STUDIES ON THE PLANT ASSOCIATIONS OF SLOPES AND SCREES OF THE WESTERN GHATS*, INDIA**

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(with 4 figs.)

INTRODUCTION

Ever since 1936, systematic and ecological studies of the Maharashtra State have been in progress in the Laboratories of the Dept. of Botany to gather the preliminary data which may ultimately be used as the basis for the vegetation mapping of the State. In these two decades or so, BHARUCHA and his co-workers have established several principal associations. These are the Nitrophilous (4), the Halophilous (6), the Hygrophilous (8), the Calcicolous (8), the Ruderals (5), the Grassland (7,9) and the associations of the weeds of the Rice-fields (3) etc.

However, the plant associations, so characteristic and peculiar to the rocky slopes and mountain screes that are so abundant on the Sahyadri ranges, have not been studied so far, mostly due to the inaccessible nature of the associations on unapproachable peaks and summits. The crest line of the Sahyadris generally varies from 600—1000 m and further all along the ranges are waterfalls and fast flowing streams, especially during the monsoon. It is during this season that the plant associations of rocks come into full bloom and vanish with the onset of the winter; and it is only during this season that studies of such kinds of vegetation on this particular type of habitat become all the more difficult due to the formation of algal cover over the rocks which makes the conditions still worse for exploration.

A review of the existing literature on the subjects shows that practically no work has been carried out on phyto-sociological or ecological basis on such types of plant associations found on rocky slopes and screes of the mountains. Hence it may be pointed out that the present work is the first of its kind in India. We have attempted to study (1) the floristic composition of the rocky associations of the Western ghats of India on a phytosociological basis; (2) the detailed ecology of the habitat of the rocky associations; (3) the chemical composition of the rocky soils, and (4) the life forms of the plants.

For this purpose, four localities namely (1) Kanheri caves, Borivali; (2) Parsik hill, Kalwa (near Thana); (3) Ghat range, Khandala, and (4) Surtembi hill, Igatpuri have been surveyed and we established four rocky associations and their six allied sub-associations, which have been grouped under two different categories on the basis of the degree of inclination of the rocks or the substratum on which they grow.

The term "Screes" or "Talus" is generally applied to a mass of boulders and broken rocks of all sizes which accumulates on a cliff or a mountain slope, having been broken from the main rocks by weathering and rolled

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* A chain of mountains.

** Received for publication 15.I. 1962.

down under the action of gravity. But in the present work we have termed the screes in the broadest sense and applied it to the rocky areas having precipitous slopes with rough topography. The term „Slope" is applied here to the „moderate and gentle" rocky slopes having gentle rolling topography. This is based on the classification put by WILDE (32) of the principal types of land with regard to their degree of slope. The classification is given below:

Slope in Degrees	*Types of Topography*	*Type of slope*
0 — 5°	Level or undulating	—
5° — 15°	Gently rolling	Gentle
15° — 30°—	Rolling	Moderate
30° — 45°	Hilly	Steep
45° or more	Rough	Precipitous

According to OTTLI (20) plants growing on rocks and rocky substratum are termed as Petrophytes (Rock-plants). He classified them as follows:

- Petrophytes (Rock-plants)
  - Lithophytes
  - Chomophytes (an aggregate)
    - Exochomophytes (Surface-plants)
    - Chasmophytes (Crevice-plants)

The exochomophytes are merely immigrants from other formations such as swards, meadows, bush, heath, forest, etc.

Lithophytes according to WARMING (30) are those plants that can colonize steeply inclined and bare rocks. They are exclusively cryptogamic, and include algae, lichens and mosses, these being the first to settle upon the steepest rocks. McDOUGALL (13) also terms such plants as lithophytes. On the other hand, chasmophytes, according to him (30) are those plants which are rooted in the clefts of rocks filled with detritus. In these clefts particles of earth conveyed by wind and water accumulate. The amount and rate of accumulation depend upon the width and situation of the clefts. In the soils thus constituted, plants settle down and their dead fragments further add to the supply of nutritive material in the cleft. Thus when a rock has a very steep surface and is devoid of crevices or clefts, only lithophytes develop upon it, and when, on the contrary, the rocks show cracks and clefts, chasmophytes develop in them.

The present work was carried out on the vegetation that is found growing mostly in the rocky crevices or depressions in the rocky substratum where the soil and other organic matter can substantially hold the growth of plants. It is under such particular type of habitat conditions that various types of plants, belonging to different life-forms, are able to group themselves sociably and are thus able to thrive as an association.

The smallest unit of vegetation, according to BRAUN-BLANQUET (11) is classified as "Sub-association" or "Facies", and is subordinate to the association in the large sense. This is rather characterized by "differential" species which occur more sparingly, in other expressions of the association, or are poorly developed. Thus there cannot be a sharp distinction between the association and the sub-associations. Our work too clearly indicates the close floristic relationship among the associations and the sub-associations.

ASSOCIATIONS OF SLOPES AND SCREES.

Based on these concepts, the phyto-sociological survey of the rocky vegetation was carried out intensively during the year 1954—1956, according to the method of BRAUN-BLANQUET and PAVILLARD (2). During this period about 200 relevés were taken and in all 99 species were collected from different localities under these associations. A less number of species is attributed mainly to the habitat factors such as small nature of crevices or depressions on rocks, shallow sandy loamy soil, inclined rocky areas, etc. which leave very little scope for the settlement and development of varied types of species. Thus, among these species also, we find that most of them are "thero-phytes".

All these species are classified into seven groups or classes viz., (1) Accidentals or Escapes, (2) Companion species, (3) Species of Alliance, (4) Species of order, (5) Differential species, (6) Characteristic preferential species and (7) Characteristic exclusive species. The distribution and fidelity of the species of the above classes of the rocky associations and sub-associations are given in Table I which clearly shows the relationship between the major associations and their allied sub-associations on the basis of BRAUN-BLANQUET's system. It also shows that the associations are comparatively richer in the total number of species than their allied sub-associations, the latter being in the stage of development.

The four main rocky associations, thus established, are of:

(1) *Ischaemum semisagittatum* ROXB. (Ischaemetum semisagittati),
(2) *Geissaspis cristata* W. & A. (Geissaspetum cristatae),
(3) *Tripogon lisboae* STAPF. (Tripogetum lisboais), and
(4) *Arthraxon quartinianus* NASH, (Arthraxetum quartiniani).

The six other *sub-associations* allied to the above four major associations on the basis of the seven classes of species, as shown in Table I, are of (1) *Ischaemum semisagittatum* ROXB. and *Ischaemum aristatum* LINN. (Ischaemetum-Ischaemetosum aristatae; (2) *Ischaemum semisagittatum* ROXB. and *Smithia salsuginea* HANCE. (Ischaemetum-Smithietosum salsuginae); (3) *Geissaspis cristata* W. A. and *Anotis foetida* BTH. & HK. (Geissaspetum-Anotietosum foetidae); (4) *Geissaspis cristata* W. & A. and *Cyanotis fasciculata* SCHULT. (Geissaspetum-Cyanotietosum fasciculatae); (5) *Geissaspis cristata* W. & A. and *Murdannia semiteres* SANT. (Geissaspetum-Murdannietosum semiterae) and (6) *Tripogon lisboae* STAPF. and *Ischaemum diplopogon* HK. (Tripogetum-Ischaemetosum diplopogoni).

The first two sub-associations of *Ischaemum aristatum* and *Smithia salsuginea* are allied to Ischaemetum semisagittati, whereas the sub-associations of *Anotis foetida*, *Cyanotis fasciculata*, and *Murdannia semiteres* are linked with Geissaspetum critatae. The last one of *Ischaemum diplogon* is allied to Tripogetum lisboais.

According to our phyto-sociological data, the first two major associations and their respective allied sub-associations are grouped into the "alliance" of *Fimbristylis tenera* R. & S. or Fimbristylion tenerae; whereas the

TABLE I

Showing the Distribution and Fidelity of the Species of Classes among the Rocky Associations and Sub-Associations

Associations and Sub-associations / Species of Classes	Ischaemetum semisagittati	Ischaemetum-Ischaemetosum aristati	Ischaemetum-Smithietosum salsuginae	Geissaspetum cristatae	Geissaspetum-Anotietosum foetidae	Geissaspetum-Cyanotietosum fasciculatae	Geissaspetum-Murdannietosum semiterae	Tripogetum lisboais	Tripogetum-Ischaemetosum diplopogoni	Arthraxetum quartiniani
Characteristic exclusive species	2	—	—	1	—	—	—	1	—	1
Characteristic preferential species	2	2	2	2	1	1	1	5	2	3
Differential species	4	3	1	1	—	—	1	1	1	—
Species of the order	3	3	3	3	3	3	3	3	3	3
Species of alliance	7	6	5	8	6	7	6	6	5	7
Companion species	28	27	14	30	17	9	19	21	8	26
Accidentals	2	—	—	—	—	1	—	—	—	—
Total no. of species in each Association & Sub-association	48	41	25	45	27	21	30	37	19	40

latter two major associations and the allied sub-association are grouped into the alliance of *Arundinella pumila* STEUD. or Arundinellion pumilae.

The alliances of Fimbristylion tenerae and Arundinellion pumilae have been placed into the "Order" of *Anotis foetida* BTH. & HK. or Anotietalia foetidae.

The above order falls into the "Class" of *Chasmophiles* of the Maharashtra State. The *circle* of vegetation is the "natural vegetation of the Western ghats".

These phyto-sociologically grouped associations are further grouped ecologically also on the basis of slope or degree of inclination of rocks, according to the classification of WILDE (32) as given earlier. Thus these associations can be grouped as follows:

Associations	Slope in Degree	Type of Slope	Group
1. Ischaemetum semisagittati and its allied sub-associations	15°—30°	Moderate	Slope
2. Geissaspetum cristatae and its allied sub-associations	0°—20°	Gentle	
3. Tripogetum lisboais and its allied sub-associations	40°—95°	Precipitous	Screes
4. Arthraxetum quartiniani	70°—90°	do	

It is clear from the above classification that the first two associations and their allied sub-associations prefer to grow on moderate to gentle slopes whereas the latter two associations and the allied sub-associations prefer the precipitous slopes. On the basis of this Ischaemetum semisagittati, Geissaspetum cristatae and their allied sub-associations have been grouped under the *Associations of Slopes*; and Tripogetum lisboais, Arthraxetum quartiniani and the one allied sub-association have been grouped under the *Associations of Screes.*

TABLE II.

Showing the affinities among the rocky associations, both phyto-sociologically and ecologically

No. Associations	Phytosociological groupings	Ecological groupings
1. Ischaemetum semisagittati and its allied sub-associations 2. Geissaspetum cristatae and its allied sub-associations	Both fall under the alliance of Fimbristylion tenerae	Both prefer moderate to gentle slope or "Slope"
3. Tripogetum lisboais and its allied sub-association 4. Arthraxetum quartiniani	Both fall under the alliance of Arundinellion pumilae	Both prefer precipitous slope or "Screes"

TABLE III.

Showing the average Min. and Max. values of various physical and chemical factors of the soils of the 4 principal rocky associations and 6 allied sub-associations in a condensed form.

Factors	Associations & Sub-associations of slopes.		Associations & Sub-associations of Screes.	
	Average values in %	Remarks (Comparative)	Average values in %	Remarks (Comparative)
Moisture-content	2.44— 3.65	Low	3.15— 4.49	Moderate
Mechanical analysis:				
Coarse sand.	32.00—56.74	Coarse sand	23.36—34.51	Sandy-loam
Find sand.	14.20—26.14	to	26.58—42.96	to
Silt.	8.12—18.58		9.75—19.82	
Clay.	6.43—19.95	Sandy-loam	5.99—27.95	Clay-loam
pH.	6.2 — 6.9	Weakly acidophilous	6.8 — 7.2	Weakly acidophilous
Calcium carbonate	0.15— 0.51	Low	0.41— 0.57	Moderate
Organic matter	3.58—13.75	High	2.05— 6.52	Moderate
Silicon dioxide	59.24—71.66	High	56.15—68.73	Moderately high
Alluminium oxide	2.08— 4.81	Moderate	2.39— 5.32	Moderate
Calcium oxide	0.89— 1.78	Moderate-low	1.11— 2.26	Moderate
Exchangeable calcium	6.21—17.3 m.e.	Moderate-low	12.60—29.0 m.e.	Moderate
Ferric oxide	11.4 —15.4	High	12.00—14.91	High
Exchangeable iron	0.23— 0.30 m.e.	High	0.24— 0.28 m.e.	High
Phosphorus pentoxide	0.13— 0.30	Low	0.15— 0.27	Low
Exchangeable phosphate	0.03— 0.10 m.e.	Low	0.03— 0.03 m.e.	Low
Total exchangeable bases	14.2 —26.5 m.e.	Moderate-Low	29.5 —41.8 m.e.	Moderate

% = Percentage of air dry soil. m.e. = Milligram equivalent per 100 g of soil.

From the above data and Table II, it is quite clear that a definite affinity exists among the rocky associations, both phyto-sociologically and ecologically with regard to the species of alliance and the nature of the slope respectively.

SOILS OF THE ASSOCIATIONS OF SLOPES AND SCREES.

The structure and composition of a plant cummunity is determined by its habitat and the competition among its individuals. According to BRAUN-BLANQUET (11) habitat is the more important factor. The operative factors of the habitat which are essential for the description and characterization of a community are best considered under four heads namely, the climatic, the edaphic, the topographic and the biotic. Though each of them affect the vegetation in its own way, a plant association is the result of the interaction of all these factors which are closely inter-related. Under the edaphic factor, THÜRMAN (27) lays greater emphasis on the physical nature of the soils, whereas UNGER (28) attached greater significance to the chemical composition of the soil. However, our investigation reveals that both these factors are equally important and have a combined effect on the development of vegetation.

The soils were, therefore, collected from different localities under the associations and sub-associations for detailed analysis of various physical and chemical factors. The pH of the soils was determined electrometrically. The organic matter values were estimated by WALKLEY & BLACK (29) rapid titration method. The other factors like the moisture-content, the texture of soils, calcium carbonate, the oxides of silicon, calcium, iron, phosphorus, alluminum; and calcium, iron, phosphorus, and total bases in exchangeable form were determined according to the methods given by A.O.A.C.(1), PIPER (22) and WRIGHT (33).

DISCUSSION

Mechanical analysis and Moisture-content.

From Table III, it will be seen that the soil texture of the rocky associations and sub-associations is generally sandy. However the associations of "Slope" thrive better on more sandy soils, i.e. from coarse-sand to sandy-loam soils than their counterparts from "Screes" as is evidenced from the readings given in the Table.

Correspondingly the values of the moisture-content of the soils show a low value because of their sandy nature. Subsequently the values of the soils of the associations of slope are comparatively lower (2.4—3.6%) than the values obtained from the soils of the associations of screes (3.1—4.4%), the values thus obtained being on air dried basis. Hence, the moisture is dependent on the mechanical composition of the soils (10).

Similar values were also obtained in the over-grazed grassland soils (9) where the lowest value was 3—3.9% because of the sandy texture of the soils, whereas the cut and grazed grassland soils which are clayey, possessed as high as 8.4% of moisture.

Hydrogen-ion concentration:

The pH values of the rocky soils, in general, varies from 6.2—7.2, but mostly between 6.2—6.9, as given in Table III. These values clearly show that the rocky associations and sub-associations thrive on weakly acidophilous to neutrophilous soils. The pH values of the associations of slopes (6.2—6.9) show that they prefer rather weakly acidophilous soils than the associations of screes which prefer neutrophilous soils (6.8—7.2). These values are in concurrence with the respective textures of the soils. The low values or the weakly acidic nature of the soils are also due to the high amount of rain. Under low rainfall pH values are higher denoting alkalinity while under high rainfall pH values are low indicating soil acidity (24). Since these rocky associations also come under the influence of high rainfall (about 200—500 cm), the pH values, too, show a tendency towards acidity because of continuous leaching down of the bases from the upper strata of the soil. This has been proved also in the case of grassland associations (9).

Calcium carbonate.

Though the amount of Calcium carbonate (0.15—0.75%) of the soils of the rocky associations is rather low, still it is enough for the development of the vegetation. The carbonate values might have been higher but for the fact that carbonates are leached down to a great extent on inclined or slopy areas during the monsoon (24), more so when the degree of inclination of the rocky substratum is so varied under natural conditions.

Organic matter.

The influence of organic matter on the soil and vegetation is well-known. The results of the organic matter-content given in Table III show that the soils of the rocky associations have a fairly good amount of organic matter present in them, their average values ranging between 2.05% to as high as 13.75%. As compared to the soils of one of the grassland associations namely Arthraxetum meeboldiae (9) which has the highest value (6.36%) amongst the grassland soils, it will be clear that the rocky soils are comparatively richer than the grassland soils. Among the rocky associations themselves, it is clear from Table III that the soils of the associations of slopes (3.58—13.75) have comparatively more amount of organic matter than the soils of the associations of screes (2.05—6.25%). This is in complete harmony with the fact that the former associations grow on moderate to gentle slopes with lesser degree of inclination (0°—30°) than the latter which prefer to grow on precipitous slopes or screes (40°—95°). This is also in absolute agreement with the hypothesis of WARMING (30) who stated . . . "the more flat and horizontal is the rocky tract, the more does it favour the accumulation of detritus and of vegetable fragments".

Silica.

The values of the silica-content of the rocky associations have been furnished in Table III which indicate that the average values of these soils lie between 56.1—71.6%. DESIGMOND has pointed out that the silica values of the sandy soils of the humid regions average from 80—85%. Our results, more or less,

PLATE I

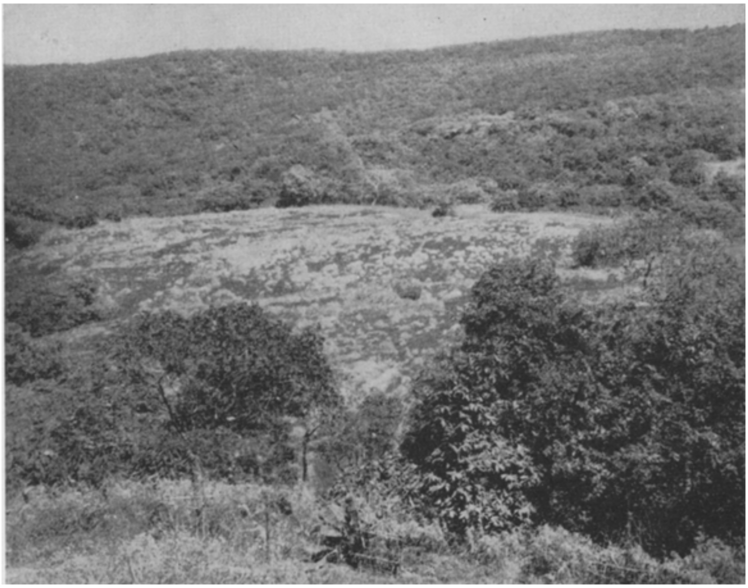

Photo 1: Shows the Association of *Ischaemum semisagittatum* on top of Kanheri Caves.

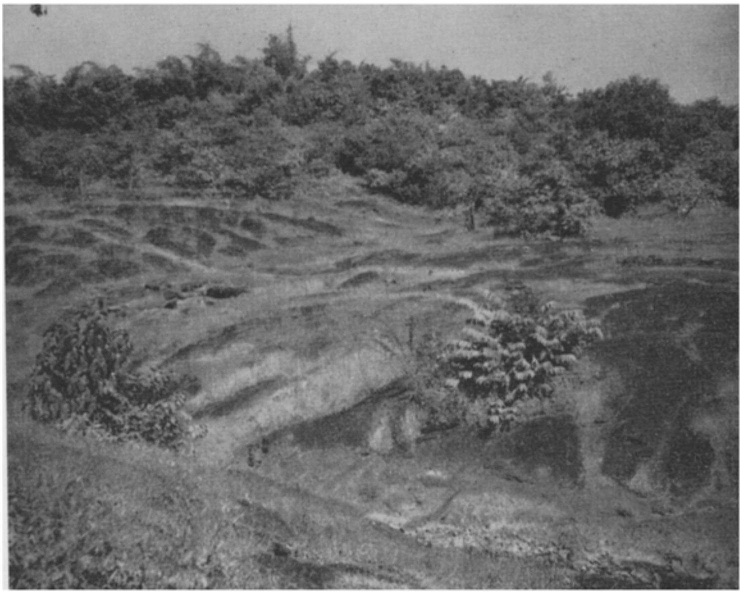

Photo 2: Shows the Sub-accociations of *Anotis foetida* and *Murdania semiteres* at the base of Kanheri Caves.

support his contention. Further, our values can be compared with the values of silica obtained by MARBUT (16) in the soils of the United States, which are also based on the texture of the soils. These values show that the amount of silica increases as the sandy texture of the soils increases. The value of silica, from the soils of the associations of slope (59.24—71.66%) and the associations of screes (56.15—68.73%) show that the soils of the former associations, being more sandy, have comparatively little more silica than the soils of the latter.

Silica-sesquioxide ratio.

This ratio serves as an index of the degree or the extent of weathering. This ratio of the whole soil has no significance since the grains of sand are chemically inert. The ratio of the whole soil is always high due to the high content of quartz. A high silica-sesquioxide ratio indicates a relatively low degree of chemical activity and slow rate of decomposition; i.e. a higher ratio is associated with immature, unweathered soils while a low ratio indicates maturer soils. In warm humid climates this ratio is high in immature soils.

From the average values given in Table III, it is seen that the ratio varies from 8.27—11.85%. The high ratios denote that the plant associations generally grow on rocks which are either immature or in the process of weathering. Due to the heavy rains in the regions surveyed, there is constant erosion which carries away much of the residual products of weathering. Consequently, fresh rock is constantly exposed to the surface. It is, therefore, not surprising that the silica-sesquioxide ratio obtained in our investigation is fairly high.

Calcium oxide and Exchangeable calcium.

Though calcium carbonate and exchangeable calcium are the important fractions of the soil, the total calcium, as expressed in terms of calcium oxide is also important since its value or quantity, larger or smaller, helps in determining the rate of leaching. The more actively the soil is leaching, the greater is the degree to which calcium oxide is leached and the poorer the upper soil. Podsolic soils are particularly poor in calcium (6).

The average amount of calcium oxide of the rocky soils, as given in Table III, varies from 0.89—2.26%. As compared to MARBUT's values (16) where the silica content is very high (76.54—91.49%) and correspondingly calcium oxide values low (0.80—0.01%), the rocky soils are slightly richer in calcium oxide due to a rather little less amount of sand particles in the soil texture as compared to the soils of MARBUT. However, our results are in accordance with HILGRAD's statement (14) that the humid climate soils contain less calcium oxide. In general, total calcium values are poor.

Similarly the values of the exchangeable calcium of the soils of the rocky associations are rather low (6.21—29.0 m.e.%) as can be seen from Table III. In the mangrove soils (6) where calcium carbonate is low, the exchangeable calcium ranges from 27.75 to 64.5 m.e.%; in deciduous forest soils (24) where calcium carbonate is practically absent, the exchangeable calcium ranges from 13.4 to 37.0 m.e.%; in the hygrophilous *Asteracantha* soils (14) where calcium carbonate is also low, the exchangeable calcium varies from 22.0—31.6 m.e.%; whereas in the grassland soils (9) which also lack calcium

PLATE II

Photo 1: Shows the Association of *Tripogon lisboae* on screes at Khandalla.

Photo 2: Shows the Association of *Tripogon lisboae* on screes at Igatpuri.

carbonate, the amount of exchangeable calcium ranges from 7.0—34.0 m.e.%.

From the above discussion it is seen that our results favorably compare with the results of the deciduous forest and the grassland soils. Though our values are low, yet they are enough to cater to the needs of the plants. These low values for exchangeable calcium of the rocky soils can be attributed to the nature of the soils which are generally more sandy and less clayey and therefore, contain less exchangeable calcium in the colloid complex. In support, we may quote DESILVA (13) who states "the exchangeable calcium content of a soil is really a function of the clay fraction of the soil which is the active agent of the exchange phenomena. Therefore, the greater the exchangeable calcium content or saturation capacity of the soil, more clayey and therefore, heavier and moister the soil tends to be".

The other possibility for poor calcium values is that due to heavy rains and slope areas, the soils are subjected to heavy leaching; consequently the calcium-ion is replaced by H-ion, thus making the soil acidic and low in exchangeable calcium. Our pH values also show that the rocky soils are weakly acidic to neutral in reaction. RUSSEL (25) and WEIR (31) also support this contention.

Ferric oxide and exchangeable iron.

The average values of ferric oxides of the rocky soils which vary from 11.4—15.4% as given in Table III show that the amounts of ferric oxides as compared with other oxides except silica, are quite high. Correspondingly it can be seen that the values of the exchangeable iron of these soils are also quite normal.

The average values for exchangeable iron of the rocky soils vary between 0.23—0.30 m.e.%. In the case of the calcareous (8) and the mangrove soils (6), the amount of exchangeable iron ranges from 0.05—0.210 m.e.%; in the case of grassland soils (9) the values vary from 0.055—1.793 m.e.%; whereas in *Asteracantha* soils (18) the amount ranges from 0.03—0.21 m.e.%. Thus it can be seen that next to grassland soils, the rocky soils contain higher amount of exchangeable iron than the others. These values can also be attributed to the acidic nature of soil which, according to RUSSELL (25), also increases the iron-content in exchangeable form. Our values can safely be compared with the values of exchangeable iron of over-grazed grassland soils (9) which are slightly rocky in nature, since they vary between 0.11—0.16 m.e.%. Our soils are, as a matter of fact, richer in exchangeable iron than the soils of the over-grazed grassland associations.

Phosphorus pentoxide and exchangeable phosphates.

From the figures given in Table III it is seen that the soils of the rocky associations contain, on an average, 0.13—0.30% of phosphorus pentoxide. The rocky soils like all other soils are also poor in phosphorus. LYON & BUCKMAN (15) state that in the soils of the humid regions, the amount of phosphorus pentoxide varies from 0.03—0.40% and our results are in close agreement with theirs. Even in the sandy soils of U.S.A., as stated by MARBUT (16), the values of phosphorus pentoxide vary from 0.02—0.10 only.

Similarly, the data for exchangeable phosphates of the soils of the rocky associations shows that our soils are moderate to low (0.26—0.69 m.e.%) in exchangeable phosphate. This is, as it should be, for the rocky soils in general, are weakly acidic to neutral besides being comparatively rich in iron. But as compared to the grassland soils where the amount ranges from 0.0009—0.0083 m.e.%, our soils are generally rich in exchangeable phosphates. This is probably due to the fact that in our soils, organic matter is very high as compared to the grassland soils, which clearly shows that organic matter increases phosphate availability.

Total exchangeable cations.

The values for total exchangeable cations or bases as given in Table III, show that on an average, they vary from 14.2—41.8 m.e.%, which is rather low as compared to the *Asteracantha* soils (18) where the value ranges from 34.2—43.0 m.e.%. The low values are due to the fact that the rocky soils, in general, are sandy in texture. PERKINS & KING (21) have pointed out that as the particle size in the soil separates decrease, i.e., sand fraction decreases and clay fraction increases, base exchange capacity also increases per weight and vice versa. Moreover, the influence of rain water as a leaching agent and the subsequent removal of the simple salts and the lesser availability of the essential elements from the surface layer has been well stressed by SALISBURY (26), PURI (23) etc. This also accounts for low values of the total exchangeable bases of the soils of the rocky associations.

Summarizing we conclude that the four rocky associations and their six allied sub-associations have been regrouped under the "Associations of Slopes and Screes". These associations grow, in general, on sandy to sandy loam type of soils having a high silica content and are weakly acidic to neutral in reaction. These soils are moderate to low in calcium carbonate, possess high amount of organic matter which has a positive correlation with the slope or inclination of the rocky areas. Though the soils are poor in calcium oxide and exchangeable calcium, the quantities are sufficient for the requirements of the rocky associations. The values of ferric oxides and exchangeable iron show that they are quite high and are readily available to plants. A low line status has possibly lowered the phosphorus pentoxide and exchangeable phosphate content of the soils. The high ratios of silica-sesquioxide and the sandy texture of the soils tell upon the total exchangeable bases which are, in general, low. The ratios also reveal that the rocky substrata of these associations are immature due to constant weathering.

A detailed phytosociological and ecological account of each of the four rocky associations and the six allied sub-associations will be published in a series in due course.

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