

TABLE I

Yield and Composition of Sulphate-Deficient Paddy after Various Treatments

| Season         | Treatments                                      | Appearance of crop after treatment | Yield per plot of 180 sq. ft. |           | Composition of crops at maturity (on dry matter) |       |       |       |
|----------------|---|------------------------------------|-------------------------------|-----------|--|-------|-------|-------|
|                |   |                                    | Straw lb.                     | Grain lb. | Straw  |       | Grain |       |
|                |   |                                    |                               |           | N%   | S%    | N%    | S%    |
| A              | Untreated-affected                              | Chlorotic                          | 6.5                           | 5.3       | 0.85   | 0.062 | 1.22  | 0.094 |
|                | Untreated-healthy                               | Green                              | 11.5                          | 9.7       | 0.40   | 0.22  | 0.98  | 0.138 |
|                | MgCl <sub>2</sub>                               | Chlorotic                          | 5.8                           | 4.9       | 0.88   | 0.064 | 1.28  | 0.08  |
|                | MgSO <sub>4</sub>                               | Green                              | 12.3                          | 9.0       | 0.38   | 0.133 | 0.99  | 0.128 |
| B              | Untreated-affected                              | Chlorotic                          | 6.0                           | 4.6       | 0.82   | 0.057 | 1.32  | 0.084 |
|                | Untreated-healthy                               | Green                              | 11.4                          | 9.8       | 0.9  | 0.118 | 1.00  | 0.119 |
|                | Gypsum (CaSO <sub>4</sub> )                     | "                                  | 12.6                          | 10.2      | 0.38   | 0.138 | 0.95  | 0.135 |
|                | Iron pyrites                                    | "                                  | 13.1                          | 11.3      | 0.39   | 0.129 | 0.98  | 0.129 |
|                | Sulphur   | "                                  | 13.5                          | 11.6      | 0.7  | 0.127 | 0.97  | 0.115 |
|                | NH <sub>4</sub> Cl                              | Chlorotic                          | 6.8                           | 5.2       | 0.85   | 0.061 | 1.21  | 0.081 |
|                | (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> | Green                              | 11.2                          | 9.5       | 0.42   | 0.133 | 0.97  | 0.124 |
|                | Urea  | Chlorotic                          | 7.5                           | 6.2       | 0.77   | 0.09  | 1.28  | 0.88  |
|                | Urea + CaSO <sub>4</sub>                        | Green                              | 12.4                          | 10.2      | 0.41   | 0.118 | 0.96  | 0.119 |
|                | Ca-H <sub>2</sub> P <sub>4</sub>                | Chlorotic                          | 6.2                           | 5.8       | 0.78   | 0.149 | 1.26  | 0.80  |
| Superphosphate | Green   | 12.0                               | 9.9                           | 0.40      | 0.124  | 1.01  | 0.115 |       |

plant. The test is, however, not specific because nitrogen accumulation has been found to occur also in certain other deficiencies studied by the author.<sup>7</sup> (2) The chlorotic plants contained much less total sulphur than the healthy plants. Microtests with benzidine hydrochloride showed the complete absence of sulphate in the chlorotic plants whereas the healthy plants always showed the presence of sulphate. (3) There was no difference between the chlorotic and the healthy plants in regard to their calcium, magnesium or phosphate contents. (4) The manganese contents of the healthy plants and the sulphate-treated plants were distinctly higher than those of the chlorotic plants. (5) The chlorotic plants contained higher percentages of soluble nitrogen and lower percentages of soluble sugars than the healthy plants.

Selected data are presented in the accompanying table to illustrate the salient features of the work. Only the percentages of nitrogen and sulphur are given as these represent the most important information. Full details will be published shortly.

From the experimental work summarized above it will be seen: (1) that the chlorotic plants contained much less sulphur than the healthy plants; (2) that these chlorotic plants responded to sulphate treatment which led to maximum yields and caused a large increase in sulphur content in the plant; and (3) that sulphate treatment corrected all the abnormalities in the chlorotic plants. It may, therefore, be concluded that the symptoms shown by the chlorotic plants are due to a deficiency of sulphate and that added sulphate acted as a direct nutrient to the plant.

It is necessary to point out that from the data

in hand no conclusion can be drawn in regard to the minimum percentage of sulphur in the plant or in the soil which will prevent the chlorosis.

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## NEW YEAR'S HONOURS

HIS MAJESTY THE KING has been pleased to confer the distinction of Knighthood on Dewan Bahadur A. Lakshmanaswami Mudaliar, Vice-Chancellor, University of Madras, Dr. C. W. B. Normand, Department of Meteorology, Mr. C. C. Inglis, Director, Indian Waterways Experiment Station, Poona, Mr. B. J. Wadia, Vice-Chancellor, Bombay University, and Mr. J. J. Gandhi, of the Tata Iron and Steel Company. Mr. F. C. Minett, Director, Imperial Veterinary Research Institute, Izatnagar, becomes a C.I.E. These distinguished personages are all familiar to readers of *Current Science*. Our heartiest felicitations to them!

## ZOOGEOGRAPHICAL DIVISIONS OF THE WESTERN GHATS, AS EVIDENCED BY THE DISTRIBUTION OF HILL-STREAM FISHES

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### INTRODUCTION

THE importance of treating the Western Ghats hill ranges along with the narrow strip of the West Coast as a distinct zoogeographical subdivision of Peninsular India has been recognised by several workers. Blanford in his classical work on the distribution of vertebrates of India designates this area as the Malabar Tract. Based on the distribution of freshwater sponges and polyzoa, Annandale found it necessary to divide Peninsular India into two subdivisions, (a) main area consisting of the Peninsula east of Western Ghats, (b) Malabar zone including Western Ghats and the West Coast. Prashad,<sup>30</sup> taking into consideration the results of systematic work on various groups of animals, suggested Peninsular India and Ceylon as one of the five divisions of India, with the Malabar zone as a distinct subdivision. A critical study of the literature on the fish fauna of Peninsular India not only indicates the necessity to regard the Western Ghats together with the hill ranges of Ceylon as distinct from the rest of Peninsular India and Ceylon but also points out the need for further dividing Western Ghats into distinct zoogeographical divisions. The facts of distribution which favour such a division and the probable causes that are responsible for the isolation of fishes on the Ghats are recorded in this paper.

### ORIGIN AND EVOLUTION OF WESTERN GHATS FISH-FAUNA

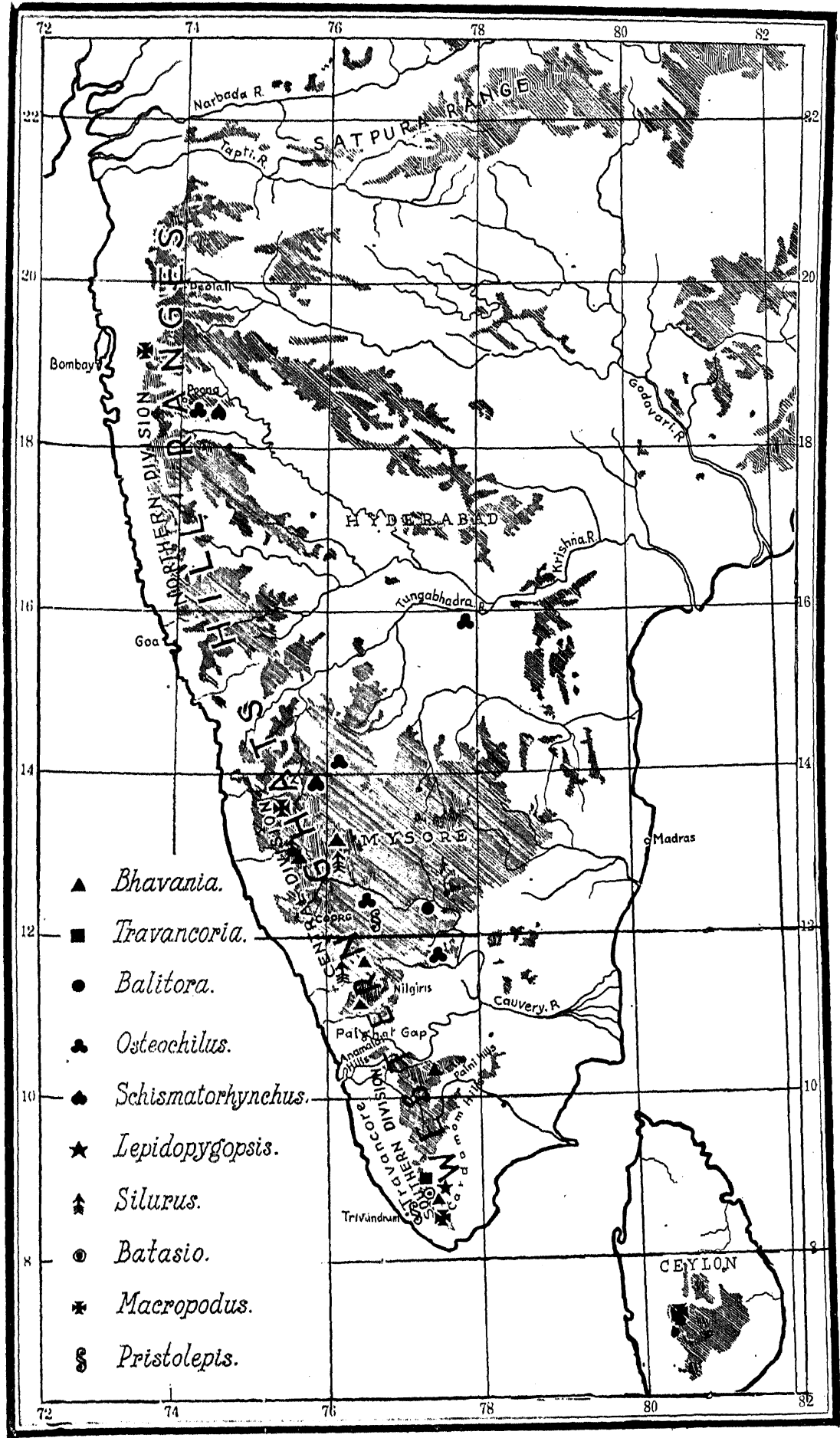
A brief review of the origin, affinities and the evolution of the fish-fauna of the Western Ghats is an essential prerequisite for an attempt to divide the Western Ghats into zoogeographical divisions based on the distribution of fishes. We owe much of our knowledge of the fishes of the Western Ghats to the outstanding researches of Hora on their systematics, affinities and distribution. The two noteworthy features of fishes of the Western Ghats are (i) their close affinity to the fishes of Malay Peninsula and Archipelago and (ii) richness of the endemic forms. Important among the fishes of Eastern affinity on the Ghats are *Balitora*, *Travancoria*, *Bhavana*, *Schismatorhynchus*, *Thynnichthys*, *Osteochilus*, *Silurus*, *Batasio*, *Pristolepis* and *Marcopodus*. The close similarity of the fish-fauna of Peninsular India with that of the Malaya region is explained by Hora<sup>18</sup> on the hypothesis that both are derived from a primitive stock of fishes which originated in Southern China. According to Hora freshwater fishes migrated in batches from the original stock in different directions from the place of their origin about the Miocene Period. One such

batch migrated southwards along the Indo-Malayan mountains to the region of Malaya Archipelago and another westwards to the region of Eastern Himalayas and from there to Peninsular India. "It seems probable from the records of distribution of certain specialised hill stream fishes that the Satpura trend of elevated country, which during the Miocene and later periods stretched diagonally across India to the Himalayas, permitted the dispersal of the hill stream forms, by a series of river captures or through deflection, from the Eastern Himalayas to the western limit of the Satpuras and the Vindhya, whence subsequent to the elevation of the Western Ghats, the fauna migrated along the ghats southwards to the hills of the Peninsula" (Hora).<sup>18</sup> Reports on collections of fishes from isolated hill ranges such as Rajmahal hills in Behar, Sihawa range and Bailadila range in C.P. by Hora,<sup>16,17,19</sup> from Hazaribagh district by Das<sup>2</sup> clearly indicate close affinity between fishes of these hill ranges and those on the Western Ghats on the one hand and those in Assam on the other; which supports the view that these hill ranges should have been continuous, forming highway for migration of fishes from east to west during the Miocene period. The richness of the endemic forms is to be attributed to the long isolation of the fish-fauna on the hill ranges of the ghats and the consequent evolution of large number of new forms.

### ZOOGEOGRAPHICAL DIVISIONS OF WESTERN GHATS

At the period of the first influx of fishes from the East on to the Western Ghats, it is assumed, that the whole of the Western Ghats, from the Tapti river to the hills of Ceylon, was a continuous range, which permitted the dispersal of fishes throughout the Ghats through a system of river captures due to a differential rise of the Western Ghats. Subsequent to this period there have been geological changes by which parts of this once continuous hill range became isolated into hill groups thus restricting the movements of fishes. Such geological changes are (1) separation of Ceylon from the Peninsula, (2) denudation of the ghats by the upper reaches of the rivers of the Peninsula resulting in the formation of deep river valleys and (3) Deccan Trap eruptions.

*Ceylon.*—A list of freshwater fishes of Ceylon prepared from the series of articles by Deraniyagala<sup>3-6</sup> shows the basic continuity of the fish-fauna of Ceylon and Peninsular India. As many of the South Indian genera and species of fishes are represented in the fauna of Ceylon, it is clear that Ceylon became separated from India after the migration of these fishes to the island. In Ceylon there are a number of endemic forms such as *Horadandia atukorali* Deraniyagala, a small-sized cyprinoid, an anabantoid *Malpulutta kretseri* Deraniyagala and a few species of *Garra*, *Rasbora*, *Barbus*, *Labeo* and *Clarias* which have evolved as a result of long isolation of the island from the mainland. This is further evidenced by the recent discovery by Deraniyagala of Siwalik mammals in Ceylon which although generically identical with those of India, have been isolated sufficiently long to form separate species.



Map of the Western Ghats showing the distribution of certain hill-stream fishes.

Based on the distribution of fishes, three zoogeographical divisions of the Western Ghats can be recognised. For purposes of description they can be termed Northern, Central and Southern Divisions. The Northern Division consists of the Deccan Trap area from the Tapti river up to 16° n. latitude about the level of Goa. The Central Division extends from 16° n. latitude southwards and includes the Malnad parts of Mysore State, Coorg, Wynaad, parts of South Canara district and Nilgiris. The Southern Division comprises Anamalai, Palani and Cardamom hills of Travancore.

*Northern Division.*—The classical work of Sykes on the fishes of Deccan (1841) is in main the basis of our knowledge of the fishes of this division. Fraser<sup>7,8</sup> and Hora and Misra<sup>15,26</sup> have recently described extensive collections of fishes from the environs of Deolali and Poona. Hora and Misra have recorded 50 species from Deolali and 53 species from Poona and a list prepared from these two areas together contains about 70 species. The occurrence of *Schismatorhynchus* Bleeker and *Mystacoleucus* Gunther is of special significance; besides the Western Ghats, the former is found in the Malaya Archipelago, while the latter is found in Burma, Siam, Malaya, etc., but nowhere else in India. These two genera show the Malayan affinities of the fauna of this part of the Western Ghats (Hora).<sup>26</sup> Suter has reported 17 species from Poona in addition to the number described by Hora and Misra from that area and his record of *Osteochilus nashii* (Day) and *Garra bicorunta* Rao is of zoogeographical interest as it extends the distribution of these species to the Northern Division. Rahimulla and Das<sup>31-33</sup> have reported on the fishes of Hyderabad and the list of fishes of Hyderabad prepared by Rahimulla (manuscript) contains 93 species. The occurrence here of *Thynnichthys* and *Osteochilus* is noteworthy as they represent the eastern element in the fauna of Hyderabad. The majority of fishes in this division have a wide distribution. Further, compared with the Central and Southern Divisions the fish-fauna of Northern Division is noticed to be markedly poor. Except for *Parasilorhynchus prateri* Hora, *Horachthys setnai* Kulkarni, a species each of *Rasbora*, *Danio* and *Barbus* and a few others the endemic forms are also few here. Forms of zoogeographical interest such as *Balitora*, *Bhavana*, *Travancoria*, *Pristolepis*, *Silurus*, *Batasio* and others which occur lower down on the ghats are absent in this division.

*Central Division.*—The fish-fauna of the Central Division is comparatively better known. In recent years Rao,<sup>34</sup> Hora<sup>10,12,25</sup> Mukerjee<sup>21</sup> and Bhimachar and Rau<sup>1</sup> have contributed to our knowledge of the fishes of this division. The list of fishes from Mysore and adjoining hill ranges of Nilgiris, Wynaad and Coorg, published by Hora,<sup>25</sup> contains 121 species. From the records of fishes from different parts of Western Ghats it may be estimated that the Central Division presents the richest fish-fauna. There are here certain forms of immense zoogeographical significance. The *Silurus* reported from this division is the same species that is

found from Cochin China to Eastern Himalayas. *Balitora brucei* var. *mysorensis* Hora, a variety of the Burman form occurs in Mysore. Hora has pointed out that the three species of *Scaphiodon* found in this division are referable to *Osteochilus*, a genus widely distributed in South Eastern Asia and that *Labeo nukta* Sykes, actually belongs to the Malayan genus *Schismatorhynchus* which was hitherto known only from Sumatra and Borneo. All these except *Schismatorhynchus* and a species of *Osteochilus* which are reported from the Northern Division, are restricted to the Central Division. It is significant that these are absent in the Southern Division. The South Indian Homalopterid genus *Bhavana* occurs both in the Central and Southern Divisions. While classifying the fishes of this division in respect of the different drainages it was noticed that several of Sykes' Deccan species are found in the headwaters of the Tungabhadra river and these are strikingly absent south of this drainage.

*Southern Division.*—John<sup>27</sup> and Hora and Law<sup>22</sup> have reported on large collections of fishes from Travancore. The northern part of this division, namely, Anamalai hill ranges is still a virgin field. Hora and Law<sup>22</sup> in their article "Freshwater Fish of Travancore", list 76 species. To this list has to be added the new species of Globe fish—*Tetradon* (*Monotretus*) *travancoricus* and the gobioid—*Sicyopterus griseus* (Day) recently reported by Hora and Nair<sup>23</sup> and also Sundara Raj's<sup>35,36</sup> new find *Lepidopygopsis typus* and a species of *Barbus*. It is possible that *Lepidopygopsis* has affinity with the Schizothoracine fishes found in Yunnan. The discovery of a new Homalopterid—*Travancoria jonesi* and a Siluroid—*Batasio travancoria* by Hora,<sup>21,20</sup> deserves special mention as they show close relationship with Eastern fishes. All these except *Sicyopterus* are endemic in this division.

In addition to the above dissimilarity among the fishes of the Central and Southern Divisions, it may further be pointed out that there is abundant endemicity among the fish-fauna of the two areas. Out of 121 species from the Central Division 24 are restricted to that area. If the range of distribution is extended to Deccan also about 33 species are endemic which are absent from the Southern Division. Thirteen out of 81 species in Travancore are endemic there. Hora and Law<sup>22</sup> state "The high endemicity of the Travancore fauna is an evidence of its antiquity and long isolation from the fauna of the mainland of India and adjacent countries. After migration from north-east to south-west, the fauna came to a blind end in the Peninsular region and when, with the formation of the Rajmahal-Garo hill gap and due to other causes, it became isolated and it had sufficient time to blossom out into distinct species while still retaining its family affinities with the parent stock." It may be stated that this remark holds good equally to the fauna of the whole of the Western Ghats. The fauna of Travancore, in particular, has further been isolated from the neighbouring hill ranges of Nilgiris and Mysore,

### DISCUSSION

From the foregoing observations it is clear that (1) there is dissimilarity among the fish-fauna of the three divisions of the Western Ghats, (2) the Central and Southern Divisions not merely have large number of fishes of far-eastern affinity but also possess rich endemic forms. An attempt will now be made to account for such geographical differentiation among the fishes of Western Ghats.

It is argued that the geographical differentiation or the dissimilarity between the fishes of the Central and Southern Divisions is due to the presence of a low stretch of land in east to west direction about 16 miles wide and hardly about a thousand feet in elevation known as the Palghat Gap between Nilgiris and Anamalai hills, acting as a barrier for the intermingling of fishes of the two areas, just as the Rajmahal-Garo hill gap which is a barrier between Eastern Himalayan region and Peninsular India. It is well known that a low land like the Palghat gap forms an effective barrier for the intermingling of fishes of the neighbouring hill ranges. With the formation of the Palghat gap the fauna of the Central and Southern Divisions became isolated. In his article on the Dragonflies of Western India, Fraser<sup>9</sup> has referred to the Palghat gap as being an important barrier affecting their distribution. He states, "A study of the fauna on the two sides of the gap has served to show that narrow as it is, it is sufficient to divide the fauna into northern and southern groups". From the distribution of the fishes of Peninsular India it is clear that the Palghat gap must have occurred after the migration of fishes to the extreme south of India on to the Travancore hills. Hence the view expressed by Medicott and Blandford<sup>28</sup> that "It is also possible that the isolation of the different hill ranges of South India, such as the Shivarai, and the denudation of the Palghat gap south of the Nilgiris, are due in part to ancient marine action of the date as the formation of the Shyadri escarpment" cannot be regarded as correct. It is possible that it is a valley of a former river. It may be stated that whatever may have been the cause of the formation of this gap, it must have been an elevated country at the time of the migration of fishes southwards with the drainage facilitating such a migration.

In respect of geological formations the Northern Division is one which was subjected to violent volcanic eruptions resulting in the formation of Deccan Traps and is formed of basaltic rocks while the Central and Southern Divisions are formed of archæan rocks and are comparatively undisturbed parts except for erosion by the upper reaches of rivers. The poor fish-fauna of the Northern Division is probably due to the fact that considerable amount of their existing fauna must have been destroyed by the volcanic eruptions and that is why Homalopteridæ, *Silurus*, *Batasio*, etc., are not found there. The Central and Southern Divisions, being comparatively stable land masses, appear to have presented a favourable habitat for these fishes to thrive. Further isolation of the hill ranges in these divisions may have been responsible for the evolution of a large number of new forms giving high endemicity to these areas. The rapid

speciation in the streams on the hill slopes covered with thick tropical forests in these divisions from Miocene period onwards is not a matter of great surprise as they are subjected to heavy monsoons resulting in varied types of seasonal habitats.

The distribution pattern of fishes on the Western Ghats lends support to the view that the freshwater fishes from the east came to the Western Ghats by a series of successive waves of migration. Roughly four such waves of migration can be recognised. The first batch of fishes migrated to the ghats at a time when the conditions were more or less stable and specialised forms like the Homalopteridæ had not yet evolved. Ceylon, which was not detached from the peninsula at this period, received part of this generalised fauna. The second wave of migration from the east came after the separation of Ceylon from India but before the formation of the Palghat gap and must have been preceded by violent orogenic changes for such specialised hill stream forms as the Schizothoracinae and the Homalopteridæ had already come into existence by then. This wave of migration spread to the extreme south of the peninsula and we have evidence of it in the present-day fauna. The third wave of migration from the east came after the formation of the Palghat gap and gave a rich fauna to Mysore and the adjoining hill ranges. Forms like *Silurus*, *Schismatorhynchus*, *Osteochilus*, *Balitora* and others must have come with this batch and the Palghat gap appears to have prevented their further migration southwards. It is assumed that about this period the Deccan plateau was about to have volcanic eruptions, the occurrence of which resulted in the elimination of much of the then existing fauna in the Northern Division. The fourth wave probably came after the Deccan Traps had been laid bringing with it forms like *Schismatorhynchus*, *Mystacoleucus*, *Thynnichthys* and *Osteochilus* to the Northern Division.

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### MAGNETISM IN RELATION TO STRUCTURE\*

AFTER a brief introduction by Prof. Krishnan, the discussion was opened by Sir C. V. Raman, F.R.S., N.L., with the subject "Magnetic Susceptibility of Minerals". He outlined the work that had been carried out in his laboratory for some time. Starting with a tektite from the island of Billiton which proved to be an isotropic glass-like material, successively other minerals have been studied for their magnetic behaviour. An examination of a number of tourmalines showed considerable variations in both susceptibility and anisotropy and the interesting result that there was a close correlation between the two was obtained. Results of even greater theoretical and practical interest were obtained with the minerals iron pyrites and augite.

The iron pyrites used in the investigations were obtained from Nepal in the form of cubes with well-developed faces and of a tin-white colour, instead of the more common golden yellow. The crystals exhibited a brilliant metallic lustre. The susceptibility of the large number of specimens investigated varied from  $0.2 \times 10^{-6}$  to  $190 \times 10^{-6}$ , the greater part, however, being near the lower value. All the specimens showed a decrease in susceptibility with increase in field strength, the dependence on the field strength being larger, the larger the susceptibility of the specimen. Temperature had apparently no influence nor was there any sign of remanent magnetism.

The behaviour of augite also showed interesting points, the mineral being axially ferromagnetic, anisotropic at low fields and isotropic at high field strengths. While no generalisations could be attempted at this stage, the observations may be considered to open up a fresh field and, as in other cases the magnetic investigation of naturally occurring minerals may throw light where studies with pure substances have failed!

\* Report of a discussion at the Joint Annual Meeting of the Indian Academy of Sciences and the National Academy of Sciences, held at Poona, on 28-31 December 1944, with Professor K. S. Krishnan, F.R.S., in the Chair.

Dr. Mata Prasad, of the Royal Institute of Science, Bombay, next presented a brief resumé of the work carried out by him in collaboration with Dr. S. S. Dharmatti and other students, on "Ionic Susceptibilities and Molecular Configuration". After dealing with the historical background, both in theory and in experiment, which showed clearly the anomalous state of affairs in the correlation of theory with experiment, Dr. Prasad dealt at some length with his work on the sulphur group and in the alkaline earth group. The use of susceptibility data in the assignment of structures was illustrated by taking as examples sulphur monochloride (disulphur dichloride), the selenium analogue and chromium dioxide. It may be mentioned in passing that these results are not quite in accord with structures indicated by the study of other properties, a point to which attention was drawn in the course of the discussion.

An interesting observation pointed out by Dr. Prasad in dealing with the alkaline earth group was the apparent variation in the cationic susceptibility with the nature of the anion when salts of organic acids were studied. There appeared to be a correlation between "the total number of electrons" or the "number of carbon atoms in the molecule" and the increase in cationic susceptibility. Here again, one cannot overlook the possibility that the real abnormality is with the organic ion.

Dr. S. V. Anantkrishnan, of Madras Christian College, Tambaram, followed next with "Diamagnetism and Chemical Bonding". While Pascal's additivity relationship has served a useful purpose in correlating diamagnetic susceptibility with the structure of carbon compounds, as in case of other physical properties, a different method of interpretation is possible correlating susceptibility with molecular structure in the light of present knowledge on the nature of valency. Following the method of Gray and Cruikshank, but using Slater's method for the evaluation of ionic susceptibilities, the paramagnetic contribution through bond formation can be evaluated as 'bond-depressions'. Using these values and the known values of bond moments, diamagnetic susceptibilities of a large number of compounds on calculation gave consistently close agreement with the experimentally determined values. It was also noticed an empirical curve could be drawn correlating bond-order with bond-depressions and, using this curve, the calculated and observed values in the case of resonance structures showed good correlation. By the same procedure the susceptibilities of the ammonium and the nitrate ions could be evaluated and the sum of these gave the molecular susceptibility of ammonium nitrate within the limits of experimental error. It may be remarked that the accuracy of susceptibility determination preclude any use of this as a means of determining structure, but there is no reason to consider that these data should be interpreted without reference to existing knowledge as to structure and valency.

In the brief discussion that followed, Dr. C. Mahadevan, Dr. Dharmatti, Principal S. Bhagavantam, Prof. T. R. Seshadri, the Chairman and others took part.