for the Tidy's test are low in 1940 and 1941 and uniformly high in 1942. When the level is low, they are considerably higher obviously the result of concentration during the hot weather, as in 1942. The water in the reservoir consisted only of rain water gathered from a relatively clean catchment area of uncultivated land. Therefore the high figures for organic matter in 1942 cannot be said to be due to the presence in excessive amounts of organic matter of animal origin. This is inferred from the very low figures for "ammoniacal nitrogen" and "albuminoid nitrogen".

(b) *Ammoniacal nitrogen.*—The figures were very low and varied from 'Nil' to 0.004 parts per 100,000 during the period of investigation, without any marked seasonal variations.

(c) *Albuminoid nitrogen.*—The figures were very low in 1940 and 1941 and higher in 1942 and followed those for the Tidy's test.

(d) *Nitrites (or Nitrous nitrogen).*—Were occasionally present in traces during the south-west and north-east monsoon rains.

(e) *Nitrates.*—Varied from a trace to 0.004 parts per 100,000. They were present in smaller amounts (.001) during the north-east monsoon season when the level of water was high in the reservoir and in comparatively large amounts when the level was very low.

(ix) *Phosphates:* (P_2O_5) varied from 'Nil' to 0.004 parts per 100,000, the latter figure being noted when the level was high.

(x) *Silicates:* (SiO_2) varied from a minimum of 1.06 on 24th January 1941 and 28th April, 1942 to a maximum of 1.34 parts per 100,000 on 24th December 1942. They were also found to be higher during the south-west and north-east monsoons. They were most probably leached out from the soil of the catchment area.

(xi) *Total Iron* (Fe): was estimated on settled and filtered water samples; it was always present and varied from 0.001 and 0.008 parts per 100,000. No seasonal variations were observed.

G. BIOLOGICAL CONDITIONS

(TABLES III & IV)

a. ***Phyto-plankton:*** Macrophytic vegetation was entirely absent in the reservoir. Phyto-plankton was not rich but was larger than the zoo-plankton in the number of species. (1) The total number of phytoplankton species found was 28 and the percentage composition of the genera are given below:

Serial No.	Name of algal groups.	No. of organisms.	% of the total.
1.	Desmids	16	57.1
2.	Chlorococcales	2	7.2
3.	Xanthophyceae	1	3.6
4.	Myxophyceae	1	3.6
5.	Dinophyceae	1	3.6
6.	Bacillariophyceae	7	25.0
			100.1

It will be seen from the above that Desmids constitute the largest group, while Diatoms, Chlorococcales, Xanthophyceae, Dinophyceae and Myxophyceae come next in order of descendance.

(2) *% Composition of Phytoplankton Species occurring during different seasons of 1940-1942, (total number of Phytoplankton species is 28).*

Algal groups.	Cold Weather.		Hot Weather.		South-west Monsoon.		North-east monsoon.		
	1941	1942	1941	1942	1941	1942	1940	1941	1942
1. Desmids ..	25	18	Dry	Dry	21	4	36	40	36
2. Chlorococcales ..	..	0	,,	,,	7.0	11.0	11	11	7
3. Xanthophyceae ..	1	..	..	..	..	..	..	..	..
4. Diatoms ..	25	18	,,	,,	0	0	18	14	14
5. Dinophyceae.	4	4	,,	,,	4	4	0	0	0
6. Myxophyceae.	4	4	,,	,,	0	0	4	4	0

It will be seen from the above that during the north-east monsoon season of 1940, 1941 and 1942, Desmids constituted the largest group and together with Chlorococcales formed nearly 50% of the total number of species. Diatoms were subdominant forming 14-18% of the total. Blue-greens forming only 4%.

In the cold weather of 1941 and 1942, the number of species of Desmids and Diatoms was found in nearly equal numbers. Compared with their occurrence in the previous season, Desmids were comparatively lower, but Diatoms had increased. Dinophyceae and Myxophyceae constituted each 4% of the total number of species.

In the hot weather the reservoir became dry completely and all the organisms had died out.

Next, in the south-west monsoon season of 1941, 21% of the species were Desmids, 7% Chlorophyceae and 4% Dinophyceae. But in 1942, 4% were Desmids, 11% Chlorophyceae and 4% Dinophyceae. It is interesting to record that the organisms of the three groups developed soon after the reservoir had become dry.

(3) *Dominant forms:* Among the Desmids, the dominant organisms were *Desmedium Baileyi, Hyalotheca undulata, Onychonema unicinatum*; and the common forms were *Arthrodesmus convergens, Euastrum Spinulosum. Staurastrum Cyclacanthum, Staurastrum Japanicum* v. *apiculiferum.*

Botryococcus Braunii was the common organism of the Xanthophyceae group.

Microcystis flosaquae was the most dominant and the only organism of the Myxophyceae group, and *Peridinium gatunens* was the common organism and the only one of the Dinophyceae group.

Seven forms of Diatoms were seen. Among them, *Melosira granulata, Melosira granulata* v. *valida, Navicula cryptocephala* v. *intermedia* and *Stephanodiscus astrea* were the common forms occurring at one time or other.

(4) *Periodicity of the Dominant Organisms:*

(*a*) *Desmedium Baileyi* was found to be rare in September, common in October and very common in November and abundant in December 1940. It became rare in January and February 1941. The reservoir was dry in March, April and May. It was very rare in June and July 1941, rare in August, common in September and October, very common in November and abundant in December 1941. It became rare again in January, very rare in February 1942. The reservoir became dry, again, in March, May 1942. It was not detected in April 1942, when there was some water in the reservoir. It became rare in June, very rare in July and scarce in August, and was not found until December 1942, when it became very common.

(2) *Hyalotehca undulata* was stray in September, rare in October and common in November and very common in December 1940. It was rare in January and very rare in February 1941; the reservoir was dry in March, April and May 1941. It was found again as very rare in August, common in September, most common in October, very common in November and common in December 1941. It was not seen until December 1942.

(3) *Onychonema uncinatum* was found to be stray in October and November, and common in December 1940, stray again in January and June 1941, very rare in July, August, rare in September, common in October, very common in November and most common in December 1941. It was rare in January and stray in February and common in December 1942.

(4) *Microcystis flos-aquae:* This organism was most dominant in January and February, 1941, rare in December, 1941, common in January, 1942 and most common in February, 1942. It became rare in June, very rare in July and August, 1942 and was not found during the rest of the year.

(*b*) ZOO-PLANKTON.

(TABLE IV)

The Zoo-plankton was represented by the four groups (i) Protozoa, (ii) Rotatoria, (iii) Copepoda and (iv) Cladocera. The total number of Zoo-plankton organisms found was 20; and the percentage composition of each of the several genera is given below:

Serial No.	Name of Genera.	Number of Species.	Percentage of the total.
1.	Protozoa	1	5
2.	Copepoda	3	15
3.	Cladocera	5	25
4.	Rotatoria	11	55
	Total	20	100

It will be seen from the above that rotifers constitute the major group, next come cladocerans, next copepods and last protozoans.

(*a*) *Rotatoria:* Among the 11 forms of rotifers, the organism which was most dominant at one time or another was *Anuraea valga* which was found to be common in October, 1940, very common in November, 1940 and again common in July, 1941. On other occasions it was either rare, very rare or absent.

(*b*) *Copepoda:* Nauplius larvae were most abundant in December, 1940 and July, 1941; very common in June and November, 1941 and January, 1942; common in November, 1940, October and December, 1941 and February, 1942. On other occasions it was rare, very rare or absent.

Next, *Diaptomus* was most dominant in September, 1940, very common in October, 1940, August, September, December, 1941, January and February, 1942; and common in November 1940; in July and October, 1941 and April, 1942. On other occasions it was either rare, very rare or absent.

(*c*) *Cladocera:* Among the cladocerans the most dominant organism was *Moina* which was found in abundance in November, 1940; common in September and October, 1940, June to November, 1941 and in July 1942. On other occasions it was either rare, very rare, or absent.

(*d*) *Protozoa:* Among the protozoans, *Difflugia* was the only dominant form which was found in abundance in June, 1941. It was very common in February and September, 1942; and was common in July, August and September, 1941; and on other occasions it was either rare, very rare or absent.

Copepoda and *Rotatoria* are known to be universally distributed in association with *Cladocera*. Standing pools are known to swarm with one or more species of each of the above three genera, which are known to be strictly seasonal in their life habits; and as the pools dry their eggs sink into the mud

TABLE No. A

Showing the seasonal variations in the Physico-Chemical and Biological Characteristics of the Errakuppam Reservoir

DURING 1940—1942.

SEASONS	COLD WEATHER		HOT WEATHER	S. W. MONSOON		N. E. MONSOON		
Years	1941	1942	1942	1941	1942	1940	1941	1942
A. PHYSICAL :								
1. Depth in Feet	1'6" - 0'6"	3'3" - 0'6"	0'5."	1'0" - 2'9"	1" - 2"	5'6" - 2'4"	5'6" - 4'0"	0'1" - 4'0"
2. Colour	Brown	Br. - Red	Red	Red	Red	Red	Red	Red
3. Turbidity (Cm)	2·4 - 2·0	2·6 - 0·6	...	3·8 - 0·6	...	6·4 - 1·6	6·0 - 4·5	4·5
4. Temperature (°C)	28·0 - 28·8	25·4 - 31·0	31·4	30·4 - 26·2	32·6 - 2·76	29·1 - 26·3	29·2 - 25·8	29·4 - 27·0
B. CHEMICAL :								
5. Total solid parts per 100,000	15·6 - 17·1	14·4 - 19·4	23·3	26·8 - 21·3	14·0 - 46·5	9·8 - 16·0	20·8 - 12·8	91·0 - 18·8
6. D.O. (CC/L) ,,	5·70 - 4·78	5·07 - 5·00	3·51	4·70 - 5·37	4·21 - 5·07	5·25 - 4·79	5·35 - 5·61	4·18 - 5·75
7. % Saturation ,,	99·1 - 84·2	84·6	...	81·7 - 90·8	76·6 - 87·7	92·8 - 81·0	97·0 - 91·5	74·3 - 98·4
8. pH ,,	7·4 - 7·6	7·7	7·7	7·2 - 7·0	7·2 - 7·1	6·8 - 7·1	6·9 - 7·7	7·4 - 7·0
9. Free CO_2 ,,	0·12 - 0·15	0·20 - 0·18	0·18	0·24 - 0·22	0·16 - 0·15	0·11 - 0·13	0·26 - 0·15	0·15 - 0·07
10. CO_3 ,,	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
11. HCO_3 ,,	1·52 - 1·77	1·34 - 1·59	2·32	3·05 - 1·52	2·56 - 2·94	0·94 - 1·16	1·59 - 1·13	3·66 - 1·07
12. CaO ,,	0·70 - 0·81	0·62 - 0·73	1·06	1·20 - 0·70	1·18 - 1·35	0·43 - 0·53	0·73 - 0·53	1·68 - 0·49
13. Chlorides ,,	3·4 - 4·9	2·7 - 3·4	1·4	1·3 - 2·7	1·2 - 1·6	1·5 - 2·5	1·9 - 1·5	2·7 - 1·3
14. Oxygen absorbed (Tidy) ,,	0·139 - 0·138	0·094 - 0·133	0·173	·075 - ·110	0·15 - 0·28	·068 - ·076	·069 - ·040	·154 - ·060
15. Ammoniacal N ,,	Trace	Nil	Nil	Tr. - ·004	Tr.	·002 - Tr.	Nil	·004 - Tr.
16. Albuminoid N ,,	·020 - ·016	·002 - ·016	0·016	·006 - Tr.	·009 - ·045	·004 - ·006	·002 - Nil	·024 - ·016
17. Nitrous N ,,	Nil	Nil	Nil	Nil	Nil	Trace	Trace	Nil
18. Nitric N ,,	Nil	·001 - Nil	Trace	·002 - ·003	·001 - Tr.	·001	·004 - ·001	·001 - ·004
19. Phosphates (P_2O_5) ,,	0·001	·003 - Tr.	Trace	·004 - ·002	Tr.	·002 - ·004	·002 - ·004	Tr. - ·004
20. Silicates ,,	1·06 - 1·08	1·24 - 1·22	1·06	1·16 - 1·24	1·16 - 1·14	1·14 - 1·20	1·30 - 1·20	1·14 - 1·34
21. Iron ,,	0·001	0·001	0·002	·001 - ·003	·001 - ·003	·004 - ·001	·004 - ·001	·002 - ·001

SEASONS	COLD WEATHER		HOT WEATHER	S. W. MONSOON		N. E. MONSOON		
Years	1941	1942	1942	1941	1942	1940	1941	1942
C. BIOLOGICAL								
22. Aquatic Vegetation	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
23. Phytoplankton (c, cc or ccc)	Microcystis flos-aquae (ccc)			Desmedium Baileyi (c) Hyalotheca undulata (c) Peridinium gautunens (c)	..	Desmedium Baileyi (c,cc,ccc) Hyalotheca undulata (c,cc) Euastrum spinulosum (c) Onychonema uncinatum (c) St. cyclacanthum (c) St. Javanicum V. apiculiferum (c) Peridinium gatunens (c) Stephanodiscus astrea (c)	Desmedium Baileyi (c,cc,ccc) Hyalotheca undulata (c,cc) Onychonema uncinatum (c) Peridinium gatunens (c) Melosira granulata (c) M. granulata v. valida (c) Navicula cryptocephala v. intermedia (c)	Desmedium Baileyi (cc) Euastrum spinulosum (c) Onychonema uncinatum (c) Stephanodiscus astrea (c)
24. Zoo-Plankton		Nauplius (ccc) Diaptomus (cc) Difflugia (cc)	..	Anuraea valga (c) Nauplius (ccc) Diaptomus (c,cc) Moina (c) Difflugia (c,ccc)	Diaphanosoma (c) Moina (c) Difflugia (cc)	Anuraea valga (c,cc) Nauplius (c,ccc) Diaptomus (c) Moina (c)	Nauplius (ccc) Diaptomus (c,cc) Moina (c)	Anuraea valga (c) Nauplius (c)

where they remain until favourable conditions return for their regeneration during the next rains. In temperate regions the maximum development occurs when the water reaches its highest temperature, but there are other factors which may modify the time. In the case of the reservoir under study Copepods, Cladocerans and Rotifers occur in abundance in the cold weather and also during the south-west and north-east monsoons when the atmosphere and water temperatures are comparatively lower than during the hot weather. Then the water contains lower amounts of organic matter, phosphates, nitrates, silicates, salts of calcium and magnesium, but an abundance of detritus and dissolved oxygen.

H. INTER-RELATIONSHIP

(VIDE TABLE A)

This minor irrigation reservoir was examined for **28 months** from September, 1940 to December, 1942. On the basis of the availability of water in the reservoir, the investigation covers 4 natural periods : **(a)** from 30th September 1940 to 25th February, 1941, **(b)** from 27th June, 1941 to 20th February, 1942, **(c)** April, 1942 ; and **(d) from 30th June 1942 to 24th December, 1942.** The conditions of existence in each of the above periods are next considered briefly.

(a) *First period from 30th September* 1940 *to 25th February*, 1941 (*6 months*).

From September to December, 1940, the total rainfall was 38.58″ which amounted to 73.2% of the total annual fall. But in January and February, 1941, there was practically no rainfall. Highest level of 5′—6″ was reached on 28th October, 1940 and thereafter the level fell until there was no water in the reservoir after February 1941. The colour of water was reddish or brownish : and was most turbid during the period.

The biological conditions during this period varied. Three distinct phases in the plankton could be easily noted : (i) The first phase : from September, 1940 to November, 1940 when 32.51″ of rainfall was recorded. Zoo-Plankton alone was dominant, *Diaptomus, Moina* and *Anuraea valga* being the dominant organisms. No Phyto-plankton. There was plenty of reddish coloured water in the reservoir, which was well oxygenated. pH was 6.8 ; bicarbonates, lime, organic matter, free and albuminoid nitrogen and nitrous and nitric nitrogen were low. But comparatively larger amounts of phosphates, silicates and iron were present.

(ii) *The second phase December,* 1940 ; was dominated by 3 species of *Desmids* : *Desmedium, Hyalotheca* and *Onychonema.* Nauplius larvae were dominant with *Peridinium gatunens, Stephanodiscus astrea* being sub-dominant. The water was also very highly turbid with a brownish colour, 81% saturated with oxygen and pH was 7.1. Bicarbonates, lime, organic matter, ammonias, nitrites, nitrates, silicates and iron were low but a comparatively large amount of phosphate was present.

(iii) *Third Phase : January and February.* 1941 : This was dominated by the Blue-green alga, *Microcystis flos-aquae with Botryococcus Braunii,*

and a few Desmids being sub-dominant. The conditions of existence had thoroughly changed. The level of water was lowest and the water continued to be brownish and highly turbid though well oxygenated pH varied between 7.4—7.6. Free CO_2, bicarbonates, lime, organic matter, and albuminoid nitrogen were comparatively higher than during the previous period. Nitrites and [illegible] Iron was also

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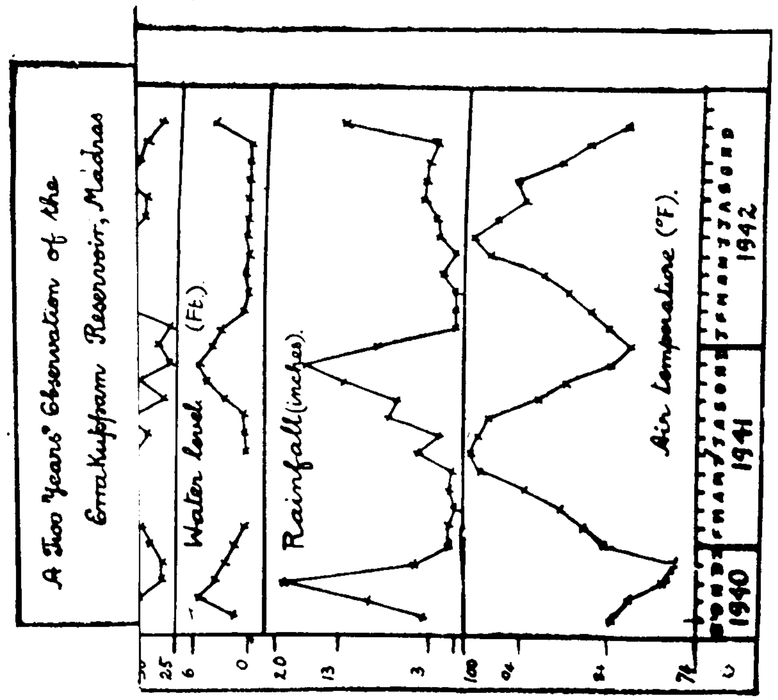

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(c) *Third period :* In March. 1942, there was no water, and in April, 1942, a pool was formed on account of 1.37″ of rainfall. Zoo-plankton such as *Diaptomus,* and *Diaphanosoma* and *Ceriodaphnia* were sub-dominant, and *Botryococcus Braunii* and *Peridimium gatunens* were also found in small numbers (r). The water was very low, reddish in colour, and the temperature high.

(d) *Fourth period: June to December, 1942*: Plant organisms were scarce in all the months excepting December when Desmids were dominant, but animal organisms were present in large numbers on account of drought conditions. The rainfall during this period was 17.69" from June to November, 1942 and 12.94" in December alone. So, the level of water was very low, excepting in December 1942 but the temperature, bicarbonates, lime, organic matter, albuminoid nitrogen, and nitrates were higher and the phosphates, silicates and iron were lower.

I. DISCUSSION

The dominant features of this minor irrigation reservoir are: (i) The catchment area of the reservoir contains very little of cultivable land. (ii) The soil in and around is laterite which contains essentially of iron, alumina and silica. (iii) Practically rain water being the surface run off is collected in the basin. (iv) Water level is not constant but is widely fluctuating and tends to modify the factor complex of the habitat. (v) The reservoir is small and very shallow and is exposed to the sweep of wind from all directions. So, there is the possibility for stirring and mixing of the whole volume of water and this is indicated by the colour and transparency of the water. (vi) The colour of the water is reddish and its transparency is very low. The actual bulk of plankton is rather small. (vii) When the reservoir is full or half-full, there is the dominance of Zoo-plankton consisting of rotifers, cladocerans and copepods. This is followed by a rich Desmid phase with a few *Diatoms* and *Peridinium gatunens* in the north-east monsoon season (October to December). Following the Desmid phase is the Blue-green algal phase accompanied by a few Desmids and Diatoms in the cold weather (January and February) when the water level is lowest. The above sequence of algae and animals is found in the normal year in 1940-41 and is repeated in 1941-1942, when there is high rainfall. But, in 1942-1943, which is a partial drought year though the number of plant and animal organisms is smaller than in the previous years, Zoo-plankton is found to be greater.

Another interesting feature is the yearly occurrence of the Desmids soon after the reservoir had become dry. They seem to survive the drought period forming *zygospores* contrary to the prevailing view that they die quickly if they dry up in their vegetative condition. This observation simply confirms Iyengar's finding (1938) in this regard.

Pearsall (1932) has examined the composition of the phyto-plankton in relation to the physical and chemical conditions in English lakes. He found no relation between peaty water and the occurrence of Desmids but found the latter in waters which were clearest, least coloured, contained low organic matter, calcium content, N/P ratio, carbonate hardness and pH. Phosphates and silicates were high. Except for the differences in colour of the water which was highly coloured reddish and for the high total solids, his other findings are confirmed. All other factors in our reservoir are almost similar to those described by Pearsall (loc-cit) for waters containing a preponderance of Desmids. Iyengar (1940) has reported the occurrence of the members of the *Chlorophyceae*, the most prominent groups being the *Volvocales*, *Desmidiaceae* and *Chlorococcales* in the highly muddy and yellowish-brown to reddish-brown temporary, small rain water way-side pools in Madras. In the Errakuppam reservoir, which is several hundred times bigger than the pools examined by Iyengar (loc-cit), Desmids occur under almost similar conditions here as in his rain water pools. But, Hutchinson et al (1932) have

ated that the presence of a large number of Desmids is not determined solely ; the concentration and the Na+K/Ca+Mg ratio. Several other factors are oubtless concerned, he had stated. Sulphates should be taken into account the distribution of Desmids. But Fritsch (1907) found Desmids to be even ore abundant and varied in the waters of Ceylon than in temperate waters. e found filamentous forms in abundance in small stagnant ditches and rockools and attributed their presence to the result of a longer evolution and daptation to poorly aerated waters. In the case of the reservoir covered by is study, although filamentous Desmid flora was dominant as in the waters f Ceylon, it cannot be stated that the water was poorly aerated. On the ther hand it was well oxygenated in the sense that the water was saturated 5 to 99%.

Next, Pearsall (loc-cit) found an abundance of Blue-green algae in ummer after a Diatom maxima when nutrient salts were minimum and organic atter as indicated by albuminoid nitrogen high. In the case of our reservoir *icrocystis flos-aquae* was found to attain its maximum after a Desmid hase in the cold weather, when organic matter (Tidy's) and albuminoid itrogen were also comparatively high.

According to Pearsall (loc-cit) *Melosira granulata* shows a definite orrelation with waters rich in organic matter and in Myxophyceae and forms naxima in waters of low calcium content. But in the reservoir under disussion, this organism was sub-dominant on 22nd December, 1941, when organic natter (as represented by Tidy's absorbed oxygen figure and albuminoid itrogen) was very low, when the Myxophycean element was rather "rare" (r) and the calcium content also was very low.

So, the conditions of existence in Errakuppam reservoir for the major portion of a normal year when there is a fairly large volume of water resemble essentially those of English, primitive lakes in its chemical and biological characteristics. The important differences are its shallowness, high turbidity, solids and periodical drying.

J. ACKNOWLEDGMENTS

My grateful thanks are due to Dr. V. Brehm of the Biological Station, Lunz, Austria and to Dr. P. Bourrelly and to his two colleagues Monseiur E. Mangium and Monseiur P. Fusely of the Museum National D'Histoire Naturalle, Paris for help in the identification of Zoo-plankton and Phytoplankton respectively.

K. SUMMARY

1. The conditions of existence of an astatic type of water in Madras was investigated for 28 months.

2. This minor-irrigation reservoir is filled with rain water from a lateritic catchment area containing no cultivable land; and the water is most turbid and reddish coloured. About 60% of the Phytoplankton consists of Desmids, which survive the drought period forming *zygospores*.

3. Blue-green algae also occur at a later stage when the organic content is higher.

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ɩVOIR, MADRAS.

ɩposition		Phosphates (P_2O_5)	Silicates (SiO_2)	Total Iron	METEOROLOGY
trous	Nitric				
r.	0.001	0.003	1.28	0.002	B.S.S. — C.B.S. — N.W.
,,	0.001	0.002	1.20	0.004	do.
,,	0.001	0.004	1.16	0.001	C.S. — N.W.
,,	0.001	0.004	1.14	0.001	B.S.S. — C.B.S. — N.W.
		1941			
ɩl	Nil	0.001	1.06	0.001	B.S.S. — C.B.S. — N.W.
,,	,,	Nil	1.08	0.001	do.
..	..	..	..	..	.. ..
..	..	..	..	..	.. ..
..	..	..	..	..	.. ..
r.	0.002	0.004	1.24	0.002	C.S. — H.W.
il	0.002	0.002	1.18	0.003	B.S.S. — C.B.S. — H.W.
,,	0.003	0.002	1.16	0.001	B.S.S. — C.B.S. — S.W.
r.	0.002	0.002	1.24	0.001	B.S.S. — C.B.S. — N.W.
,,	0.002	0.002	1.30	0.001	do.
,,	0.004	0.004	1.28	0.001	I.B.S.S. — H.W.
,,	0.001	0.004	1.20	0.001	do.
		1942			
il	.001	.003	1.24	.001	B.S.S. — C.B.S. — S.W.
,,	Nil	Tr.	1.22	..	B.S.S. — C.B.S. — M.W.
.	..	..	..	..	.. ..
il	Tr.	Tr.	1.06	.002	B.S.S. — C.B.S. — S.W.
.	..	..	..	..	.. ..
il	.001	Tr.	1.16	.004	B.S.S. — C.B.S. — M.W.
,,	.001	,,	1.14	.004	B.S.S. — C.B.S. — H.W.
,,	Tr.	,,	1.15	.001	do.
,,	.001	,,	1.14	.001	B.S.S. — C.B.S. — S.W.
,,	.001	,,	1.16	.008	B.S.S. — C.B.S. — H.W.
,	.002	,,	1.14	.002	B.S.S. — C.B.S. — S.W.
r.	.004	.004	1.34	.001	I.B.S.S. — N.W.

ear Blue Sky H.W. : High Wind
oudy Sky S.W. : Slight Wind

TABLE I : SHOWING THE MONTHLY RAINFALL (in inches) AT RED HILLS AREA AND THE AVERAGE TEMPERATURE (°F) AT THE MADRAS CITY.

Months		1940		1941		1942	
		Rainfall (inches)	Temp. (°F)	Rainfall (inches)	Temp. (°F)	Rainfall (inches)	Temp. (°F)
January	..	Nil	74.4	0.08	84.3	Nil	84.1
February	..	,,	76.3	0.25	86.5	,,	86.0
March	..	,,	82.3	Nil	89.2	,,	88.5
April	..	1.75	84.0	0.49	93.0	1.37	91.3
May	..	4.49	87.6	Nil	98.1	Nil	97.4
June	..	1.82	87.5	4.32	99.1	1.89	99.2
July	..	3.63	86.0	1.16	98.6	2.18	96.8
August	..	2.45	84.9	7.17	97.3	3.80	93.6
September	..	3.67	83.9	6.67	91.9	3.68	94.2
October	..	9.83	81.6	12.46	88.7	3.53	89.6
November	..	19.01	77.7	16.64	83.8	2.61	86.3
December	..	6.07	76.6	8.73	82.9	12.94	82.1
Total	..	52.72	..	57.97	..	32.00	,,

THERMAL SPRINGS OF INDIA

By S. KRISHNASWAMY

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Thermal springs are those, whose waters are at a higher temperature in comparison with the mean temperature of the locality.

Every student of Geology knows that the heat of these waters is due to their contact with hot rock. In general, the water of warm and hot springs probably rises from considerable depth. In many cases the source of heat probably is igneous rock (lava) which has not yet become cold. It may be lava which was forced upward toward but not to the surface, or it may be the deeper parts of lava which flowed out on the surface.[1] It is well known that the rocks on the surface have become consolidated and cooled. Therefore the only great store-houses of hot rock will be the bowels of the Earth. Ordinarily the cold crust of the Earth does not allow the loss of heat from the interior of the Earth. But favourable conditions are augured in, at intervals of time, as when excessive strains are accumulated in the Earth or due to isostatic causes, dislocations and fissurings in the crust take-place, thus making it possible for the hot rock masses to pour out and the heat to escape.

Such dislocations and fissurings are intimately associated with the phenomena of earthquakes and with vulcanism.

The thermal springs are commonly found in such zones of crustal weakness and they are specially interesting from the light they throw upon the causes of seismic and volcanic phenomena.

A glance at a map of India shows their distribution in intimate connection with the major and minor trend-lines of crustal-weakness, mainly in association with the major and minor fold-axes of Indian orography. The main distributaries are :—

(1) The North Sahyadri region.

(2) The Central Indian tract.

(3) The Indo-Himalayan area.

The North Sahyadri region includes all the area along the west coast, south of the valley of Tapti and north of Goa, enclosed between the parallels 72°30′ E. and 73°50′ E.

The Central Indian tract includes :—

(1) The Eastern parts of the Rajputana agency.

(2) Parts of Central India, of the Central Provinces and of Orissa and Madras.

[1] Salisbury, R. D.—Physiography (1919), p. 79.

The Indo-Himalayan area, includes the region of the Indus valley, the foot-hills of the Himalayas, the outer-Himalayas and the associated arcs in Assam.

If the presumed intimate association with the fold-axes of Indian Orography is correct, it stands to reason to suppose that the thermal springs of the Eastern Rajputana agency are the oldest, being associated with the fold lines of the Aravallis. Viewed at in this manner the thermal springs of the Indo-Himalayan area should be mere late chapters in India's thermal history. Subsequent to these annals, the various recent earthquakes would have added on their own quota to this long list of thermal springs.

Therefore it is easy to realise that at no stage can the list of such springs be claimed to be complete, since almost every major earthquake and major volcanic outburst is in a position to open up vents through which these heated waters may issue.

North Sahyadri Region

Oldham[2] gives the following list of springs :—

1.	Rajapur	.. 16°38′ N.	73°36′ E.
2.	Mat	.. 16°57′ N.	73°33′ E.
3.	Sanjameshwar	.. 17°11′ N.	73°39′ E.
4.	Rajwari	.. 17°15′ N.	73°37′ E.
5.	Aravalli	.. 17°19′ N.	73°36′ E.
6.	Uneri	.. 17°75′ N.	73°24′ E.
7.	Khed	.. 17°43′ N.	73°27′ E.
8.	Wudaoli	.. 17°56′ N.	73°16′ E.
9.	Savi	.. 18° 6′ N.	73°24′ E.
10.	Pali	.. 18°33′ N.	73°17′ E.
11.	Vijrabhai	.. 19°29′ N.	73° 6′ E.
12.	Nimboli	.. 19°31′ N.	73° 4′30″ E.
13.	Kulbhone	.. 19°30′ N.	73° 3′ E.
14.	Vehloli	.. 19°30′ N.	72°55′ E.
15.	Tuk Muk	.. 19°32′ N.	73° 0′ E.
16.	Haloli	.. 19°40′ N.	72°58′ E.
17.	Kokner	.. 19°42′ N.	72°54′ E.
18.	Satiwali	.. 19°45′ N. (App.)	72°51′ E.
19.	Goregaun	.. 19°50′ N.	72°53′30″ E.
20.	Anaval	.. 20°52′ N.	73°22′ E.
21.	Tulsi-Sham	.. 21°04′ N.	71°06′ E.
22.	Jalandar	.. 23°19′ N.	71°39′ E.

These springs are all situated close to the West Coast (in no case exceeding 25 miles from the coast) on low elevations (below 200 feet above sea-level) and occur either singly or in groups. The temperature of the waters ranges from 100°-157°, the highest recorded being from Mat (16°57′N: 73°33′E), the temperature of this spring being 157° : the average temperature of these springs is about 107°.

[2] Oldham, T.—Thermal Springs of India, M.G.S.I. XIX, pt. 2, p. 7-11.

In the above list, the following large springs deserve special mention :—

Mat.—(16°57′ N.: 73°33′ E.)—Temperature 157°—This thermal spring is situated about a mile to the north of the river Kanjlee, midway between the ghats and the sea in Hutkumbi Mahal. Duncan[3] writes "People are said to be afraid to use the water of this spring on account of the increased consumption of grain and ghee it occasions by creating a voracious appetite.

Rajwari.—(17°15′ N.: 73°37′ E.)—Temperature 110°—There are two springs very close to each other, near to the Sangameshwar stream in the Ratnagiri taluk. The waters of these springs are said to be 'very hot'—almost boiling. Giraud[4] gives the flow as 1½ gallons per minute.

Arauli.—(17°19′ N.: 73°36′ E.)—Temperature—105°—This thermal spring is situated in the Kundari Mahal, close to the Shastri (Sangameshwar) stream. It is remarkable for its sulphur-impregnated waters which are said to possess medicinal properties.

Pali.—18°33′ N.: 73°17′ E.)—Pali lies on the right bank of Amba river "a mile from Palee in the Tanksee taluk of the (Colaba) collectorate"[5]. This spring is noted for its insipid and sulphurous waters, but on standing becomes good and pure.

Vijrabhai.—(19°29′30″ N.: 73°6′ E.)—Temperature—136°—The springs are in the bed of a river at each side of the hill on which the Fort is, about 48 miles north of Bombay."[6] The waters of this spring are at a considerably higher temperature than the usual average. There are four springs situated close to one another and the temperature of the different springs varies a good deal, but are in all cases much higher than the average temperature for these springs in this region.

Nimboli.—(10°31′ N.: 73°4′30″ E.) and Haloli (19°40′ N.: 72°58′ E.) are two of the others noted for the sulphurous nature of the waters.

Anaval.—(20°52′ N.: 73°22′ E.)—Temperature 115°-120°—This spring known in sanskrit as Ushona Udaki is 'said to have been produced by an arrow shot by Rama, in order to supply 18,000 priests who had been miraculously transported there by Hanuman and had no water.'[7] It is situated some 50 miles to the south-east of Surat close to the Anaval village, from which it takes its name.

The following spring is recorded from Kutch, situated between the North Sahyadri region and the Indo-Himalayan area :—

Mhurr.—(23°20′ N.: 69°00′ E.)—This spring has been recorded by Wynne[8] as situated "on the line of the fault which runs along the northern base of the Mhurr hill" "water warmish, saline".

The Indo-Himalayan area.—For purposes of description it is convenient to divide this area into three divisions :—

(*a*) The Indus Valley Division.
(*b*) The Himalayan Division.
(*c*) The Assam Division.

3 Duncan—Trans. Med. Phys. Soc. Bombay, Vol. I.
4 Giraud—Bomb. Med. Phys. Soc. V, p. 256.
5 Giraud—Loc. Cit.
6 Sykes—Geol. Trans. London. 2nd Series IV, p. 427.
7 White—Trans. Roy. Asiatic. Soc. III, pt. 2, 372 (1833).
8 Wynne, A. B.—Geology of Cutch—M.G.S.I. IX, pt. I (1872).

(*a*) *The Indus Valley Division*

Oldham[9] gives the following list :—

1.	Mangapir	24°59′ N.	67°06′ E.
2.	Jein Pir	25°00′ N.	68°03′ E.
3.	Tong.	25°46′ N.	67°36′ E.
4.	Pokran	25°48′ N.	67°48′ E.
5.	Rani-jo-kot	26°07′ N.	67°58′ E.
6.	Khosra-Ka-Wahi	26°08′ N.	67°70′30″ E.
7.	Garm Ab.	26°13′ N.	67°42′ E.
8.	Khai	26°15′ N.	67°42′ E.
9.	Kandhar	26°14′ N.	67°35′ E.
10.	Lakhi	26°16′ N.	67°55′ E.
11.	Pir Ari	26°18′ N.	67°47′ E.
12.	Naing	26°19′ N.	67°32′ E.
13.	Sehwan	26°23′ N.	67°54′ E.
14.	Phadak	26°25′ N.	67°33′ E.
15.	Gorandi	26°26′30″ N.	67°32′ E.
16.	Gaji Pir	26°27′ N.	67°30′ E.
17.	Tandra Rahim Khan	26°30′ N.	67°30′ E.
18.	Wahi-Pandi	26°41′ N.	67°16′ E.
19.	Lakha	28°01′ N.	67°30′ E.
20.	Uch	28°45′ N.	68°40′ E.
21.	Doza Knushti	?	?
22.	Garmo	29°09′ N.	69°53′ E.
23.	Garmab	29°33′ N.	69°54′ E.
24.	Bindar Pir	30°25′ N.	70°30′ E.
25.	Tausa	30°42′ N.	70°37′ E.
26.	Bukur	31°37′ N.	71°07′ E.
27.	Sodhi	32°35′ N.	72°19′ E.
28.	Bukh Ravina	32°40′ N.	71°51′ E.
29.	Hoosein Abdul	33°50′ N.	72°45′ E.
30.	Peshwar	34°00′ N.	

The springs in the above list are situated both on low elevations as well as on high altitude the Sodhi spring being located at a height of 2500′; equally varying as their situation is the temperature of the waters of these springs, which varies from tepid warmth to about 127°, the average temperature being about the boiling point of water.

Below is given the description of a small number of large springs :—

Manga Pir.—(24°59′ N.: 67°06′ E.)—Temperature 127°—This is the name given to a group of three springs situated within a small radius; the temperature of the waters of the three springs is different, varying from 99° to 127°. Regarding these, Vicary[10] says, "two springs are in a basin enclosed by hills, excepting to the north-west and the valley through which there is an entrance from the south-east, springs are in centre of basin, half a mile apart; water sweat". The northern spring is hotter 124° than the other 99°. "Both rise from partings of the strata, which crop out at angles of 50°". The waters of these springs are sulphurous in nature and precipitate a blackish deposit on the stones.

9 Oldham, T.—Op. Cit.—pp. 12-18.
10 Vicary—Q.J.G.S.L. (1847), p. 337.

Lakhi.—(26°16′ N.: 67°55′ E.)—Temperature 105 —This like the Manga Pir comprises a group of three springs, dedicated to Paroach and Mahadeoe, " whose temperatures are 102°, 103° and 105°," and are situated 15 miles to the S.E. of Schwan on the road to Hyderabad. About these springs Macdonald[11] writes " water is like that of the Mugger-Pir hill ; said to have been supped by Lal Shah Bay, a saint who stands to the Sindians in the same relation as Moses to the Hebrews."

Gazi Pir.—(26°27′ N.: 67°30′ E.)—This spring on the Bhil hill, a few miles west of Shah Hoosein rises " from the head of a waterfall . . . . . from one of the numerous clefts which everywhere intersect the Hala mountains, the water being of a pale green colour, with a strong smell of sulphuretted hydrogen and forms large deposits of Tufa."[12] The temperature of the water is about the boiling point.

Uch.—(28°45′ N.: 68°40′ E.)—It is situated on sandstone strata in a valley half-a-mile broad and 2½ miles long. " Vicary was told that a tepid spring existed in the centre of the valley."[12]

Garmab.—(29°33′ N.: 69°54′ E.)—The waters of this spring contain many dissolved salts, including salt-petre. It is situated at the foot of the Mair Hill, 12 miles from Harrand.

Sodhi.—(32°35′ N.: 72°19′ E.)—Temperature—75°. It is the one in the Indus valley region which is situated at the highest elevation, (about 2500′ above S.L.) in a small ravine close to Sodhi village. The waters of this spring are calcareous in nature and they tend to deposit calcareous tufa about the vents.

Bukh Ravine.—(32°40′ N.: 71°51′ E.)—This ravine is close to Musa-khal in Waziristan. Water gives off sulphurretted hydrogen and deposits sulphur.[13]

2. THE HIMALAYAN DIVISION

The springs in the N.W. Himalayas can be divided for purposes of description " into three series—marginal, medial and northern ; the first situated on or near the southern margin of the hills ; the second, among the peaks of the Himalayas ; and the third, north of these, in Tibet."[14]

Oldham[15] furnishes the following list of springs :—Marginal or outer Himalayan series of springs :—

1.	Turnawai	..	34°16′30″ N.	73°21′ E.
2.	Saira	..	33°37′ N.	74°02′ E.
3.	Rajawar	..	33°18′ N.	74°25′ E.
4.	Aknur	..	32°53′ N.	74°48′ E.
5.	Lausah	..	32°23′ N.	76°05′ E.
6.	Teva	..	32°08′ N.	76°14′ E.
7.	Tatwani	..	32°07′ N.	76°46′ E.
8.	Bhasra		31°14′ N.	76°47′ E.
9.	Suni	..	31°14′30″ N.	76°47′ E.
10.	Sansaodarah	..	30°25′ N.	78°11′ E.
11.	Bhadri	..	30°05′ N.	78°28′ E.
12.	Naini Tal	..	29°23′ N.	79°31′ E.

[11] Macdonald—Suw. Rep. 1861-63, appendix (xxxii).
[12] Vicary—Q.J.G.S.L. (1847), p. 345.
[13] Fleming.—J.A.S.B. XXII, 265.
[14] Oldham, T.—Thermal springs of India—M.G.S.I. XIX, p. 18.
[15] Oldham, T.—Loc. Cit.

Central Himalayas (Medial series) :—

13.	Theed	..	34° 5′ N.	74°55′ E.
14.	Pampur	..	34° 1′30″ N.	74°59′ E.
15.	Islamabad	..	33°44′ N.	75°13′ E.
16.	Tatwani			
17.	Bashisht	..	32°16′ N.	77°13′ E.
18.	Kelat	..	32°12′ N.	77°12′ E.
19.	Dharmaur	..	31°59′ N.	77°17′ E.
20.	Kaluth	..	32°01′ N.	77°23′ E.
21.	Manikaru	..	32° 2′ N.	77°25′ E.
22.	Khirgunga	..	31°59′ N.	77°32′ E.
23.	Babut	..	31°44′ N.	77°17′ E.
24.	Jaori	..	31°32′ N.	77°50′ E.
25.	Natpa	..	31°35′ N.	78°02′ E.
26.	Rarang	..	31°31′ N.	78°20′ E.
27.	Puari	..	31°33′ N.	78°21′ E.
28.	Palia	..	30°54′ N.	78°23′ E.
29.	Banassi	..	30°56′ N.	78°23′ E.
30.	Jumnotri	..	31°00′ N.	78°31′ E.
31.	Kharsali	..	30°57′ N.	78°31′ E.
32.	Huri	..	30°54′ N.	78°44′ E.
33.	Gaurikund	..	30°39′ N.	79°04′ E.
34.	Badrinath	..	30°45′ N.	79°22′ E.
35.	Tappban	..	30°29′ N.	79°40′ E.
36.	Bhapkund	..	30°36′ N.	79°51′ E.
37.	Kulsari			
38.	Agur	..		

Northern or Tibetan series of springs :—

39.	Buh	..	35°30′ N. (App.)	74°00′ E.
40.	Issar	..	37°05′ N.	72°50′ E.
41.	Duchin	..	35°58′ N.	74°50′ E.
42.	Bisil	..	35°53′ N.	75°27′ E.
43.	Chutrum	..	35°42′ N.	75°28′ E.
44.	Tosha	..	35°44′ N.	75°44′ E.
45.	Hoto	..	35°43′ N.	75°47′ E.
46.	Chongo	..	35°41′ N.	75°48′ E.
47.	Sneuron	..	35°16′ N.	75°42′ E.
48.	Khorkun	..	35°20′ N.	76°50′ E.
49.	Panamik	..	34°47′ N.	77°34′ E.
50.	Knarung	..	33°53′ N.	77°26′ E.
51.	Kisik Kinl	..	35°40′ N.	78°48′ E.
52.	Gokra	..	34°28′ N.	79°02′ E.
53.	Kuim	..	34°18′ N.	79°02′ E.
54.	Chigar	..	34°05′ N.	78°06′ E.
55.	Shushul	..	33°05′ N.	78°41′ E.
56.	Pugha	..	33°13′30″ N.	78°22′ E.
57.	Kuruchun	..	33° 5′ N.	77°35′ E.
58.	Tsomoriri	..	32°40′ N.	78°10′ E.
59.	Damchok	..	32°40′ N.	79°29′ E.
60.	Changrizang	..	32°03′ N.	78°40′ E.
61.	Kienlung	..	31°02′ N.	80°33′ E.
62.	Terthapur	..	31°06′ N.	80°44′ E.

NEPAL.

63. Sheopuri.
64. Tatapani.
65. Hangthuwa
66. Nangin

SIKKIM ASSAM GROUP

67.	Mechi	.. 26°50′ N.	88°30′ E.
68.	Puklaz	..	
69.	Phug	.. 27°11′ N.	88°24′ E.
70.	Yeumtong	.. 27°46′ N.	88°43′ E.
71.	Momai	.. 27°52′ N.	88°40′ E.
72.	Mangpmu	..	

TIBET

73. Changra

ASSAM

74.	Kopili	.. 25°31′ N.	92°40′ E.
75.	Nainba	.. 26°02′ N.	93°53′ E.

The springs about the foot hills of the Himalayas are comparatively low lying on varying heights ranging from 1,150′—7,000′ above sea-level, the highest being Tatwani (32°07′ N.: 76°46′ E.) on the Lum, beyond Bhand. The waters in the different springs possess extremes of temperatures, some being as low as 72°, while yet others are above the boiling point of water. The springs in the Central Himalayas are situated not only at slightly higher levels, but also their waters are on the average much hotter (av. temp. 134°) the lowest recorded temperature being 100° (Kaluth) and the highest 202° (Mànikan).

Those in Tibet are also situated on higher altitudes as compared to the outer Himalaya, but one not so high, in comparison to the Central Himalayan ones. The waters are also anything from tepid to extremely hot ones registering temperatures of even 175°—185° (Chorkuun—185°). There is not much of available information concerning the Nepal springs. Regarding the Sikkim group (Sikkim and Darjeeling territories), Oldham[16] writes "here we find a small group of thermal sources, several of which are remarkable both for the great elevations above sea-level at which the springs emerge and also for the very high temperature of the water."

3. THE OUTER HIMALAYAN AREA

Rajwari.—(33°18′ N.: 74°25′ E.) Temperature about 140°.

There are three springs close to each other two hot and one cold in between the other two. One of the former is sulphurous in taste.

Aknur.—(32°53′ N.: 74°48′ E.)

This is the collective name to a group of springs on the right bank of the Chenat river on the Trikota Dur mountain. The waters of this spring are hot only for a part of the year.

[16] Oldham, T.—Op. Cit., p. 32.

Lunseh.—(32°23′ N.: 76°03′ E.)—Temperature 72°.

This spring contains many dissolved salts and hence is highly saline.

Tera.—(32 08′ N.: 76 14′ E.)—Temperature 108°

Parish[17] gives the situation "as about 6 miles in a right line from Kangra to the north-west opposite to the village of Silot on the river Guj, a feeder of the *Beas.*" The waters are limpid saline, slightly alkaline. 1000 grs. of water evaporated gave a solid residue of :—

Nacl.	..	9.233
$Cacl_2$	..	0.546
$CasO_2$	..	0.120
$CaCO_4$	..	0.100

A subsequent examination of a larger quantity proved the presence of bromide of sodium 0.012.[18] Encrustation of salts chiefly NaCl is noticeable all about the vent of the spring.

Tatwani.—(32 07′ N.: 76°46′ E.)—Temperature 120°.

This spring is remarkable both for its high elevation as well as for its contained salts, calcareous and ferruginous. "Taste is most nauseous and exceedingly adhesive: chiefly bitter, with a kind of metallic flavour."[19]. The springs are situated on the Lum (name obtained from Lon-salt) a tributary stream of the Brini, 3 miles away from Bhand.

Bhasra.—(31 14′ N. 76°47′ E.).

This spring takes its name from the nearby village of Bhasra. The waters are strongly saline and on account of its aperient action, they are much recommended in cases of goitre, dropsy and rheumatism.[20] .

Suni.—(31°14′30″ N. 77 11′ E.)—Temperature 135°.

This comprises a small group of springs on the right bank of the Sutlej, near to Suni, and is noted both for the sulphurous and saline nature of the waters as also for the many efflorescences of natural salts such as NaCl, Na_2SO_4 & C, around their mouths.

Naini Tal.—(29 23′ N.: 79 31′ E.)—"At the eastern end of the lake; a spring issues from beneath large rocks in the bed of the overflow channel; the water is very sulphurous and deposits a yellowish incrustation. There are said to be several other sulphurous springs on the bed of the lake."—Fedden.

[17] Parish.—J.A.S.B. XVII. VI. p. 285.
[18] Marcadieu.—Ind. Ann. Med. Science III. 532 & IX. 109.
[19] Stewart. Dr. C. J.—MSS. Corr.
[20] Wade.—J.A.S.B. VI. p. 153.

CENTRAL HIMALAYAN AREA

In the Kashmir Valley we find a few springs whose waters emit a peculiar rotting-fish-smell, that of H_2S.

Most of the springs on the peaks of the Himalayas are remarkable for the many dissolved salts they contain.

Bashisht.—(32°16′ N.; 77°13′ E.)—Temperature—138°—This spring of stinking water (due to H_2S present) is found in the valley of Kulu on the [illegible] bank of the river Beas. It contains many dissolved salts chief amongst which are :—

Nacl, Na_2So_4, $CaCl_2$ and $CaCO_3$.

Manikarn.—(32°2′ N.; 77°25′ E.)—Temperature—202°—This is the name given to a small group of springs in a valley tributary to that of the Beas River. They are of enormous volume. The hottest springs are close to the right bank of the Parbatty near the village of Manikarn.[21] The waters are at the highest temperature recorded over here and, like those of the Bashisht contain many dissolved salts and deposit a ferruginous travertine.

Regarding the actual temperatures of the waters, Malle[22] says, "The hottest springs, those above 180°, were in a state of ebullition, due no doubt, in part to an escape of gas . . . . from (some) both water and steam which were squirted forcibly through a small vent. On partially [illegible] ing the opening with the ball of a thermometer, the [illegible]. The heat given off from the spring of largest volume is so great that one [illegible] approach within several feet."

Jaori.—(31°32′ N.; 77°50′ E.)—This group [illegible] on the left bank of the Sutlej, 3 miles [illegible]. Lloyd and Gerard[23] in their tours in the Himalayas [illegible] the clear crystal hot waters, their saline taste and on the absence of any odour. Incrustation of ferruginous deposits is noticeable in the stones and boulders [illegible] in the immediate neighbourhood.

Palia.—Commonly called "Asurigadh" (30°54′ N.; 78°23′ E.) Near the head waters of Jumna, in the bed of the stream several [illegible] clear though sulphureous water are noticeable.

Jumnotri.—(31°10′ N.; 78°31′ E.) Temperature—192.6°—This [illegible] is perhaps with the exception of the higher temperature of the water [illegible] in many respects to Palia (Asurigadh). As in the case of [illegible] the neighbourhood are stained with the red deposit of ferruginous matter.

Tapoban.—(30°23′ N.; 79°40′ E.) Temperature—99°-127°. Schlagintweit[24] reported about these springs. He wrote "There are four [illegible] groups—two about half a mile from the village and two other [illegible] mile from the first. Those near the village have a temperature of [illegible] 109°, the others 123° and 127°. The water is clear and [illegible] yellowish sediment."

[21] Marcadieu—Journ. A.S.B.—XXXV. p. 189
[22] Malle, F. R.—MSS. Notes (1864), quoted by Oldham, Op. Cit. p. 24
[23] Lloyd & Gerard—"Tours in the Himalayas", [illegible]
[24] Schlagintweit—Official returns No. [illegible] quoted by Oldham T. Op. Cit. p. 26

TIBETAN AREA

Oldham[25] lists the following springs from this area :

		35°30′ N.	74°00′ E.
1.	Buth	37°05′ N.	72°50′ E.
2.	[illegible]	35°38′ N.	74°50′ E.
3.	Dachin	35°53′ N.	75°27′ E.
4.	Bisil	35°42′ N.	75°28′ E.
5.	Chutran	35°44′ N.	75°44′ E.
6.	Tosha	35°43′ N.	75°47′ E.
7.	Hoto	35°41′ N.	75°48′ E.
8.	Chong	35°16′ N.	75°42′ E.
9.	Shetaron	35°20′ N.	75°50′ E.
10.	Khorzan	34°47′ N.	77°34′ E.
11.	Panamik	35°38′ N.	77°26′ E.
12.	Kharung	33°40′ N.	78°48′ E.
13.	Kiu Kul	34°28′ N.	79°08′ E.
14.	Gokra	34°18′ N.	79°02′ E.
15.	Kiam	34°05′ N.	78°06′ E.
16.	Chigar	33°36′ N.	78°41′ E.
17.	Sumdo	33°13′33″ N.	78°22′ E.
18.	Pugha	33°5′ N.	77°35′ E.
19.	Kurnchu	32°40′ N.	78°10′ E.
20.	Tsomo[illegible]	32°40′ N.	79°29′ E.
21.	Damchok	32°03′ N.	78°40′ E.
22.	Changrizang	31°02′ N.	80°33′ E.
23.	Kienlung	31°06′ N.	80°44′ E.
24.	Terthapori		

The Tibetan springs are not found on such great heights as the Central Himalayan ones. Their waters again do not reach that maximum of 202° shown by the Manikarn springs in the Central Himalayas. The average temperature of the waters is however generally high above the boiling point, though tepid waters (e.g. Kharung (33°58′ N.; 77°26′ E.) are also known.

Of those quoted above the following deserve a passing mention :—

Chong.—(35°41′ N.; 75°[illegible] E.)—Temperature—169°—This spring situated on the river Braldoh in Baltistan, takes its name from the small village of Chongo, close to which it lies. It is situated 9,700 feet above sea-level. It issues from the summit of a conical mound of tufa, 30 feet high, deposited by the spring.[26]

Dachin.—(35°38′ N.; 74°50′ E.)—Temperature—154°—Vigne[27] writes "Two hot springs rise at the brink of the river, near the plain of Bonj (7000 feet above sea-level). Taste sulphureous and slightly chalybeate; sulphur deposited."

Khorzan—(34°20′ N.; [illegible] E.)—Temperature—185°—This spring [illegible] feet above sea-level, is [illegible] the Koraks, in Baltistan. "The water is sulphurous, depositing gypsum and sulphur."[28]

[25] Oldham—Official [illegible] No. 54, quoted by Oldham, T. Op. Cit. pp. 26-30.
[26] I. Godwin Austen, H. H.—Journ. Roy. Geog. Soc. XXXIV. p. 42.
[27] Vigne—Kashmir & C. II. p. 302.
[28] Vigne—op. cit. p. 388

Panamik.—(34°47′ N.: 77°34′ E.)—Temperature 170.5° to 172°—There are two springs issuing from the hill sides (height 10,500 feet) close to the village of Panamil on the river Nubra. According to Thomson,[29] who visited these springs the water is faintly sulphurous; not perceptibly saline: and there is a calcareous incrustation on the rocks.

Kisik Kiul.—(35°40′ N.: 78°48′ E.)—Temperature—120°—"In Turkestan near Kisil Kiul, there are fifty hot springs chiefly containing common salt; the temperatures vary from 77° to 120°. They are situated below the lake of Kiuk Kuil which is 18,000 feet above sea-level."[30] Schlagintweit records the situation as 15,010 feet above sea level.

Gokra.—(34°28′ N.: 79°02′ E.)—Elevation 16,500′—Temperature about 150°—This spring close to the village of Gokra in Yarkand is remarkable for its carbonic acid gas content. This forms a member of a group of several others in the immediate neighbourhood.

Knarung.—(33°53′ N.: 77°26′ E.)—It is in Ladakh and is noted for the tepid waters.

Pugha.—(33°13′30″ N.: 78°22′ E.)—Elevation 15,269—Temperature 174°—This well known spring in Ladakh is noted for the large supply of Borax which it yields. The waters are sulphurous in nature. Close by there are numerous other hot springs.

Changrizang.—(32°03′ N.: 78°40′ E.)—Temperature—117.5°—Comprises a small group of springs reputed for their curative powers in cases of chronic diseases. They are situated "on the south bank of the Para river, north-west of Changrizanf and a few miles from Shalkar."[31] The waters are sulphurous. Saline incrustations on the sides of the vents are common.

Terthapuri.—(31°06′ N.: 80°44′ E.)—These hot springs (two in number) are found close to the Lake Manasarowar in Hundes. The waters are as usual calcareous in nature and incrustations of calcareous matter are noticeable on the sides of the pools.

Schlagintweit[32] records the presence of the springs along the southern sides of the Kuenluen Range from the origin of the Indus (?) near the Manasarowar Lake to the western Kuenluen around Mustak. According to him, the springs are high lying and the waters warm.

Springs in Nepal.—According to Col. G. Ramsay, a former resident at the court of Nepal, there are two springs. Sheopuri (five days journey *from* Khatmandu in a North-westerly direction) and Tatapani (five days journey *from* the capital in a north-easterly direction). Both the springs are reputed to possess high curative properties and many invalids have derived considerable benefit by bathing in their waters. The waters of these springs possess a highly disagreeable odour and a very nauseous taste.

29 Thomson—Western Himalayas and Tibet, p. 407.
30 Schlagintweit—J.A.S.B. XXVI, pp. 112 & 118.
31 Mallet, F. R.—MSS—Notes August, 1861, quoted by Oldham, Op. Cit., p. 29.
32 Schlagintweit—J.A.S.B.—XXVI, p. 130.

Springs in Sikkim.—Oldham[33] lists the following:—

1. Mechi	..	26°50′ N.: 80°30′ E.
2. Puklaz	..	27°11′ N.: 88°24′ E.
3. Phug	..	27°46′ N.: 88°43′ E.—Temp.—112°.5
4. Yeum Tong	..	27°52′ N.: 88°40′ E.—Elev.—16,000′ Temp.—110-116°
5. Momai	..	
6. Mangpmu	..	26°38′ N.: 88°29′ E.

Practically all of them contain dissolved salts in their waters. The commonest solids are chloride of sodium, sulphate and carbonate of soda and a peculiar whitish deposit which has an offensive smell. The Yeum Tsong waters bear in addition sulphurretted hydrogen.

Assam occurrences.—According to Oldham[34] the following springs are found in the Assam hills and near to Chittagong on the sea.

Assam Hills

Kopili —25° 3′ N.: 92°40′ E. .. 122°

Namba—26°92′ N.: 93°53′ E. .. Scalding

Kopili spring is strongly saline. The Namba spring is noted for the copious discharge of H_2S gas.

Chittagong

Sitakund group—22°08′ N.: 91°43′ E.—The Sitakund group 22 miles to the north of Chittagong was investigated in detail by Pogson in 1778[35] and the description in his own words is given below:—

"There are many springs within a small radius. Babukund is at the end of a valley surrounded by hills: the water is always cold; springs are covered by brickwork. Flames in successive flashes were playing on the surface of the water, which though cold, had the appearance of being boiling, from the volume of perpetually rising bubbles of gas. Water is brackish, sulphurous and chalybeate. There are seven other springs within a circle of six miles called Nuolukka, Kodareedudhee, Burma, Sooruj, Chandur and Seeta. Nuolukka is warm and saline: vapour ignites on the application of flame. Kooaree is hot, saline, sulphurous and chalybeate; vapour ignites. Dudhee water is cold and saline; vapour does not ignite. Burma (Brahma?) very hot and saltish, slightly chalybeate: vapour ignites. Chandur, is on a hill, saline and exceedingly hot "said to have appeared within the last four months. Seeta is pure, limpid water."

THE CENTRAL INDIAN TRACTS

For purposes of description, these tracts can be divided into the following divisions:—

1. Rajputana division.
2. The South-western division.
3. The North-eastern division.
4. The Orissa and Berar division.

33 Oldham. T.—Op. Cit., pp. 32-33.
34 Oldham. T.—Op. Cit., pp. 51-52.
35 Pogson—quoted in Corbyn's Ind. Journ. Med. Phys. Sci. 1-N.S., p. 156.

The springs in the Rajputana division are at comparatively low levels and their waters are moderately hot (slightly above the boiling point of water). The waters do not contain any of the dissolved solids mentioned in the previous pages ; they are usually clear and hot, being both tasteless and odourless. Sulphurous waters are however, noticeable in one or two cases (*e.g.* Surrah : 28°13′ N.: 77°06′ E.) (Tin. 22°48′ N.: 73°30′ E.).

Oldham[36] lists the following occurrences :—

Sunah (Gurgaon district)	.. 28°13′ N.: 77°06′ E.—108°
Pakul	.. 28°21′ N.: 77°17′ E.—
Ganesar	.. 27°40′ N.: 75°53′ E.—
Kanwery (Agra district)	..
Talbrik (Alwar State)	.. 27°30′ N.: 76°25′ N.—118°
Koilesar	.. 27°04′ N.: 75°53′ N.
Mora (Alwar State)	.. 26°42′ N.: 76°44′ N.—120°
Deo Chandeswar Mahadeo (Rajputana desert)	.. 26°18′ N.: 69°51′ E.
Gangra (close to Chittoor)	.. 25°03′ N.: 74°40′ E.— 80°
Lausundra (Baroda State)	.. 22°55′ N.: 73°11′ E.—124°
Tui—(Baroda State)	.. 22°48′ N.: 73°30′ E.—

The South-western division.—The springs here are ordinary hot-water springs possessing no very distinguishing properties. They do not bear any of the dissolved salts so common in the Himalayan area.[37]

Oldham[38] describes the following from this locality :—

1. Khair Para (Sultanpur taluk)	.. 21°44′ N.: 74°30′ E.— 98°
2. Wadla (Shirpur taluk)	.. 21°28′ N.: 75°13′ E.— 90°
3. Nazardeo	.. 21°18′ N.: 75°25′ E.—100°
4. Sunafdeo	.. (Not marked in the topographical map of Khandesh.)
5. Arawad	.. 21°16′ N.: 75°28′ E.—139°

The North-eastern division.—This division includes the springs of the Central Provinces area, those in the Sone valley, in Chota-Nagpur, in Bihar, and thence north-eastward to the vicinity of the Rajmahal hills.

Springs of the Central Provinces—

1. Damarni	.. 21°10′ N.: 75°36′ E.
2. Pili (Gawilghur hills)	.. 21°30′ N.: 77°19′ E.—Temp.— 91°
3. Salbaldi	.. 21°25′ N.: 78°40′ E.—Temp.—100°
4. Anhori	.. 22°36′ N.: 78°40′ E.
5. Budi	.. 22°37′ N.: 78°47′ E.
6. Deori	.. 23°33′ N.: 80°36′ E.—Temp.— 82°
7. Bijeragogarh	.. 24°00′ N.: 80°41′ E.
8. Gupt Gudaoli	.. 25°05′ N.: 80°50′ E.
9. Manikpur	.. 25°04′ N.: 81°08′ E.
10. Kandela	.. 25°05′ N.: 81°16′ E.

Of those listed above, Pili and Anhoni springs are worthy of remark

[36] Oldham, T.—Op. Cit., pp. 33-56.

[37] " "

[38] " "

Pili.—**(21°30′ N.: 77°19′ E.)—Temperature—91°—Pili spring in the Gawilgurh hills is held to be sacred and is a centre of pilgrimage. The water is brackish and possesses a slight aperient action.**

Anhoni.—**(22°36′ N.: 78°40′ E.)**—Anhoni Samoni and Anhoni are two hot springs situated within the Narbada coal basin. They are of great interest, because of the dissolved solids, perhaps the only important example of such an occurrence outside the Himalayan area. According to Medlicott[39] of the Geological Survey of India, " a free discharge of gas occurs, which burns in a receiver with a steady blue flame, the smell being like that of hydrocarbons."

Of the two springs, the eastern one has not only a more copious discharge but possesses higher gas-content as compared to the western one.

The springs of the Sone-valley

Hurma	.. 24°31′ N.: 82°33′ E.
Ganduari	.. 23°36′ N.: 83°18′ E.
Sirguja	.. 23°41′ N.: 83°42′ E.—Temp. 186°
Thatha	.. 23°46′ N.: 84°05′ E.—Temp. 151°
Jarum	.. 23°49 N.: 84°42′ E.—Temp. 132°

Of these the most remarkable is the Sirguja.

Sirguja.—(23°41′ N.: 83°42′ E.)—Ele. 1,460 feet—Temp. 186°—Ball[40] who visited these springs writes " These springs constitute by their number and copious outpourings a very remarkable and in this part of India at least, a unique display. They are all arranged, with one exception, on or in the immediate vicinity of a strong ridge of pseudomorphic quartz and breccia, which evidently marks a line of fracture. It is not easy to say how many distinct active springs there are at Tattapani : but these were seen by me certainly not less than a score, besides which there are indications of many others whose action has either temporarily or wholly suspended. The temperature of the springs varied from 130° to 190°."

Chota-Nagpur Occurrences

Katkamsandi	.. 24°07′ N.: 85°16′ E.—Temp. 110°
Gandwani	.. 23°45′ N.: 85°25′ E.—Temp. 92°
Kowa Gandwani	.. 23°43′ N.: 85°26′ E.—Temp. 92°
Indra Jurga	.. 23°50′ N.: 85°30′ E.—Temp. 102°
Belkapi	.. 24°09′ N.: 85°41′ E.—Temp. 190°
Kesodeh	.. 24°11′ N.: 86°04′ E.—

These are noteworthy for the sulphurous nature of their waters, practically all of them throwing out H_2S. The Katkamsandi and Belkapi springs also possess in addition many dissolved solids, chiefly of the muriates of soda and potash, alkaline sulphates, CO_2, sulphur, Silica and Sulphate of Iron. These form deposits—some of considerable size—on the surface, close to the springs.

[39] Medlicott, H. B.—G.S.I.—Quoted by Oldham, Op. Cit., p. 38.

[40] Ball, V.—M.G.S.I. XV. p. 21.

Bihar Occurrences

*Sheopur (Manbhum district).	23°40′ N.: 86°37′ E.
Tantolya (close to Panchayat Hills) ..	23°41′ N.: 86°48′ E.—Temp. 190°
Nuchibad ..	23°43′ N.: 86°48′ E.
Susinia ..	23°24′ N.: 87°02′ E.
Ahmedpur (Birbhum) ..	23°48′ N.: 87°13′ E.
*Tantipara (Birbhum) ..	24°53′ N.: 87°26′ E.—Temp. 162°
Tantlui (Birbhum) ..	24°03′ N.: 87°22′ E.—Temp. 150°
Ratbalia (Bhagalpur) ..	24°11′ N.: 87°09′ E.
Numbhil ..	24°10′ N.: 87°10′ E.
Bara (Bhagalpur) ..	24°21′ N.: 87°15′ E.—Temp. 145°
Jeswapani (close to Rajmahal hills) ..	24°26′ N.: 87°31′ E.—Temp. 87°
*Monghyr (called Sitakund).	25°22′ N.: 86°36′ E.—Temp. 140°
Paharpur (Bhagalpur) ..	25°18′ N.: 86°34′ E.—Temp. 104°
Bhimband ..	25°04′ N.: 86°27′ E.—Temp. 147°
Bharari ..	25°07′ N.: 86°24′ E.—Temp. 145°
Sitaura (foot of Rajghir hills) ..	25°03′ N.: 85°29′ E.—Temp. 110°
Rajghir (Southern face of Rajghir hills) ..	25°01′ N.: 85°29′ E.—Temp. 108°

(*Hot sulphurous springs throwing much of H_2S gas.)

Sheopur.—(23°40′ N.: 86°37′ E.)—It lies close to the eastern margin of the famous Jherria coal-field, on the left bank of the Damodar River, near the village of Sheopur in the Manbhum district. The waters are sulphurous and much of H_2S is thrown out.

Nuchibad.—(23°43′ N.: 86°37′ E.)—This spring is situated in metamorphic country close to the Chanch colliery, a little to the south of it. The water is sweet.

Tantipara.—(23°53′ N.: 87°26′ E.)—Elev. 290′—Temp. 162°—Name given to a small group of hot springs in Birbhum close to the village of Tantipara. "The hotest spring has a temperature of 162°, the coldest 128°"[41]. The springs throw out much of H_2S gas.

Jerwapani.—(24°26′ N.: 87°31′ E.)—Temperature—87°—This spring of warm waters lies at the faulted boundary of the metamorphics with the Damudas in the southern parts of the Rajmahal hills, close to the village of Gopikandar.

Sitakund.—(Monghyr)—(25°22′ N.: 86°36′ E.)—Elev. 160′—Temp. 140°—This spring is named after the heroine of the great epic Ramayana—Sita. "Sita was pursued by a giant and seeing no other mode of escape took refuge, under ground."[42] There however seems to be no confirmation of this

[41] Sherwill—Rep. Stat. Geog. on Beerbhum, page 14.

[42] Archee—Tours in Upper India. Lond. 11 (1833), p. 118.

legend. In India, names are given to places and streams, without necessarily any specific significance. The waters of the Sitakund of Monghyr taste bitter and they have a stinking smell owing to the presence of H_2S.

Bharari.—(25°07′ N.: 86°24′ E.)—Temperature—145°—"The springs here are known by the name of Janum Kund. They issue out from two orifices in a heap of Jaspideous hornstone rocks. A fine botryoidal sinter deposited from the hot water covers all the rock near."[43]

Raj Ghir.—(25°01′ N.: 85°29′ E.)—Temperature—100°—There are numerous hot springs both in the centre as well as along the southern face of the Rajghir hills. In between, there are also a few cold springs. They all rise out of hornstone rocks.

Orissa and Berar Occurrences

Oldham[44] describes the following springs :—

Oteri	20°12′ N.: 85°34′ E.
Atmalik	20°45′ N.: 84°37′ E.
Loagudi	19°19′ N.: 84°27′ E.
Kotgaon	20°15′ N.: 82°35′ E.
Mezka	
Dalli	20°35′ N.: 81°07′ E.
Chinkadan	21°32′ N.: 81°00′ E.
Unapdeo	19°51′ N.: 78°28′ E.
Ganeri	19°51′ N.: 78°26′ E.
Arjuna	19°50′ N.: 78°51′ E.
Khair	19°54′ N.: 78°57′ E.

Of these Loagudi, Mezka and Khair deserve some notice.

Loagudi.—(19°19′ N.: 84°27′ E.)—Ele. 1,300′—Temp. 110°—This sulphurous spring is "on the eastern face of the Gitrabadi hill, about eight miles from the village of Puramari."[45]

Mezka.—This hot spring is remarkable for the acrid taste of its waters and for the peculiar burnt-charcoal like smell which it emits.

Khair.—(19°54′ N.: 78°57′ E.)—Ele. 870′—Temp. 87°—A group in Eastern Berar arising from the limestone-sandstone (Vindhyan) junction. The springs are intermittent, copious in summer and dry or nearly so during the rainy season. The waters of these, are remarkably pure and uncontaminated.

Southern Occurrences.—This heading will include the following regions—(a) Hyderabad State and (b) The whole of South India.

Hyderabad State.—"West of Hyderabad, there is a small group of thermal sources."[46] The more important springs are given below :—

Kaulagi ..	17°21′ N.: 77°12′ E.	
Ramteeruth ..	16°59′ N.: 77°14′ N.	
Calwa ..	15°36′ N.: 78°16′ E. ..	90°
Lanjabanda ..	15°30′ N.: 78°03′ E.	
Mahanandi ..	15°29′ N.: 78°41′ E.	
Wuddyralla ..	14°58′ N.: 78°18′ E.	

[43] Sherwill—Kurrukpuri Hills—J.A.S.B. XXI (1852), p. 198.

[44] Oldham, T.—Op. Cit., pp. 44-76.

[45] Official Records—Quoted by Oldham, T.—Op. Cit., p. 45.

[46] Oldham, T.—Op. Cit., p. 47.

Most of the springs in this State give an alkaline reaction with litmus paper. Their waters are clear and warm rather than hot and they usually possess a pale bluish tinge.

Ramteeruth is a fault-spring. Calwa is the collective name given to another group of fault springs which flow out through numerous fissures on the sides of the country rocks. Thick beds of calcareous tufa occur around the springs.[47]

South India.—The more important springs occur in the Godavari district, close to the valley of the lower Godavari river.

Two springs Gondala (17°19′ N.: 81°00′ E.) and Buga (17°56′ N.: 80°45′ E.) have been recorded by Oldham.[48] The first one is remarkable for the many dissolved solids it contains. Voysey[49] remarks "the odour of sulphurretted hydrogen (is) sensible but slight; 2,880 grains evaporated left 6 grains of saline matter, consisting of sulphate of soda, common salt and muriate of lime." According to Adolf Schlaginweit[50] it is a fault spring gushing out from "great fissure location or faults which have accompanied the upheaval of the Eastern Ghats, although in the immediate neighbourhood no peculiar alteration in the general features of the country is visible." The spring is situated in the sandy bed of the Godavari river and according to Blandford "emerges fully 12 feet below the sandy surfface of the river bed. Temperature (is) 140°, as nearly as I could take it, probably a degree higher a little deeper down. The spring is near the boundary of the metamorphics and sandstone, near a fault."[51]

The second one Buga, is a usual valley spring and not associated with any faults. It occurs in a sandstone—limestone country. The other occurrences in South India reported by the Collector of Karnul (Kurnool) and quoted by Oldham[52] are given below :—

Chinna Tekur	..	15°43′ N.:	78°03′ E.
Bodavanipalli	..	15°40′ N.:	78°06′ E.
Wulandikonda	..	15°38′ N.:	78°02′ E.
Yembayi	..	15°34′ N.:	78°11′ E.
Dhone	..	15°22′ N.:	77°56′ E.
Malakapuram	..	15°21′ N.:	78°02′ E.
Narmur	..	?	?
Brahmagundam	..	—	—
Panem	..	15°32′ N.:	78°23′ E.
Gadigerevala	..	15°37′ N.:	78°29′ E.
Chamakapalli	..	—	—
Rangapuram	..	—	—
Kotakapalli	..	—	—
Muttalur	..	15°12′ N.:	78°38′ E.

47 Newbold—Mad. Journ. Lit. & Sci. XV, p. 160.
48 Oldham, T.—Op. Cit., pp. 46-47.
49 Voysey—J.A.S.B. II, p. 396.
50 Schlagintweit—Adolf—Rep. Magnetic Survey of India, J.A.S.B. (1857), p. 103.
51 Blandford, W. T.—Of the G.S.I. quoted by Oldham, T., Op. Cit., p. 47.
52 Oldham, T.—Op. Cit., 49-51.

Alamur	..	15°09′ N.:	78°39′ E.
Budravaram	..	15°14′ N.:	78°43′ E.
Chagorimari	..	—	—
Sirwell	..	15°20′ N.:	78°36′ E.
Gajjalabonda	..	—	—
Gopavaram	..	15°26′ N.:	78°40′ E.
Gazulapalli	..	—	—
Kadmala Kalva	..	15°30′ N.:	78°45′ E.
Tinimapuram	..	—	—
Salem	..	11°37′ N.:	78°13′ E.
Irade	..	12°43′ N.:	75°13′ E.
Bhuga	..	14°25′ N.:	78°53′ E.
Botha	..	17°47′ N.:	74°26′ E.

In giving this list, Oldham[53] remarks, "I give this list with a view to licit further information rather than as a satisfactory account of these sources. have endeavoured to ascertain from sheets of the Atlas of India, the geographical co-ordinates of the localities noted but have failed to have many of them." Ie adds "they are all said to be hot; but are most probably only of constant erhaps tepid temperature.

Tattapani.—(33°37′ N.: 73°56′ E.)—Temperature 180°-190°—It is a arge thermal sulphurous spring at Tahi on the Pounch in the Pounch State. The spring issues from a pre-Tertiary limestone, at its junction with the Subathu Nummulitic beds. The volume of water is large, and the water itself s perfectly clear and limid, with a temperature between 180° and 190°; jets and bubbles of sulphurretted hydrogen issue intermittently, but in volume, arge enough to suffuce the atmosphere with its unpleasant odour."[54] Wadia ascribes the source of the heat, to the chemical action of the hydrocarbons derived from the adjacent Subathuu limestone, with pyrites, as represented by equation—FeS_2, CH_4, 30—$2H_2S$, FeO, Co_2."[55] Pascoe's[56] explanation of the cause of the origin of sulphur in these waters as due to the interaction of hydrocarbons with gypsum, is (probably) true in this case too.

Sangla.—(33°40′ N.: 74°18′30″ E.)—This is another very small sulphurous spring, occurring in Pounch State in Eocene limestone strata.

Thermal Springs reported from the Barren Island.—(See V. Ball's paper on the Volcanoes of the Bay of Bengal in the Geological Magazine, Vol. VI, p. 23.)

Close to the landing stage in the Barren Island, there is a hot spring whose waters are perfectly clear and sweet and absolutely non-sulphurous in nature. The temperature of the waters has been variously estimated by different observers; but the rather authoritative investigations of the Andaman Commission have shown it to be between 158° and 160°.

53 Oldham, T.—Op. Cit., 49-51.
54 Wadia, D. N.—Geology of the Poonch State and Punjab, M.G.S.I., LI, pt. 2 (1928), pp. 207-208.
55 Wadia, D. N.—Loc. Cit., p. 208.
56 Pascoe, E. H.—M.G.S.I. XL, p. 480.

Hot-spring in Barren Island.—Situated on the beach at the landing place. Temperature is rapidly falling off. Temperature of the different springs was seen to increase with their proximity to the lava. Water is good when hot. On cooling the water is brackish. We find 200 grains of saline matter per gallon of water. Drinking water is obtainable only from wells. (Mallet, F.R., M.G.S.I. XXI.)

Hot-spring on the Mekran coast.—" Near Jashak at the western end of the coast we find a thermal spring of temperature 128° situated near high-water mark and but little above the sea-level. It is unimportant in volume and has six or seven little surface basins close together. The water emits a strong odour of sulphur and forms a stalagmitic deposit round its margin. There are also springs of pure hot water near Karachi beyond the eastern boundary of the region." [Stiffe's article in the Q.J.G.S. XXX (1874), p. 51.]

THE HYDROGRAPHY OF THE CAUVERY BASIN: ITS GEOGRAPHICAL SIGNIFICANCE

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The Cauvery basin in the South is as important as the Ganges basin in North India. Though the length of the Cauvery is very short when compared to the Ganges yet the economic development of the area drained by this river is so varied and complicated because of the complexity of physical environment that it becomes desirable to study the basin in its true perspective. In our survey of the basin some problems become marked such as the hydrographic features, the water power resources and the irrigation developments. This paper, therefore, deals with a geographical survey of the entire basin giving special attention to the above mentioned problems.

The Cauvery is commonly termed the Dakshina Ganga (the Ganges of the South) and is the most sacred river in South India. The river rises near the Brahmagiri Hills in Coorg at a place called Tala Cauvery.* The river is roughly 528 miles in length, and its drainage area is about 28,000 sq. miles. It passes through three political States, *viz.*, Coorg, Mysore and Madras; more than half its length is in the State of Madras, about one-fifth is in Mysore and one-tenth in the tiny State of Coorg.

Kanake is an important tributary of the Cauvery and meets it at Bhagamandala about 20 miles from the Brahmagiri hills of the Western Ghat region. The Hirigange Hole with its tributaries drain the whole north plateau of Mercara and contribute an immense bulk of water to the Cauvery.

From Frazerpet to Ramnathpura the river flows in a north—north-easterly direction but from Ramnathpura it maintains an easterly direction. Before the water of the Cauvery is impounded at Krishnarajasagar by the construction of an artificial reservoir, the river is joined by its important tributaries the Hemavati and the Lakshmanatirtha, both having their sources in the rainy State of Coorg. At Sreerangapatam the river breaks into two branches, the North Cauvery and the South Cauvery which reunite again forming the river island of Sreerangapatam.

The Cauvery takes the south-easterly direction and is joined by the Kabbini a very important tributary of the Cauvery in the District of Mysore. At Sivasamudram the river breaks into two branches developing two important falls and the reunited river after having given rise to the river island of Sivasamudram for the second time, passes through the hilly forested region developing ravines, rapids, cascades and falls. At Wodapati, after the celebrated Hogenakal falls, the river turns southwards maintaining this direction for a long distance till Erode is reached, when the river takes again the south-easterly direction till it reaches the Bay of Bengal. The important tributaries

* Tala Cauvery is a very sacred place visited by several thousand Indians every year to celebrate the Cauvery feast in October.

of the Cauvery before it reaches Erode are the Lokapavani, the Shimsha, the Arkavati in the North, Palar and Bhavani in the West. At Srirangam the Cauvery river bifurcates itself into two branches for the third time forming the river island of Srirangam.

From Srirangam the river is cut into several branches for irrigation purposes but the most important are the Coleroan, the Cauvery, the Arasaleu and the Vettar which are nothing but tiny channels, and so carry very little water to the sea.

The Geology of the Basin: The Cauvery basin has been carved from the most ancient land mass of the earth. The river for a long distance passes through the Western Ghat region and the Eastern Ghat region consisting of the most ancient and the most complicated rock types of varying hardness and composition giving rise to sandy pebbly and rocky beds in different places. The river in some places traverses beds of granite rock and others, gneisses, schists and charnockites of the Eastern Ghat region. These different rocky beds have varying resistant power; the differential erosion therefore has given rise to rapids and some times falls.

In many places along the basin, the rocks have developed joints and faults, and these features are also partly responsible for the development of cascades and falls.

The Physical Environment of the Basin: The dominant factor of climate that gives rise to a distinctive landscape in different courses of the river is the rainfall. There is very great difference in both the total amount of rainfall and the regime of rainfall, which becomes really complicated, for the western portion of the basin records more rainfall during June to September and the eastern portion from October to January. The total amount of rainfall over the entire basin is regulated more by relief than any other factor. The hilly Western Ghat regions get more rain than the rain shadow plateau to the east of Ghat region. The upper course of the basin records on an average of more than 100 inches per year and most of the rain fall occurring from June to September, the rest of the year is not without rains the amount being comparatively less. The middle course of the basin records less rainfall and is not sufficient for the successful cultivation of rice. The average amount of rainfall is about 30″—35″. The amount of rainfall that occurs along the deltaic region of the basin is not sufficient again though most of the rain occurs during the winter months a period when loss by evaporation is comparatively less. The insufficiency of rainfall is due to the weakness of the South-west retreating monsoon and the North-east winter monsoon. Moreover, the entire deltaic region is a treeless plain devoid of forests to act as barriers against the rain-bearing clouds and to give rise to heavy rains. The most important feature of the rainfall in the basin is marked differences in the amount from year to year; differences which may mean prosperity one year and scarcity another.

The vegetation along the course of the river is the reflection of climate and soil modified by the activity of man. Dense evergreen tropical forests are found along the upper course of the river and when the middle basin is reached, the forests are replaced by woodlands and shrubby vegetation. The woodland vegetation is distributed here and there in hilly regions not easily accessible to man, and is Government controlled. The lower basin is a treeless plain and the vegetation must have been mercilessly destroyed

in the past to give place to subsistance agriculture. The soil in the upper basin and the lower basin is very fertile and gives very good yields. But the soil of the middle basin is stony and sandy. In some places the red soil predominates. Broadly speaking, we find three soil types, namely, the lateritic soil in the upper basin, the red soil in the middle basin and the alluvium in the lower basin.

HYDROGRAPHY OF THE CAUVERY BASIN

(THE REGIME OF THE CAUVERY)

The Cauvery is an important perennial river in South India. There is a marked difference in the flow of water of the Cauvery during different seasons —July and October are the flood months when rains will be plenty and the general level of water in the basin is about forty to fifty feet. In the winter months there will be very small amount of rainfall in the upper course of the river as a result of which the water level in the Cauvery will be lowest, and more than half the supply of water to the lower Cauvery basin comes from the tributaries that have their sources in the Western Ghat region, i.e., the Hirenge Hole, the Hemavati, the Lakshmantirtha, the Kabbini and the Bhavani. These small tributaries have cut deep ravines, their thalwegs being far below the general surface level. The source of water in them might probably be due to springs. The overflow of the underground reservoir may appear in definite springs or in general seepage that contributes to the flow of the surface streams. The Cauvery might be receiving water from under- ground sources, and this is one of the reasons why water is found for all months of the year and why the river is considered as the most sacred one.

With the commencement of the mango showers or coffee blossoms in March or April, there will be sufficient amount of water in the Cauvery river, and this gradually increases with rains in the month of May. There will be plenty of water during the period of general rains and in the month of September there will be a break in occurrence of rainfall. The rain starts again in October with the result the floods of July or August appear again. But great reservoirs have been built at Krishnarajasagar and Mettur to check the flood water and to regulate the flow of water in the river.

From February to May, the river suffers great loss by seepage, evapo- ration and irrigation with the result that the amount of water it sends into the sea, is very small, and sometimes it so happens that the mouths of the river have to be artificially dammed to prevent an inflow from the sea.

THE WATER POWER RESOURCES OF THE BASIN.

South of the Krishna River in a plateau region like peninsular India and with absolutely no prospects of finding the coal or oil deposits the importance of the Cauvery as a source of power is not at all overestimated. But for the Cauvery river, Mysore and the adjoining region would have been 100 per cent agricultural and there would have been almost nil advancement in the industrial development of the basin.

Water power is a natural source of the greatest value and of greater possibilities for the future. Huge potential water power depends on favou- rable conditions of environment which include (a) heavy rainfall, fairly uniform discharge of water through natural lakes, forested watersheds or artificial storage behind dams; (b) a slope or gradient that makes necessary the water of the stream to be used for power development, and a rocky bed so that very little water would be wasted in the form of seepage. The Cauvery river satisfies almost all the conditions. The upper basin is an area of very heavy rainfall distributed for nearly nine months of the year with a maximum from June to September. The river has a high gradient and has developed rapids, cascades and falls, and it provides admirable sites for the construction of artificial dams to store the water and to allow a regular flow of water during the period of less rains. At present there are only two places where the water of the stream has been used for the development of power. One power generating station is set up at Sivasamudram and the other is at Mettur.

The Sivasamudram hydro electric scheme has been the first electrical undertaking in India or indeed in the East. The work was started in 1898 and completed in 1902. At present the production of power is about 69,000 E.H.P. The Krishnarajasagar Reservoir, which has a capacity of 44,000 million cubic feet of storage above the minimum draw off, regulates a constant flow of water to feed the generating station at Sivasamudram. The Mettur Hydro-electric scheme supplies about 14,000 K.W. and the power is supplied to the Districts of Salem, Trichinopoly, Tanjore, North Arcot, South Arcot, Chittor and Chingleput.

The Cauvery basin region is in the process of industrialisation: the great textile industries, the leather industries and the chemical industries will demand large amount of hydro electricity and the potential power resources of the river are very great and if skilfully developed will not only meet the demand of the basin but a surplus will be available for transmission to the outer regions. Mekedatu project is being contemplated by the Mysore Government and if completed it will produce about 15,000 K.W. at the first stage of development.

Irrigation and Agriculture: The greatest value of the Cauvery lies in the use of its water for irrigation purposes. In fact the lower basin has become, so to say, the granary of Peninsular India. Wet crop cultivation is the typical feature of this deltaic part of the basin. Two or three crops a year are not uncommon and this practice is there from time immemorial. The fertility of the soil is renewed every year due to the deposition of silt and alluvium during flood periods of the river and also the addition of manures by the farmers.

The river during its upper and lower courses passes through a rain deficit area. The rainfall is not sufficient to cultivate moisture loving cereals like rice which is par excellence, the staple food crop of the majority of population. Moreover, the rainfall is characterised by its very irregular occurrence. In some years there may be very heavy rains and in other years the amount of rainfall may be far below the average. So it has been a practice of the people of the lower deltaic region to build anicuts and to store the flood waters of the river and to use it during periods of deficiency. Apart from the other methods of irrigation the construction of canals to irrigate thousands of acres of land is a typical feature of the lower basin. Large dams have been recently constructed to impound the flood waters of the basin and to use it for several agricultural purposes. The most important irrigation projects that have been completed are the Krishnarajasagar Reservoir and the Mettur reservoir. The Irwin canal tract in the Mysore State is one of the most important wet crop producing areas, for the tract gets water from the

Krishnarajasagar Reservoir. Surgarcane is the most important cash crop of the area and is grown in and around the District of Mandya. A sugarcane factory has been recently established in the town of Mandya which is developing rapidly into a city.

At Mettur a dam has been constructed mainly to impound the flood waters of the Cauvery and its tributaries the Shimsha, the Arkavati and the Kabbini and to maintain a regular flow of water in the river so that the water can be successfully utlised for the cultivation of several irrigated crops in the lower basin.

In a nut-shell, therefore, the Cauvery basin is tapped to a great extent for irrigation and the flourishing conditions of the farmers along the basin is the result of the water resources of the Cauvery available suitably for the varied agricultural purposes.

Conditions of life are not uniform all over the region, however, and the variations again give an example of climatic control on occupations. Both dry crops and wet crops are raised throughout the middle basin and the deltaic basin, but in the upper basin, with abundant monsoon rains, fairly well distributed for nearly nine months of the year, with slopy and sometimes rugged hilly topography and humid fertile lateritic soils, important commercial crops like coffee, cardamom and other sub-tropical fruits are grown. The enclosed low lands unevenly distributed are given to the cultivation of rice crop and the other garden crops like areca nuts, plantains and vegetables. The agricultural landscape in the upper basin of the Cauvery is quite distinct from the rest of the basin.

From Frazerpet down the valley the landscape changes. The open country is reached. The river flows sluggishly through a denuded plateau, enclosed on both sides by scattered distantly placed rounded hills which give a distinctive physical landscape to the middle basin of the river.

In some places, where the river flows through a deep ravine far below the general surface level, water is not easily available for irrigation purposes, and as a rule, dry crops such as ragi, jola, and oil seeds predominate. But from Krishnarajasagar dam down to the river island of Sivasamudram, the basin on both sides provides irrigation facilities for wet crop cultivation. Water is provided through the Irwin Canal and its several branches for the cultivation of rice, sugarcane and other garden crops.

From Sivasamudram down the basin, we get a woodland region not easily accessible to man to bring it under cultivation. In some scattered places of this region with level topography, cultivation of dry crops is again typical. In and around Mettur we find some area under canal irrigation, the important crops being sugarcane, rice and irrigated cotton.

From Srirangam down the river till it reaches the Bay of Bengal, we get, agriculturally speaking, the most flourishing part of the basin. It is the deltaic region of the Cauvery. The coastal plain consists of alluvium deposited by the river together with certain younger sedimentary rocks. One of the oldest irrigation works in India is the large system of canals which now cover the whole of the delta of the Cauvery basin. There are nearly 1,500 miles of main and branch canals and 2,000 miles of tributaries, irrigating nearly more than a million acres per year. Rice and several varieties of millets are equally important. Among oil seeds groundnuts become of paramount importance. It is an important legume and grown as a rotation crop. Cotton is, in the recent years, becoming important, due to the greater demand for raw cotton from the Textile Mills in and around the basin.

Population is not dense throughout the area for the upper valley region is covered with evergreen forests having a rugged topography haunted by wild beasts and elephants. Only small tributary basins are given for the cultivation of wet crops and so give rise to patches of concentration of population. For nearly six months of the year the upper basin is cut off from the rest owing to heavy monsoon showers and irregular drainage.

The middle basin is fairly well populated, agriculture becomes more important and there is a tendency for the concentration of population. This is one of the rain deficit areas of India, and occasional famines due to periodic occurrance of droughts are not uncommon. But the deltaic region is very thickly populated, the population is mainly agricultural and the towns are comparatively small. Some towns, however, have become important owing to several factors, such as market centre, religious importance and facilities for transport. They are Trichinopoly, Erode, Bhavani and Tanjore.

NOTES AND REVIEWS

THE DELIMITATION OF HUMID AND ARID REGIONS IN THE TROPICS

I

Wilhelm Lauer, in his article "Humide and aride Jahreszeiten in Afrika und Sudamerika und ihre Beziehung zu den Vegetationseurteln". (Bonner Geographische Abhandlungen, Heft. 9) has distinguished the following climatic types in Africa and South America on the basis of duration of humidity and aridity during the year.

1. Tropical continuously humid type (*Taefd*).
2. Equatorial type with one dry season ($Taet_1$).
3. Equatorial type with two dry seasons ($Taet_2$).
4. Tropical summer humid type (*Tfso*).
5. Tropical winter humid type (*Tfwi*).
6. Subtropical continuously humid type (*sTfd*).
7. Tropical and Subtropical continuously arid type (*Tfd* & *sTfd*).
8. Subtropical winter humid type (*sTfwi*).
9. Subtropical summer humid type (*sTfso*).
10. Continuously humid type of temperate latitudes (*Gfd*).
11. Autumn humid type of temperate latitudes (*Gfhe*).
12. Continuously arid type of temperate latitudes (*Gtd*).

For a classification of climate, vegetation and landscape in the tropics, the moisture conditions are decisive. The total precipitation or the duration of the rainy season has been generally used ffor the delimitation of vegetation belts in the tropics, and delimitation of vegetation belts on the basis of total precipitation is not correct, as temperature, an essential factor for evaporation, regulates the effective precipitation for vegetation. The need for finding criteria to bring out the relation between climatic factors and vegetation types was felt long time back.

The duration of the humid and arid seasons, however, appears as a useful criterion for the delimitation of the major vegetation types in the tropics and subtropics. This was already pointed out by H. V. Wissman (1939) and was proved by T. Wang (1941) in his work on the arid, humid and frigid regions in China. N. Creutsburg has published a map of the climatic types of the earth in Pett. Mitt. in 1950 in which he uses the duration of the humid season as the criterion. In this paper, Wilhelm Lauer deals with the differentiation of arid and humid climatic regions and their relation to vegetation belts.

A. Penck, in his classification (1910) considered the area of perpetual snow as a separate region, and he recognised arid, humid and frigid regions. According to Penck, climate is humid, when the annual precipitation is greater than the annual evaporation ($P < E$), and arid, when the annual evaporation is greater than the annual precipitation ($E < P$). The aridity limit is defined by evaporation being equal to precipitation ($E = P$). In frigid regions, snowfall is greater than the loss by ablation, thawing and evaporation.

While the definition of the limit of snow offers no difficulties, that of aridity does offer many. In order to use the simple formula of Penck, evaporation at a place should be known but this is scarcely determined exactly, as it depends not only on climatic components but also on the characteristics of the evaporating surface. The potential evaporation is not measured by evaporimeters. Besides the two types of evaporation: one due to climatic factors alone, and the other, potential evaporation; the actual evaporation plays an important part in determining the arid or humid condition of a place. The value of evaporation is in every case, very difficult to determine and this renders the delimitation of arid and humid regions much more difficult.

Temperature exercises a very great influence on evaporation. It is possible to ascertain a certain empirical relationship between temperature and evaporation. The temperature, as a function of evaporation could be brought into a suitable relationship with precipitation. Such a simple relationship between temperature and precipitation, to be practically applicable, must be expressed in a very simple form, such that it corresponds with conditions in nature.

On the fundamental basis, that with a rise in temperature, evaporation increases, R. Lang suggested the socalled "rainfall factor" in which he found the quotient between annual precipitation (P in mm.) and mean annual temperature (T in °C). Rainfall factor = P/T. The Lang's factor found practical application in the study of soils. But when this factor was represented by P. Hirth in his (Isonotide) maps for the whole earth, it was found to be inapplicable for the differentiation of climatic types. In Lang's formula, temperature exercises too great an influence on evaporation, in other words, with a little rise in temperature, a very great rise in evaporation takes place.

In 1926, de Martonne suggested a new formula which represents an improvement on Lang's factor. In this formula, the influence of temperature on evaporation is minimised by adding 10 to the denominator, and this also made possible, calculation with negative temperatures.

[de Martonne's index of aridity, $i = \frac{P}{(T + 10)}$, (P in mm.; T in °C.]

An index of $i = 20$ corresponds with Penck's aridity limit. This simple formula of de Martonne was criticised, as this was not suitable for climatic division of the whole world. E. Biel (1927) has shown that one should take into account the intensity of rainfall. (Intensity of rainfall = Total rainfall/No. of rainy days).

E. Reichel has improved de Martonne's quotient according to Beil's considerations and used the following formula for his research on Germany. $i = P.R./(T + 10)$, (R—No. of rainy days). In 1935, de Martonne has improved his formula further, in which he multiplied the original formula with the quotient between the number of rainy days (R) at a place and the mean number of rainy days in the surrounding region (R'). His improved formula reads, $i = P.R./(T.+10)R'$. As the number of rainy days is not generally available for stations in Africa and South America, the improved formulae of Reichel and de Martonne cannot be applied.

Finally Koeppen, in his classification of climates, differentiates A and C climates from B climates through the formula $P = 2(T + 7)$. This aridity limit of Koeppen corresponds somewhat with Penck's limit of aridity. This

is shown when Koeppen's formula is compared with de Martonne's formula which is only 3 less in the denominator, if Koeppen's index 2 is multiplied by 10, as he himself suggested, Koeppen's formula then would be: $20 = P/T + 7$, while that of de Martonne's, $20 = P/T + 10$.

In America, C. W. Thornthwaite has calculated the P – E index. The annual index is obtained by adding the index values for each month using the formula, $i = 11.5(P/T+10)^{10/9}$. Unfortunately the rainfall is measured in inches and temperature in °F, which makes calculation with this complicated formula more difficult. Thornthwaite's index 32 corresponds roughly with Penck's aridity limit.

In 1941, T. Wang had elaborated Koeppen's formula. Wang contended that the formula was not applicable, as at temperatures below —7°C, only humid condition is met with. The actual capacity of air for moisture shows however a curve which, at lower temperatures, nears the ordinate asymptotically. With these considerations, he evolved a formula representing a hyperbola, which allows for some possible evaporation even at lower temperatures, *i.e.*, makes arid condition possible even at temperatures less than —7°C. Wang's formula, which is calculated by multiplying the monthly values by 12, is $n[12n - 20(t + 7)] = 3000$, where n represents mean monthly precipitation, t, means monthly temperature, and 3,000, an empirical constant. A graphical comparison with de Martonne's formula shows coincidence at temperatures above 18°C, while at lower temperatures, the curve bends towards the humid side. For a general representation, Wang's formula is less useful owing to the difficult procedure in calculation.

A. Penck recognised three climatic regions on the basis of mean annual temperature and total precipitation. More precision is, however, possible if one applies the formulae for the monthly means. In order to keep the comparability with the annual formula the quotients are multiplied by 12. The formulae of Koeppen and de Martonne, for index 20, are: $20 = 12P/T + 7$, and $20 = 12P/T + 10$. Using this formula, it is possible to know how many months in a year have humid or arid conditions. The question here arises whether it is possible to state definitely the humid or arid condition of a place using only two factors of climate. In order to obtain a sufficiently accurate definition of humid or arid region, it is necessary to know the manifold casual relationships between climatic, pedologic, hydrologic and vegetational components of the region.

De Martonne's formula of aridity was chosen, for its simplicity and because it proved most appropriate (comparing with actual conditions) for the region under study. In order to establish whether a month at a particular place is arid or humid, de Martonne's index of aridity was calculated. All months which had index values less than 20 were considered as arid and those with more than 20 as humid. The number of arid and humid months at each station is thus known.

There are two maps, one for each continent, in which the number of humid and arid months at each station are entered. Isopleths are then drawn delimiting all places with the same number of arid or humid months. These lines which delimit regions having the same duration of humidity are called *isohygromens* (iso—equal: hygro—humid: men—month). Through the delimitation of regions with isohygromens, 13 zones have been recognised. The drawing of isohygromens was simple in regions with a dense network of stations. In regions with a low density of stations, the descriptions of climate and vegetation, besides topographic maps were used. The drawing of lines was specially difficult in regions of high relief where differences in climate are met with in a small area (e.g., Andes, E. Africa, etc.). One can understand the generalised lines in such areas. Three dimensional representation of climate and vegetation regions is indicated by a large number of profiles. The profiles show besides elevation, the number of humid months and the types of vegetation on the surface.

The author used two different types of diagrams which serve to supplement the information represented on the maps. In one diagram, the 12 months are marked on X-axis and the calculated index is plotted on the Y-axis. The points are joined by a smooth curve. This curve shows the course and duration of humidity at the station, similar to a rainfall diagram. The seasonal changes are clearly represented and the index values for each month can be read from the diagram. In the second diagram, the monthly rainfalll is taken on the X-axis and the mean monthly temperature on the Y-axis. The points for each month are joined consecutively to give a polygon for each station. This diagram shows the significance of both factors which determine the humidity of a place, namely rainfall and temperature. This is also specially useful for comparing the conditions at different stations. The number of humid or arid months is known from the line showing the limit of aridity.

II

DELIMITATION OF VEGETATION BELTS ON THE BASIS OF ISOHYGROMENS.

There is a close relationship between the duration of humidity and aridity and the vegetation types in the tropics. Jaeger in his study of tropical vegetation, has distinguished the following vegetation types :—

1. Tropical Rainforest ; 2. Wet Savanna ; 3. Arid Savanna (cultivable); 4. Thorn Savanna (uncultivable arid savanna); 5. Semi desert ; and 6. Desert.

The tropical Evergreen forest finds its limit generally at the isohygromen of 10, *i.e.*, with more than 2 arid months, the shedding of leaves of the tropical trees takes place, the luxuriance decreases, and the forest gives place to another. Exceptionally, in regions of increased precipitation during the humid season, the conditions of evergreen rainforest occur in regions of 9 humid months (*e.g.*, Guinea coast, Niger mouth, etc.).

The region of nine humid months leads generally to the "climatic vegetation type" (klimatische Vegetationstyp) of Wet Savanna, which varies from the more ecologically edaphic types of Monsoon forest to pure high grass Savanna. The limit of Wet and Dry Savanna corresponds in all Savanna regions of South America and Africa with the isohygromen of 7. The same line runs parallel to the Penck's aridity limit as determined by Jaeger for Africa and E. Sorge for South America. It departs in places, according to edaphic factors in the region of 6 humid months.

The Dry Savanna occurs between the isohygromen of 7 and 4 in Africa and undergoes several ecologic and edaphic variations. The isohygromen of 4, coincides with the climatic limit of possible rainfed cultivation

("agronomic aridity limit"; "agronomische Trockengrenze"). In South America, the transition to Thorn Savanna occurs at the isohygromen of 5.

In the region of 4 humid months, the vegetation type of Thorn Savanna is found. In the region of only one humid month, the belt of Thorn Savanna gives place to Semi-desert or desert steppe. In the region without a humid month, desert is found. The coastal deserts of Namib and Atacama are not entirely without vegetation, since sparse plant growth is yet possible through the moisture from fog.

N. Anantapadmanabhan.

GEOGRAPHICAL EXHIBITION AT KARAIKUDI

An exhibition in Geography organised by the Geography Association, Alagappa College, Karaikudi, was declared open on the 15th January, 1955, by Sri A. N. Tampi, B.A. (Oxon), Bar-at-Law, Dip. Edn. (Oxford), Principal, Alagappa College. On this occasion, a portrait of the eminent South Indian Geographer, the late Prof. N. Subrahmanyam was also unveiled by Sri P. Doraikannu Mudaliar, M.A., L.T., Principal. Dr. Alagappa Chettiar Training College. The exhibition was open for visitors for three days. It attracted over 2,500 people from in and around Karaikudi. The exhibition was divided into the following sections : (1) Weather and climate ; (2) Earth, the home of man ; (3) Land-form and relief models ; (4) Maps and charts ; (5) Know your country ; and (6) The technique of map-making. Among the numerous exhibits, a huge model of Mt. Everest showing the route taken by the recent Everest expedition, a working model of an Artesian well, a series of maps entitled "maps are liars", a 'clay tablet' of the natural vegetation of Africa, and the section on "The technique of map-making" attracted much attention.

K. V. Sundaram.

India and Pakistan, a General and Regional Geography : By O. H. K. Spate. 827 pp., 160 figs. Methuen & Co., 65s. 1954.

This is the most comprehensive book on the regional geography of India and Pakistan in any language, Indian or European, and from beginning to end, it is charged with detailed foot notes giving source-information, many of them unfamiliar to geographers outside the sub-continent. The book is divided into 4 parts ; the first deals with the physical geography, the second with the people, the third with the economy and the fourth, much the largest covering more than half the book, with the regions of the sub-continent, an admirably logical treatment.

Most books on the geography of India give a detailed analysis of its economic geography without adequately treating it from the regional point of view, but Prof. Spate, perhaps goes to the other extreme and deals with the regional geography in meticulous detail, even at the expense of economic geography. As the author himself puts it, "there is a large volume of information available about the sub-continent as a whole, widely distributed in the various reports of the Royal Commissions, Gazetteers, tariff board enquiries, etc., most of them of excellent quality," but no one has tried to give in one volume, a detailed regional account of this vast area. Spate's book, therefore, fills a void and he has put all Indian Geographers to shame by this monumental work and students of geography all over the world would be beholden to him. The author is a personification of humility when he states that his attempt "is nothing more than a reconnaissance"; enormous industry has really gone into it.

The three macro regions of the Mountain rim, the Indo-Gangetic plains and the Peninsular bloc are divided into 35 regions of the first order (excluding the islands), 74 of the second order, and with about 225 subdivisions of these, the whole thing appears bewildering, but with the author's sensible approach to the problem of regional geography coupled with his shrewd observations and brilliant generalisations, it not only becomes extremely interesting but also of great practical value, as it enables one to assess in detail in each of these small divisions, those "resources for real advance". It is quite possible that a regional geographer doing intensive field work in India might question the validity of some of these conclusions and this is as it should be. Further refinements of these regional boundaries could and should be made, but it is certain that future work would bring out with greater clarity the significance of his classification in more abundant measure.

However, it must be confessed that the diction is not always simple; it may be quite suitable to British and perhaps American students, but one wonders whether Indian and European students whose mother tongue is not English would find it easy to comprehend. The host of abbreviations which the author employs certainly contribute to making the reading even more difficult, and one wonders whether the gain in space has been really worth while.

These are but small faults in so rich a volume, which is not merely an ordinary text book of geography, but is something much more; it sets forth the geographical facts necessary for the understanding of the life of the peoples of India and Pakistan, a study which involves a consideration of many social trends and facets. Prof. Spate has done a commendable job and admittedly, it is a portrait of reality, free from any distortion.

The price of the book is beyond the reach of most Indian students and one wonders whether the publishers would consider the question of having a cheap Indian Edition for the use of students in India and Pakistan. It would be a pity if the price factor deters its frequent use by the student community.

G. K.

TRANSACTIONS AND PAPERS OF THE INSTITUTE OF BRITISH GEOGRAPHERS: (1954). Publication No. 20: 25sh. net. London: George Philip & Son Ltd. 1954.

The publication No. 20 of the Institute of British Geographers includes the following papers:—

1. The I.B.G.: Retrospect and Prospect—R. O. Buchanan (Presidential Address).
2. Central Europe—Mitteleuropa—Europe Centrale: An analysis of a Geographical term—Karl A. Sinnhuber.
3. The Solent River: A Geomorphological Study—C. E. Everard.
4. Accumulated temperature maps of the British Isles—S. Gregory.
5. Medieval Assessments in North-west Sussex—E. M. Yates.

6. The Economic Geography of Craven in the early nineteenth century—R. Lawton.
7. Land-use changes in the Chilterns—1931-1951—J. T. Coppock.
8. Observations in the delimitation of Farming type region in the Isle of Man—J. W. Birch.
9. A Comparative Study of the Landscape of the Plateau de Millevaches and the Western Cevannes—J. W. House.
10. The Northern margin of grain production in Sweden in the twentieth century—B. Fullerton.

The term 'Central Europe' has lent itself to varying definitions by different geographers. Karl A. Sinnhuber in analysing this term suggests that the term 'Middle Europe' should be used in preference to 'Central Europe' and he states that the definitions of the term, to lead to precision and clarity, could be classified into four groups: (1) as a topographical term; (2) as a physical region; (3) as a political concept; and (4) as a geographical region.

Everard gives an interesting analysis of the physical history of the Hampshire basin, based on his study of the gravel terraces found in the New Forest and Southampton regions and in the Isle of Wight. He recognises twelve stages in the formation of the terraces and suggests that they have been formed in groups alternately by marine and fluviatile agents. The fluviatile agent has been the Solent river system which has finally been destroyed by post glacial submergence.

Gregory has prepared a series of maps for British Isles depicting the mean annual and mean monthly accumulated temperatures (day degrees above 42.8°F—6°C). These maps, as the author indicates, will provide a means of studying and testing the possible interactions between accumulated temperatures on the one hand and the geographical distribution of plants on the other and thus help to determine the validity and value of accumuulated temperatures in the study of ecological problems.

The soil forms almost the sole basis of wealth in regions where agriculture is the main occupation of the people. That this had been so in medieval England has been made clear by Yates in his paper. He has chosen for his study a small area in N.W. Sussex and has shown, by discussion of medieval fiscal assessments and taxations how variations in soil fertility as between neighbouring parishes had determined the prosperity of the different units.

The value of such past records as the muster lists of 1803 and the early censuses of England in the study of the changing economy of England during the nineteenth century has been well stressed by Lawton in his paper. Utilising such material, he has given an interesting account of the change in the economic geography of the Craven District in the West Riding of Yorkshire in the first half of the nineteenth century.

Coppock's paper deals with the land use changes in the Chilterns during the period 1931-1951. Comparing the Land Utilisation Survey's maps of the area prepared during the thirties with the new series prepared by him on the same lines in 1951, he has focussed attention on the two major changes that have taken place in the land use of the Chilterns area; (1) a diminution in the extent of agricultural land due to the building of more houses, development of airfields and extension of mineral workings; and (2) an increase in the acreage of arable land at the expense of the area under permanent grass.

Birch has given a detailed account of the methods of statistical sampling and questionnaire enquiry employed by him—taking an individual farm as the unit—in defining and delimiting the farming-type regions in the Isle of Man. His general observations on the use of these techniques in mapping and studying farming distributions would be of great help to those who wish to pursue similar studies.

House analyses the changes that are taking place in the rural landscape of the Plateau de Millevaches and the Western Cevannes and shows how the character and the rate of change in these two regions are determined by the combined influences of human and physical conditions.

Fullerton describes the changes in the distribution of each of the four main grain crops of Sweeden— rye, wheat, oats, barley—during the period 1919—1944. These changes reflect the northward extension of some crops—especially spring wheat—made possible by the evolution of new varieties better suited to the more rigorous climatic conditions of the north.

A.V.

JOHANNES HUMLUM, 'KULTURGEOGRAFISK ATLAS' (Atlas of Economic Geography), Gyldendalske Boghandel, Nordisk Forlag, Copenhagen, 1955, 2 vols.

Prof. Johannes Humlum, Head of the Department of Geography at the University of Aarhus, Denmark, has just published the third edition of his Atlas of Economic Geography. This work, like the 'Erhvervsgeografisk Atlas' (only another translation of Atlas of Economic Geography) of 1936 its predecessor has ever since its first publication in 1944 been used as a text-book at the two Danish Universities, Copenhagen and Aarhus and at the secondary schools which like in the other continental European countries also take over most of the functions of the colleges, which do not exist. In its present pleasant form the atlas could be used by Indian students with great advantage.

The third edition is in some ways distinct from the earlier ones. The size has been reduced to 10½ by 7¼ inches and is for the first time published in two volumes, one comprising the text and the other the maps. While the text-volume is completely in Danish, limiting its use to the Scandinavian countries, the atlas uses in the following sequence: Danish, German, French and English in equal proportion. All explanations given to the maps may be found fully in these four languages. As the atlas is available separately, it may be used independently or in combination with any text-book, etc., on cultural and economic geography.

What makes the atlas especially valuable is the fact that the informations are up-to-date and generally based on the latest available statistics from 1950 to 1953. The picture we get reflects the post-war conditions of to-day. Just as in the earlier editions, equal-area world maps on Olaf Kayser's projection are employed, the scale is 1 : 225 M and under it an inset map of Europe of a slightly larger scale is printed. Thus only half of a page is covered by the map and there is space for explanations and small subsidiary maps. Only a few special maps cover an extra page.

The first five maps deal with the world's population and its density per square km., with excess of births (India does not at all figure prominently here), arable land and irrigation, then follow more than a humdred maps on food stuffs, live-stock, raw materials and certain basic industrial products, like iron, steel and cement. The squares and circles are directly proportional in area an dthe columns in length. The symbols which show production are coloured red, those which represent exports are in dark red and imports in black.

All the maps are clear and virtually self-explanatory. As far as India is concerned some striking features may be observed, as regards live-stock India surpasses by far the other countries in the number of goats and cattle but does by no means figure correspondingly in the production of milk, cheese and buttter, ghee included.

The text-volume is completely printed in Danish and does not have an English or other summary, which would also be impracticable for a book dealing in a more or less short and precise way with all the subjects depicted in the atlas. What makes this volume attractive are the many photographs most of them taken by the much travelled author himself. Prof. Humlum's stay at Dacca, East Pakistan, for one year in 1952-53 and his expedition to Afghanistan a few years before are reflected in many illustrations. He is no stranger to India: the dip-nets of Cochin, 'Chinna valais' as they are locally known, a typical feature of that region, did not miss his attention.

K.H.B.

THE THIRTEENTH ANNUAL REPORT

OF

THE INDIAN GEOGRAPHICAL SOCIETY

FOR THE YEAR 1954.

The Council of the Indian Geographical Society has the honour to present the following report for the period January 1, 1954 to December 31, 1954.—

The year under review has been no less difficult and trying than the previous years. Finance is the chief bottleneck as it has been. The Society is struggling hard on all fronts.

MEMBERSHIP.

The strength of the Society is shown below :

	1950	1951	1952	1953	1954
Life Members ..	19	19	20	21	23
Honorary Members ..	10	10	10	9	8
Ordinary Members ..	62	74	65	71	77
Total ..	91	103	95	101	108
Institutional Subscribers ..	206	191	206	220	210

It is paradoxical to find that the strength of the Society is not commensurate with its age and achievements. Members and institutions are particularly reminded that they will be helping the Society considerably if they pay their arrears and subscriptions as early as possible.

THE EXECUTIVE COMMITTEE :

The results of the election held in March 1954 are given below :

President : Dr. George Kuriyan.

Vice-Presidents :

Swami Pranavananda,

Sri V. Kalyanasundaram,

Dr. Miss A. R. Irawathy,

Sri M. P. Rajagopalan,

Mrs. R. Radha.

Secretary : Dr. V. L. S. Prakasa Rao.

Asst. Secretary : Miss Rukmini Naganathan.

Treasurer : Sri K. Ramamurti.

Executive Committee : Sri S. V. Ganapathy.

Members of Council :

Sri P. G. Dowie,

„ K. Rajagopalaswamy,

„ C. Rajagopalan,

„ V. S. Gananathan,

„ S. C. Bose.

The Executive Committee consists of the President, the Vice-Presidents, the Secretary, the Assistant Secretary, the Treasurer and the Editor.

FINANCES :

The financial statement for the year ended 31st December, 1954 is setforth in the Auditor's Report. Receipts for the year under various heads amount to Rs. 1,936-10-0, while expenses have been Rs. 1,903-13-0, leaving a balance of Rs. 32-13-0 and including the last year's opening balance, a sum of Rs. 303-13-6 is now in the Bank.

The Society is particularly grateful to the authorities of the Madras University for making an annual grant of Rs. 150/-. Further the Vice-Chancellor has been pleased to allow the effects of the Society to be accommodated in one of the rooms of the Department of Geography at the University Examination Hall; this has given the Society a permanent habitation and the Society takes this opportunity to place on record its deep sense of gratitude to the Vice-Chancellor. The Society also expresses its gratitude to the National Institute of Sciences of India for having donated a sum of Rs. 250/- towards publication expenses.

ACTIVITIES :

The Society is still struggling hard to publish the four numbers of the Journal. During the year, the Society has published Vol. XXIX, No. 1 and Nos. 2 & 3 as a special number on Indian Geomorphology—(a combined issue). The issue No. 4 is in press.

Under the auspices of the Society Prof. N. K. Bose, of the Geography Department, Calcutta University, gave a lecture on "The Cultural Zones of India" (January 1954). Dr. V. V. Ramanadham of Andhra University gave a lecture on "The Dynamics of Spatial Relationships" (February 1954) and Dr. K. H. Buschman of Freiburg (W. Germany), on "The Agricultural Geogra- [illegible] Germany and Scandinavia" (November 1954). Dr. George

Kuriyan, the President of the Indian Geographical Society was in U.S.A., for five months, from June to October 1954, as Consultant to the American Geographical Society on a forthcoming Geographical Compendium on India. It is a pleasure to record that Miss A. R. Irawathy, one of the Vice-Presidents of the Indian Geographical Society, took her Ph.D., degree in Geography from London School of Economics, and is now the Professor of Geography, Presidency College, Madras.

The recognition of the value of the Society's earlier contributions in the development and diffusion of geographic thought is really an inspiration and strength for further work. The Society pledges to work for the advancement of the subject as it did all these years and looks forward with full optimism, to another year of useful work.

University of Madras,
University Examination Hall,
Madras-5.
25th February, 1955.

V. L. S. PRAKASA RAO,
Honorary Secretary.

THE INDIAN GEOGRAPHICAL SOCIETY, MADRAS

Statement of receipts and payments for the year ended 31st December, 1954.

To	RS.	A.	P.
Opening Balance:			
In Current account with Madras State Co-operative Bank Ltd.	223	5	9
Prudential Deposit Account with Madras State Co-operative Bank	47	10	9
	271	0	6
	RS.	A.	P.
Ordinary Membership Subscription ..	240	11	0
Life Membership ..	200	0	0
Journal Subscription ..	1,205	1	0
Grant from the National Institute of Science ..	250	0	0
Journal Advertisement.	40	0	0
Interest on Prudential Deposit	0	14	0
Total ..	2,207	10	6

By	RS.	A.	P.
Stationery ..	20	11	0
Journal Expenses ..	1,412	10	0
Postages	298	8	0
Salary	165	0	0
Bank Charges ..	5	0	0
Sundries	2	0	0
	RS.	A.	P.
Closing Balance:			
In Current account with Madras State Co-operative Bank Ltd.	255	4	9
In Deposit account with Madras State Co-operative Bank ..	48	8	9
	303	13	6
Total ..	2,207	10	6

EXAMINED AND FOUND CORRECT

As per Cash Book & Vouchers produced,

Madras,
Dated: 24th Feb., 1955.

M. K. DANDEKER & CO.,
Chartered Accountants.