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# Kodaikanal Observatory

## BULLETIN No. CXXVII

# RELATION BETWEEN THE BASE AND THE HEIGHT OF PROMINENCES

BY

A. K. DAS AND K. SETHUMADHAVAN

*Abstract.*

The results obtained in this paper are based on measurements made on 1620 selected $H_\alpha$ dark markings during the cycle 1983-1943 and also on 188 clearly arch-type prominences out of the period 1908-1940.

The true height of an $H\alpha$ dark marking was calculated by measuring its "apparent breadth" and multiplying it by a factor R./d, where R. is the radius of the solar image and d is the distance of the marking from the centre of the sun's disk. The ratio of the length of the marking to its true height was then obtained and it was found that the ratio was most frequently 2 : 1.

A parallel investigation of the base/height ratio of arch-type limb prominences also showed that the most frequent ratio was again 2 : 1.

This result indicates that the most common and fundamental form of a quiescent prominence is the *semicircular* arch, the other forms being probably variants of this fundamental type.

### *Introduction.*

Since about 1871, when Father Secchi in Italy first organised a programme of systematic observation of prominences with the spectroscope, a vast amount of observational material relating to the varied features of prominences has been collected ; and since the closing years of the last century these visual observations and drawings of prominences have been greatly supplemented and in many respects improved upon by photographic records made possible by the invention of the spectroheliograph. Analysis of the observational data so far available has led to the classification of prominences into a number of categories, to the identification of the dark markings or filaments as nothing other than prominences projected on the solar disk and to the discovery of many important characteristics of prominences, such as their behaviour in the course of the solar cycle. One of the most striking features of stable prominences is the diversity of their forms. But in spite of the many different shapes in which they appear, these prominences have the following features in common : as a rule, their lengths are much greater than their heights and their depth or thickness is surprisingly small. A prominence is therefore often likened to a tongue of flame similar to the flame of a fish-tail Bunsen burner. According to Pettit [1] an average quiescent prominence has approximately the following dimensions : length 200000 km, height 50000 km, depth 10000 km. M. and Mme d'Azambuja's[2] estimate also agrees with Pettit's except that they find the depth to be of the order of 6000 km. Furthermore, an examination of a long series of spectroheliograms, such as we have at Kodaikanal, reveals that, although prominences can have a great variety of shapes, there is nevertheless a fundamental shape which is quite striking, namely the arch. Recently, the d'Azambujas (loc. cit.) have come to the conclusion, after an examination and measurement of many stable prominences in different perspectives, that the typical appearance of a well-developed, adult prominence is similar to that of a bridge with one or several low arches. It is of interest to note here that it seems possible to derive this shape of quiescent prominences from purely dynamical considerations, as was done by one of the present writers[3] some years ago. The object of the present paper is to derive, from a statistical study of a large number of prominences, the most frequent form of the arch, which appears to be the fundamental shape of stable prominences.

### *Observational data and procedure of analysis.*

In the present work the photographic records solely of the Kodaikanal Observatory have been utilised ; but it has been neither practicable nor necessary for the purpose in view to use all the long series of limb and disk spectroheliograms available in this observatory. Since our object is to determine whether fully grown, stable prominences have a preference for any particular type of arch shape, the simplest and most obvious method is to select for measurement a sufficiently large number of limb spectroheliograms on which clearly arch-shaped prominences appear. Accordingly, after examining all K—prominence photographs taken during the period 1908-1940 it was possible to select 188

[1] Pettit, AP. J., Vol. 76, P. 9, 1932.

[2] M and Mme d' Azambuja, Ann. de l'Obs. de Paris, tome vi, Fascicule VII, 1948.

[3] A. K. Das, Indian Journal of Physics, Vol. 15, P. 92, 1941, See also *ibid.* Vol. 14, P. 369, 1940 and Vol. 15, G. 17 1941.



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clearly arch-shaped prominences. These were measured in 1941, at the suggestion of the senior author, by Mr. C. K. Ananthasubramanyam at that time an Assistant at this observatory; but due to the exigencies of the war further progress of this work was interrupted. Recently it has been possible to take up the problem again and to examine Hα disk spectroheliograms with the object of selecting a sufficiently large number of suitable prominences appearing as dark markings on the disk. The method of selection of prominences projected on the disk is, however, not as straightforward as the selection of prominences on the limb, as will be evident from the following considerations.

If a prominence on the limb appears as a symmetrical arch with its ends exactly on the limb, a direct measurement of the base and of the height is possible and the ratio of these two quantities determines the form of the arch. Prominences, however, are seen in various perspectives and consequently the ratio of the measured base and height will vary with the perspective even if all limb prominences have precisely the same type of arch form. But if the base to height ratios are measured for a sufficiently large number of arch-shaped limb prominences and plotted as a frequency diagram, the most common form of the arch may be expected to show up as a maximum in the frequency diagram. This is in fact the basis of the procedure we have adopted for analysing our observational data relating to limb prominences as well as prominences projected on the disk. Prominences on the disk, however, appear as absorption markings and no direct measurement of the height can be made, but it is possible to deduce by simple geometry the true height from a knowledge of the "apparent breadth" of the marking and the angle between the line joining the marking to the sun's centre and the line of sight to the centre of the sun's disk as seen from the earth.

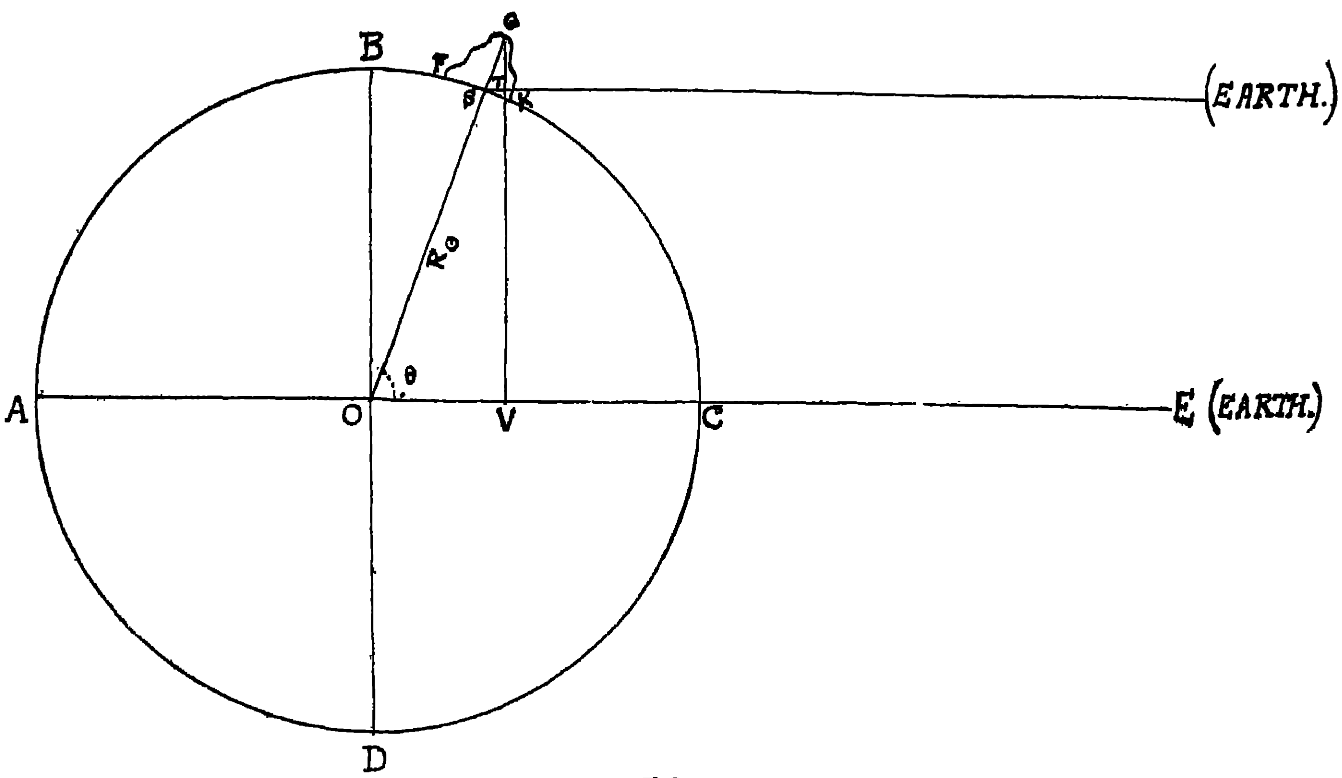


FIG 1

Let ABCD (Fig. 1) represent the sun with its centre at O, and let ECO be the line of sight to the centre of the disk C. FGK represents a section at right angles to its length of a prominence standing on the disk. Then the true height GS of the prominence, provided that it could be seen as a prominence, would appear as a height GT seen from the earth, where GTV is perpendicular to the line of sight. (Now $G\hat{O}V = G\hat{S}T = \theta$. Therefore $\operatorname{cosec} \theta = \frac{GO}{GV} = \frac{GS+SO}{GT+TV} = \frac{h+R.}{h_1+d} = \frac{R.}{d}$ putting GS=h, GT=$h_1$, SO=R. and TV=d. Also $\operatorname{cosec} \theta = \frac{h}{h_1}$. Hence $\frac{h}{h_1} = \frac{R.}{d}$, or $h = \frac{R.}{d}$.) It may be noted here that GT the apparent height as shown in the figure is slightly different from GK which is the height actually measured on the spectroheliograms. GK is sometimes less and sometimes more than GT and is also in some cases equal to GT; the differences are, however, too small to affect the final results. Thus the true height of the prominence can be deduced with sufficient accuracy if the apparent height can be determined, since R. and d are easily measured on spectroheliograms. Now a prominence on the disk appears as an absorption marking because the material of the prominence emits less light than the photospheric background against which it is seen, and consequently the breadth of the marking will depend upon the apparent height of the prominence. But the relationship between the measured breadth of the marking and the apparent height of the prominence will be complicated by the effects of the orientation of the prominence, its position on the disk relative to the central meridian and the equator and by the nature of the distribution of the material in the prominence. It is to be noted also that the breadth of a dark marking close to the centre of the disk is due only to the intrinsic depth of the prominence concerned ; the height correction factor mentioned above is therefore not applicable to markings which lie within about a third of the radius from the centre of the disk. In order to eliminate or at any rate to reduce the effects of these complicating factors we have adopted a procedure of selection, which has limited our measurements to only such H$\alpha$ dark markings as satisfy certain conditions. These conditions will be apparent from a consideration of Fig. 2 in which O is the centre

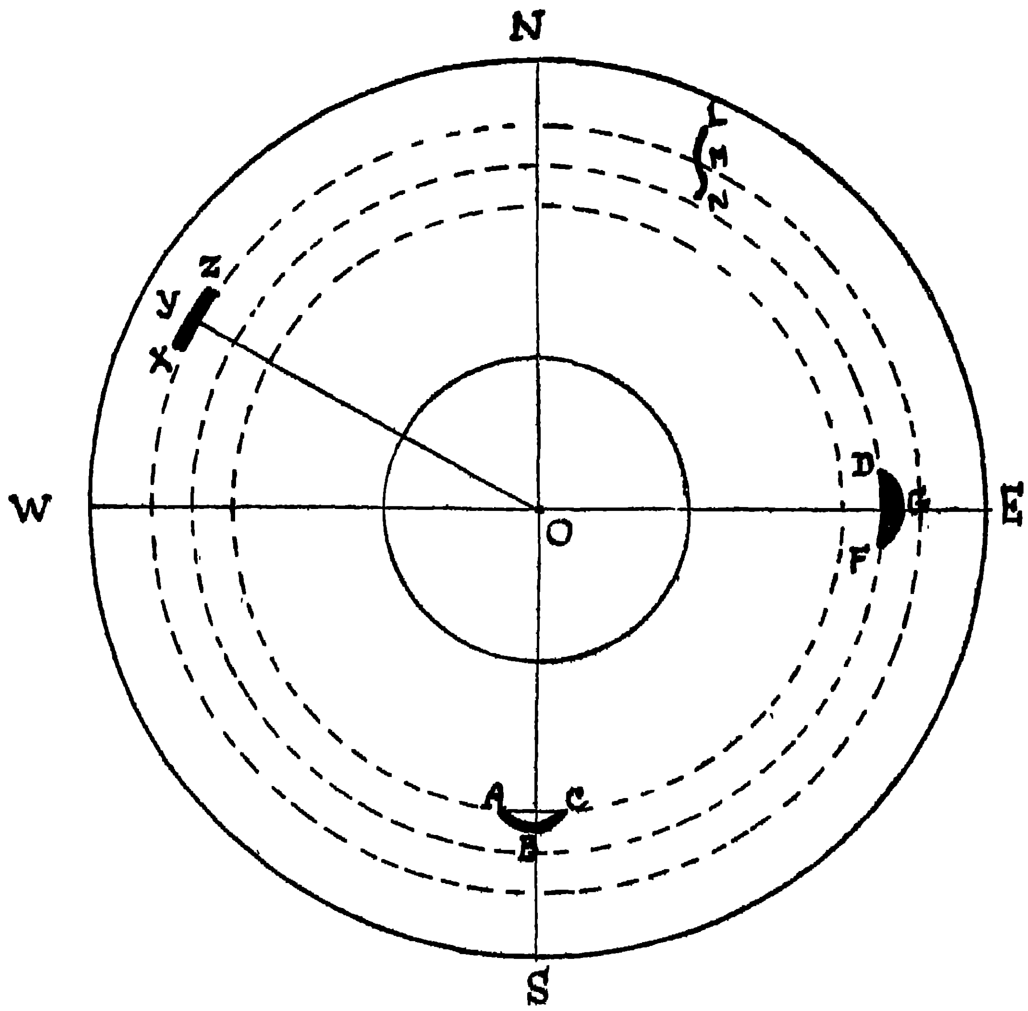


FIG. 2.

of the sun's disk as seen from the earth, NOS the central meridian and WOE is the equator. The three principal types of dark markings selected for measurement are represented by ABC, DGF and XYZ. These may be described as

(*a*) Markings seen in transverse elevation, *i.e.*, markings parallel to the parallels of latitude and situated close to the central meridian (*e.g.* ABC). Such markings are found mostly in high latitudes.

(*b*) Markings parallel to the meridians and therefore seen in longitudinal elevation (*e.g.* DGF). Such markings are observed mostly near the equator.

(*c*) Markings at intermediate latitudes and longitudes, but which lie on a circle concentric with the sun's limb (*e.g.*, XYZ).

It will be noticed that in each of the above three types the length of the marking is perpendicular to the radius of the disk passing through the centre of the marking. In this particular orientation the length of the marking as measured does not suffer from any foreshortening effect, also the height correction factor—cosecant θ—is applicable only when the marking is in this orientation. In any other orientation, such as that of the marking LMN shown in Fig. 2, the measurement of the length as well as of the height is attended with a great deal of uncertainty ; markings of this type are unsuitable for the purposes of the present study and have therefore been excluded from our measurements. The three types of markings selected according to the above criteria can be taken to be representative of markings in general for, any normally stable marking becomes one of these types during its passage across the sun's disk. Furthermore, the total number of markings utilised in our measurements is 1629 selected out of the complete solar cycle from 1933 to 1943.

*Measurements and results.*

The 1629 markings selected for measurement could be grouped into three classes according to their appearance which evidently depends upon the nature of the distribution of the material in the prominences concerned. The markings ABC, DGF and XYZ shown in Fig. 2 are typical of the three classes

(a) *Type ABC.* These were seen as "empty" arches; In these cases, the shortest length (chord of the arch) between the two ends of the marking was taken as its length. The apparent height was taken to be the distance between the chord and the summit of the marking. This distance, which we may call the "apparent breadth" for lack of a better expression, is greater than the true breadth of the marking as seen.

(b) *Type DGF.* These were seen as "filled" arches; they differed from the foregoing type in that in these the space between the arch and the chord was filled with absorbing material. The length and the apparent height were measured in the same way as in (a), the "apparent breadth" and the true breadth being identical.

(c) *Type XYZ* These were more or less rectilinear in appearance, so that the apparent height had to be taken to be equal to the actual breadth as measured and the length was measured directly as seen. These markings were probably due to prominences, which had not developed fully.

In the case of the arch-shaped limb prominences the measurements were made directly on images of about 60 mm. diameter as obtained with the spectroheliographs at Kodaikanal. But for the Hα absorption markings the spectro heliograms were put through an enlarger, and the measurements were made on enlarged images of 200 mm. diameter. The majority of the markings selected for measurement were short in length ; they were seen as single units and were taken as such. Some of the markings were fairly long and situated near the limb ; they were clearly seen to be made up of several distinct units separated from each other by pillar-like structures, indicating thereby that they were composed of several arches. Measurements were made on every individual arch in these cases. Some markings, when very near the limb, showed a bright margin ; in these cases the measurement of the apparent height included the breadth of the bright margin as well, considering it as the lower part of the entire prominence whose upper portion was responsible for the absorption marking.

To facilitate the computation of true heights from the apparent heights a table of height correction factors for different distances from the centre of the disk was prepared. This is reproduced as Table I. The results of the measurement of the base/height ratios for Hα dark markings are summarised in Table II, while Table III gives a synopsis of the result of measurement on arch-shaped limb prominences. These results are also given as frequency diagrams in Figs. 3 and 4. The above frequency tables and diagrams embody values of the base/height ratios ranging from 0·5 to 6·5. In individual measurements ratios as low as 0·3 and as high as 10·8 were obtained, but values below 0·5 and above 6·5 were so rare and random that they have been ignored. The frequencies have been worked out for the following ranges of values of the base/height ratio : 0·5—1·4, 1·5—2·5, 2·6—3·5, 3·6—4·5, 4·6—5·5 and 5·6—6·5.

It will be seen from an examination of these ranges of values that in the case of Hα dark markings the ratios in the range 1·5 to 2·5 are the most frequent (being about 46%) and the next important frequency is in the group 2·6 to 3·5 (30%), while the frequencies of other groups are inconspicuous. In the case of arch-type prominences on the limb the greatest frequency again occurs in the range 1·5 to 2·5 (70%) while the two adjacent groups 0·5 to 1·4 and 2·6 to 3·5 show a frequency of only 13% each.

The frequency diagram in Fig. 3 (for Hα dark markings) shows the predominant peak at 2 : 1 which is closely followed by ratios at 1·9, 2·2, 2·3, 2·4 and 2·5. The secondary peak at 3 : 1 is also somewhat conspicuous. In the corresponding frequency diagram (Fig. 4) for limb prominences the peak at 2 : 1 again towers high above all other ratios.

*Conclusion.*

The salient fact which emerges from the present study is that the predominant form of quiescent prominences (whether seen as dark markings on the disk or as bright prominences on the limb) is the semicircular arch (base/height ratio being 2 : 1). Other forms are probably only variations of this fundamental type. It is to be noted, however, that the ratio 3 : 1 also appears somewhat conspicuously in the case of prominences projected on the disk, though not in the case of limb prominences. This may indicate that the cycloid is also a fairly common form for prominences.

Kodaikanal Observatory,
*December, 1949.*

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## TABLE I

*Table giving factors (for converting apparent heights of Hα dark markings to their true heights) for different distances of markings from centre of sun's disk.*

Radius of sun's disk, R.=100 mm.

| Distance of marking from centre of sun's disk d mm. | Height correction factor $f=\frac{R.}{d}$ | Distance of marking from centre of sun's disk d mm. | Height correction factor $f=\frac{R.}{d}$ | Distance of marking from centre of sun's disk d mm. | Height correction factor $f=\frac{R.}{d}$ | Distance of marking from centre of sun's disk d mm. | Height correction factor $f=\frac{R.}{d}$ |
|---|---|---|---|---|---|---|---|
| 100 | 1.00 | 75 | 1.33 | 50 | 2.00 | 25 | 4·00 |
| 99 | 1.01 | 74 | 1.35 | 49 | 2.04 | 24 | 4.17 |
| 98 | 1.02 | 73 | 1.37 | 48 | 2.08 | 23 | 4.35 |
| 97 | 1.03 | 72 | 1.39 | 47 | 2.13 | 22 | 4.55 |
| 96 | 1.04 | 71 | 1.41 | 46 | 2.18 | 21 | 4.76 |
| 95 | 1.05 | 70 | 1.43 | 45 | 2.22 | 20 | 5.00 |
| 94 | 1,06 | 69 | 1.45 | 44 | 2.27 | 19 | 5.26 |
| 93 | 1.08 | 68 | 1.47 | 43 | 2.33 | 18 | 5.55 |
| 92 | 1.09 | 67 | 1.49 | 42 | 2.38 | 17 | 5.88 |
| 91 | 1.10 | 66 | 1.52 | 41 | 2.44 | 16 | 6.25 |
| 90 | 1.11 | 65 | 1.54 | 40 | 2.50 | 15 | 6.67 |
| 89 | 1.12 | 64 | 1.56 | 39 | 2.56 | 14 | 7.14 |
| 88 | 1.14 | 63 | 1.59 | 38 | 2.63 | 13 | 7.69 |
| 87 | 1.15 | 62 | 1.61 | 37 | 2·70 | 12 | 8.33 |
| 86 | 1.16 | 61 | 1.64 | 36 | 2.78 | 11 | 9.09 |
| 85 | 1.18 | 60 | 1.67 | 35 | 2.86 | 10 | 10.00 |
| 84 | 1.19 | 59 | 1.70 | 34 | 2.94 | 9 | 11.11 |
| 83 | 1.20 | 58 | 1.72 | 33 | 3.03 | 8 | 12.50 |
| 82 | 1.22 | 57 | 1.75 | 32 | 3.13 | 7 | 14.29 |
| 81 | 1.23 | 56 | 1.79 | 31 | 3.23 | 6 | 16.67 |
| 80 | 1.25 | 55 | 1.82 | 30 | 3.33 | 5 | 20.00 |
| 79 | 1.27 | 54 | 1.85 | 29 | 3.45 | 4 | 25.00 |
| 78 | 1.28 | 53 | 1.89 | 28 | 3.57 | 3 | 33.33 |
| 77 | 1.30 | 52 | 1.92 | 27 | 3.70 | 2 | 50.00 |
| 76 | 1.32 | 51 | 1.96 | 26 | 3.85 | 1 | 100.00 |

TABLE II

*Frequency tables for base/height ratios of Hα dark markings*

| Ratios / Years | 0·5 | 0·6 | 0·7 | 0·8 | 0·9 | 1·0 | 1·1 | 1·2 | 1·3 | 1·4 | 1·5 | 1·6 | 1·7 | 1·8 | 1·9 | 2·0 | 2·1 | 2·2 | 2·3 | 2·4 | 2·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0·5—1·4 | | | | | | | | | | 1·5—2·5 | | | | | | | | | | |
| 1933 | .. | .. | .. | .. | .. | .. | 2 | 2 | 2 | 2 | 4 | 1 | 2 | 3 | 3 | 3 | 7 | 6 | 3 | 8 | 5 |
| 1934 | 1 | .. | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 3 | 4 | 9 | 10 | 9 | 11 | 13 | 13 | 7 | 7 | 6 | 10 |
| 1935 | .. | .. | .. | 3 | 1 | .. | 3 | 6 | 4 | 3 | 8 | 9 | 14 | 5 | 11 | 21 | 3 | 5 | 6 | 9 | 11 |
| 1936 | .. | 1 | .. | 1 | 3 | 2 | 3 | 5 | 6 | 3 | 17 | 4 | 9 | 11 | 13 | 14 | 7 | 9 | 10 | 28 | 10 |
| 1937 | .. | .. | .. | 2 | .. | 1 | 1 | 4 | 2 | 7 | 3 | 1 | 6 | 8 | 17 | 7 | 8 | 12 | 16 | 11 | 3 |
| 1938 | .. | 1 | .. | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 5 | 1 | 2 | 8 | 4 | 6 | 6 | 6 | 6 | 7 | 8 |
| 1939 | .. | .. | .. | .. | 1 | 1 | 1 | .. | 3 | 6 | 3 | 6 | 8 | 10 | 17 | 12 | 15 | 17 | 18 | 13 | 20 |
| 1940 | .. | 1 | 1 | .. | .. | .. | 2 | 1 | 4 | 3 | .. | 5 | 6 | 5 | 14 | 9 | 6 | 16 | 23 | 7 | 16 |
| 1941 | 1 | .. | .. | .. | 1 | 1 | 6 | 3 | .. | 3 | 5 | 11 | 5 | 9 | 8 | 13 | 10 | 13 | 10 | 5 | 4 |
| 1942 | 3 | 1 | 1 | .. | .. | .. | .. | 2 | 2 | 2 | 1 | 3 | 3 | 12 | 6 | 8 | 9 | 10 | 6 | 9 | 9 |
| 1943 | 1 | 1 | .. | 4 | 2 | .. | .. | .. | 1 | 1 | 3 | 5 | 1 | 2 | 5 | 7 | 5 | 7 | 5 | 7 | 11 |
| TOTAL | 6 | 5 | 3 | 12 | 12 | 7 | 21 | 27 | 26 | 34 | 53 | 55 | 66 | 82 | 109 | 111 | 89 | 108 | 110 | 110 | 107 |
| Group percentage | 7.1% | | | | | | | | | | 46·1% | | | | | | | | | | |

| Ratios / Years | 2·6 | 2·7 | 2·8 | 2·9 | 3·0 | 3·1 | 3·2 | 3·3 | 3·4 | 3·5 | 3·6 | 3·7 | 3·8 | 3·9 | 4·0 | 4·1 | 4·2 | 4·3 | 4·4 | 4·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2·6—3·5 | | | | | | | | | | 3·6—4·5 | | | | | | | | | |
| 1933 | 2 | 4 | 4 | 4 | .. | 2 | 4 | 4 | 1 | 2 | 1 | .. | 1 | 2 | 1 | .. | 1 | 2 | .. | .. |
| 1934 | 11 | 8 | 12 | 7 | 9 | 8 | 5 | 3 | 4 | 3 | 2 | 4 | 1 | 5 | 2 | 1 | 5 | 1 | 3 | 3 |
| 1935 | 6 | 8 | 4 | 5 | 11 | 5 | 6 | 6 | 7 | 5 | 6 | 5 | 2 | 3 | 3 | 3 | 2 | 1 | 2 | .. |
| 1936 | 17 | 16 | 18 | 9 | 23 | 7 | 6 | 15 | 6 | 4 | 11 | 5 | 5 | 3 | 6 | 2 | 2 | 1 | 2 | .. |
| 1937 | 9 | 6 | 4 | 7 | 4 | 6 | 3 | 4 | 7 | 2 | 6 | 3 | 1 | 3 | 2 | .. | 1 | 3 | 1 | 1 |
| 1938 | 6 | 6 | 7 | 9 | 5 | 6 | 3 | 2 | 7 | 3 | 7 | 8 | 4 | 5 | .. | 5 | 3 | 1 | 2 | .. |
| 1939 | 8 | 6 | 12 | 6 | 20 | 8 | 10 | 4 | 4 | 9 | 7 | 3 | .. | 1 | .. | 1 | 1 | .. | 1 | 4 |
| 1940 | 7 | 10 | 6 | 6 | 10 | 12 | 3 | 4 | 3 | 3 | 6 | 3 | 5 | 1 | 2 | 6 | 1 | 2 | 2 | 1 |
| 1941 | 7 | 3 | 3 | 4 | 4 | 4 | ·2 | 2 | 1 | 3 | .. | 1 | 2 | .. | 1 | 1 | .. | .. | 1 | 1 |
| 1942 | 11 | 7 | 9 | 2 | 7 | 5 | 3 | 3 | 2 | 1 | 1 | 2 | .. | 2 | .. | 1 | 1 | 3 | .. | .. |
| 1943 | 7 | 6 | 7 | 4 | 3 | .. | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 2 | 2 | 1 | 1 | .. | .. | .. |
| TOTAL | 91 | 80 | 86 | 63 | 96 | 63 | 48 | 49 | 44 | 36 | 50 | 37 | 22 | 27 | 19 | 21 | 18 | 14 | 16 | 10 |
| Group percentage | 30.3% | | | | | | | | | | 10.8% | | | | | | | | | |

| Ratios / Years | 4·6 | 4·7 | 4·8 | 4·9 | 5·0 | 5·1 | 5·2 | 5·3 | 5·4 | 5·5 | 5·6 | 5·7 | 5·8 | 5·9 | 6·0 | 6·1 | 6·2 | 6·3 | 6·4 | 6·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4·6—5·5 | | | | | | | | | | 5·6—6·5 | | | | | | | | | |
| 1933 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. |
| 1934 | 1 | .. | 3 | .. | 1 | 2 | 2 | 2 | 1 | 1 | 1 | .. | 1 | 1 | .. | .. | 2 | .. | .. | .. |
| 1935 | 7 | .. | .. | 1 | 2 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1936 | 3 | 2 | 5 | .. | 1 | 1 | .. | 3 | 2 | .. | .. | .. | 3 | .. | 1 | .. | .. | 1 | .. | 2 |
| 1937 | 1 | 2 | 1 | .. | .. | .. | .. | 1 | .. | 1 | .. | .. | .. | .. | 1 | .. | .. | 1 | .. | .. |
| 1938 | 1 | 1 | .. | 1 | 3 | 2 | .. | 1 | 1 | 2 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| 1939 | .. | .. | 1 | 1 | .. | .. | 1 | .. | .. | .. | 1 | .. | 1 | .. | .. | .. | 1 | .. | .. | .. |
| 1940 | .. | .. | .. | .. | 1 | .. | .. | 2 | 1 | 1 | 1 | .. | .. | .. | .. | 1 | .. | .. | .. | .. |
| 1941 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1942 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| 1943 | .. | .. | .. | .. | 1 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| TOTAL | 15 | 5 | 10 | 4 | 9 | 6 | 4 | 10 | 5 | 5 | 3 | .. | 6 | 1 | 3 | 1 | 3 | 3 | .. | 2 |
| Group percentage | 3.5% | | | | | | | | | | 1·0% | | | | | | | | | |

## TABLE III

*Frequency tables for base/height ratios of arch type prominences on the limb*

| Ratios | 0·5 | 0·6 | 0·7 | 0·8 | 0·9 | 1·0 | 1·1 | 1·2 | 1·3 | 1·4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequencies | 0 | 1 | 2 | 1 | 1 | 2 | 4 | 4 | 4 | 5 |
| Group percentage | 13% | | | | | | | | | |

| Ratios | 1·5 | 1·6 | 1·7 | 1·8 | 1·9 | 2·0 | 2·1 | 2·2 | 2·3 | 2·4 | 2·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequencies | 11 | 11 | 14 | 7 | 9 | 29 | 9 | 11 | 7 | 7 | 16 |
| Group percentage | 70% | | | | | | | | | | |

| Ratios | 2·6 | 2·7 | 2·8 | 2·9 | 3·0 | 3·1 | 3·2 | 3·3 | 3·4 | 3·5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequencies | 3 | 3 | 5 | 2 | 9 | 0 | 0 | 1 | 1 | 1 |
| Group percentage | 13% | | | | | | | | | |

| Ratios | 3·6 | 3·7 | 3·8 | 3·9 | 4·0 | 4·1 | 4·2 | 4·3 | 4·4 | 4·5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequencies | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Group percentage | 3% | | | | | | | | | |

| Ratios | 4·6 | 4·7 | 4·8 | 4·9 | 5·0 | 5·1 | 5·2 | 5·3 | 5·4 | 5·5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequencies | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| Group percentage | 1% | | | | | | | | | |

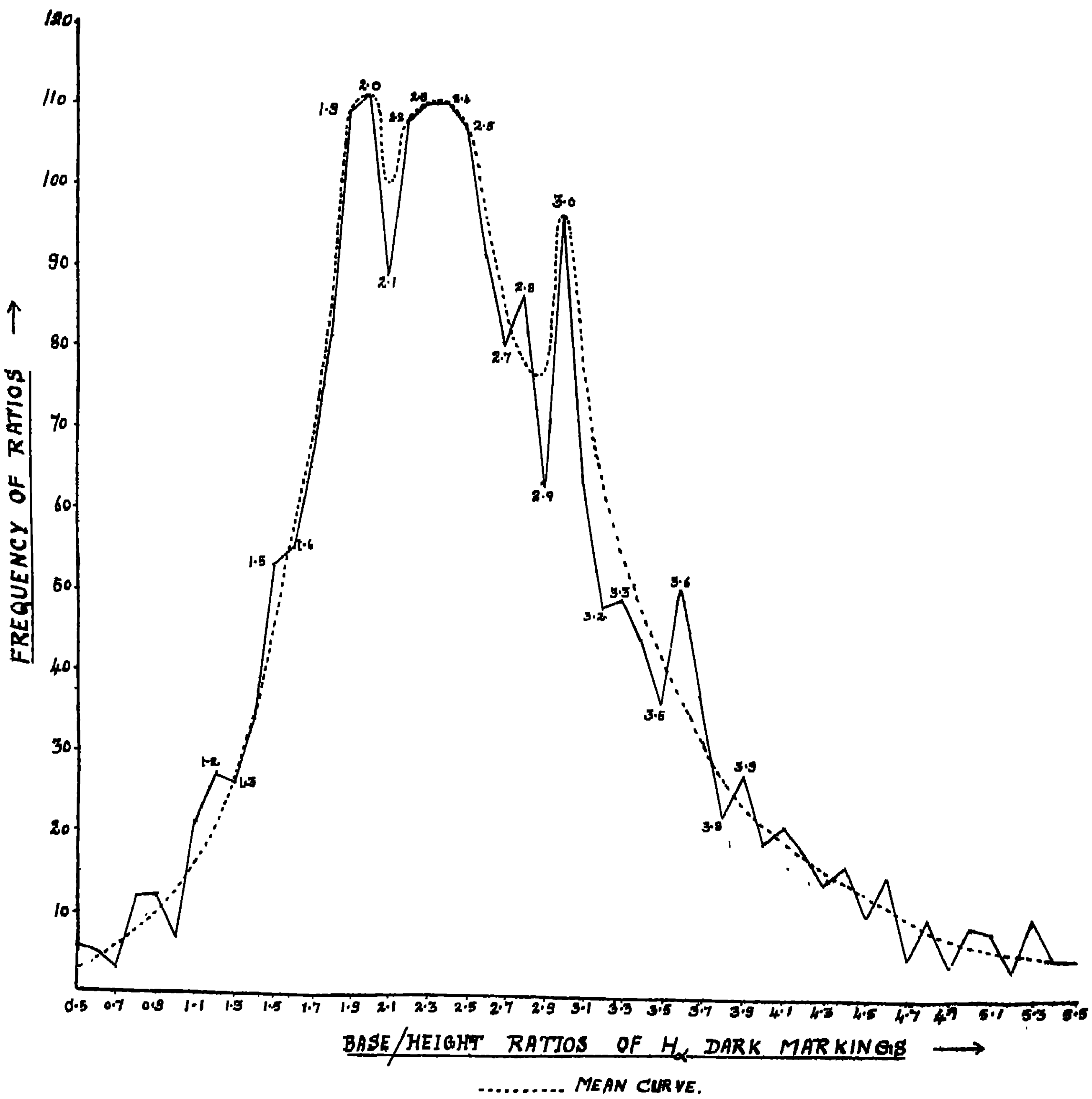
FREQUENCY OF RATIOS →
BASE/HEIGHT RATIOS OF Hα DARK MARKINGS →
........... MEAN CURVE.

FIG 3.

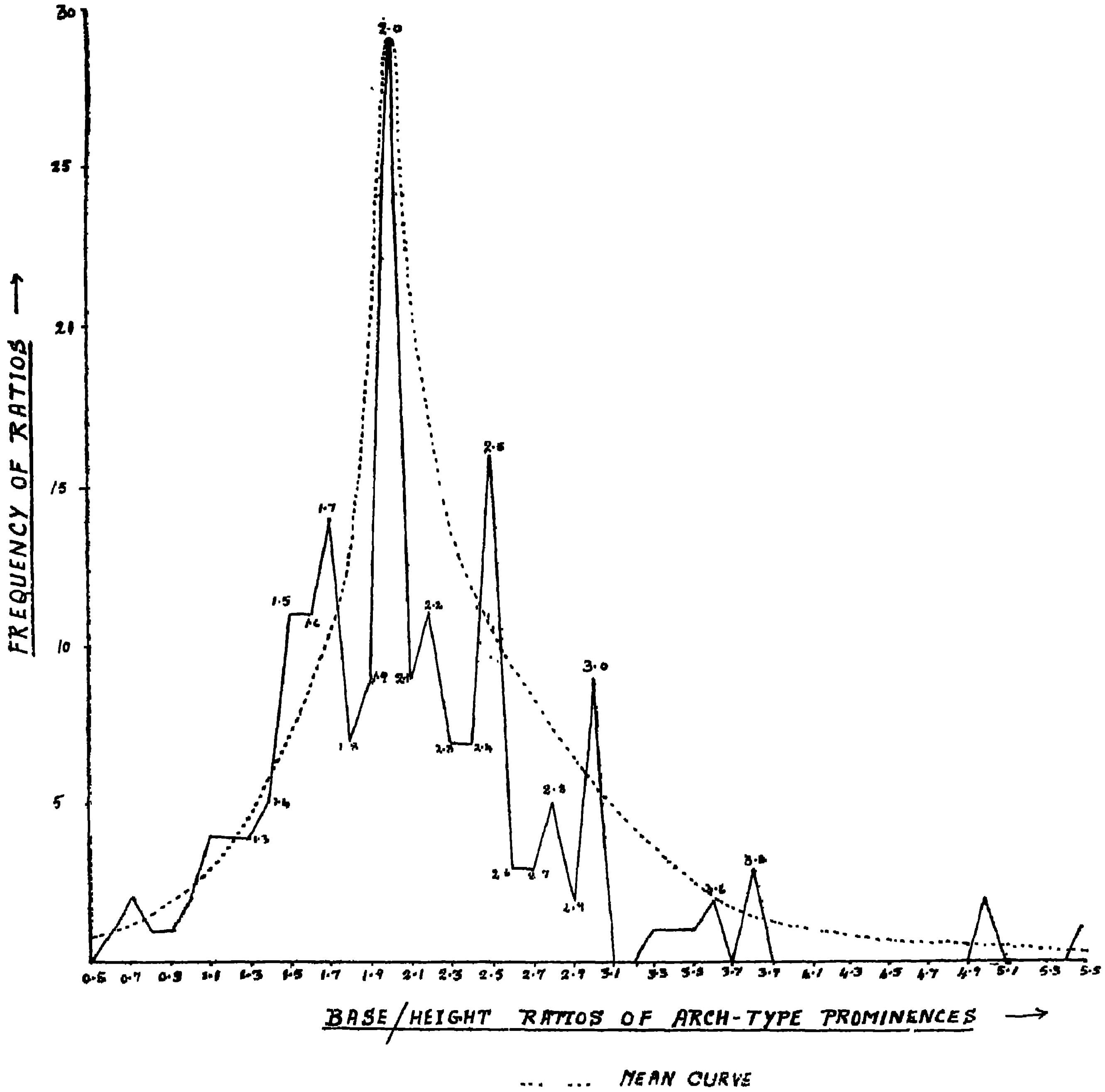


FIG 4.

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