OBSERVATIONS OF FACULAE BORDERING SMALL SUNSPOTS NEAR THE LIMB*

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It has long been known that there is a close association between sunspots and white-light faculae. No spots near the limb are observed without attendant faculae and, conversely, except for the polar faculae, which occur in zones where spots do not normally appear, there are few faculae which are not associated with spot groups at some stage of their lives. Photospheric faculae are visible only near the limb, where they may be described as consisting of a system of bright granules (ten Bruggencate 1940; Waldmeier 1955, cf. p. 205) seen against a background of material brighter than the surrounding photosphere; they are often arranged in the form of veins parallel to the limb.

During the course of the examination of a number of films‡ of spot groups near the limb we have noticed that there is a strong tendency for the facular streaks to lie in juxtaposition to any small spots in the vicinity. In such cases they appear as bright borders closely following the outlines of the spots and occurring almost invariably on the limb side.

Plate 1 gives two illustrations of this phenomenon: 1 (*a*) shows portion of an isolated group of small spots and 1 (*b*) some of the debris between the main components of a well-developed bipolar group. All the spots shown are devoid of penumbrae and appear somewhat elongated in the vertical direction owing to foreshortening (the heliocentric angles being 58 and 64° respectively). The bright borders are very conspicuous on some of the spots; their apparent widths lie between 1 and 2 sec of arc. Although there are several spots lacking a bright border and several facular veins unaccompanied by spots, there is no doubt that the phenomenon is real.

* Manuscript received September 26, 1958.

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‡ The films were taken with the 5-in. photoheliograph (Loughhead and Burgess 1958) of the C.S.I.R.O. Division of Physics Solar Observatory.

Photographs taken with the Sydney Hα-telescope, using solar image diameters of 15 and 75 mm, show normal hydrogen plages above the regions illustrated in Plate 1 but fail to reveal any detailed connexion between the hydrogen plages and the facular veins.

The same phenomenon has been observed in other spot groups near both limbs. Nevertheless, it is by no means universal: a number of spots similar to those illustrated, at comparable heliocentric angles, failed to show any bright borders. When present, however, they are almost invariably on the limb side. The effect has been observed only with spots devoid of penumbrae and sometimes occurs even with pores 1–2 sec of arc in diameter. It then takes the form of a bright point of light on the limb side of the pore, closely resembling a very bright photospheric granule.

One interpretation of the observations is that over the small umbral areas lie facular " clouds " of similar dimensions which, at the heliocentric angles concerned, appear displaced towards the limb by parallax ; the observed displacements imply a height of about 1200 km (cf. Plate 1). In addition, the faculae are supposed to be semi-transparent—so that the spots remain visible underneath—but are sufficiently emissive to appear bright when their radiation is added to that of the normal photosphere. Apart from the earlier visual observations of faculae at the limb as " projecting hillocks " (Young 1895), there are three lines of evidence which suggest that faculae do indeed lie above the lower layers of the photosphere : the resemblance of faculae to the overlying calcium plages, the difference between the periods of solar rotation derived from measurements of faculae and spots, and finally, the interpretation of limb-darkening measurements of the faculae. The first two provide no estimates of height, and the present interpretation of the limb-darkening measurements is somewhat obscure. However, according to Waldmeier (1955, cf. p. 208), the contrast of the faculae reaches a maximum at a heliocentric angle of 71° and decreases nearer the limb. This would seem to imply that the faculae are located in the photosphere (see also Unsöld 1955) ; but the vertical extension of the photosphere does not exceed a few hundred kilometres, whereas the parallax explanation requires the faculae to lie at a height of about 1200 km.

Another possible explanation may lie in the lower absorption coefficient of the umbral gas compared with that of the photosphere. This causes the umbral boundary on the limb side to appear displaced away from the limb, so that any overlying facular cloud appears to project beyond the boundary.*

Whatever the explanation of the observed asymmetry in the location of the bright borders, the observations strongly suggest the existence of facular clouds directly overlying small umbral areas. A spot is a cool region surrounded by hotter gases, whereas a facula is a hot region surrounded by cooler gases. It

* The effect of a lower absorption coefficient would be to cause the umbra to become foreshortened, as the spot approached the limb, at a greater rate than that implied by geometrical foreshortening. A similar explanation has been used to account for the Wilson effect (Loughhead and Bray 1958). However, measurements made to detect any such anomalous foreshortening, based on the same data, have proved inconclusive owing to changes in the size of the spot during its passage across the disk and to irregularities in its umbral outline.

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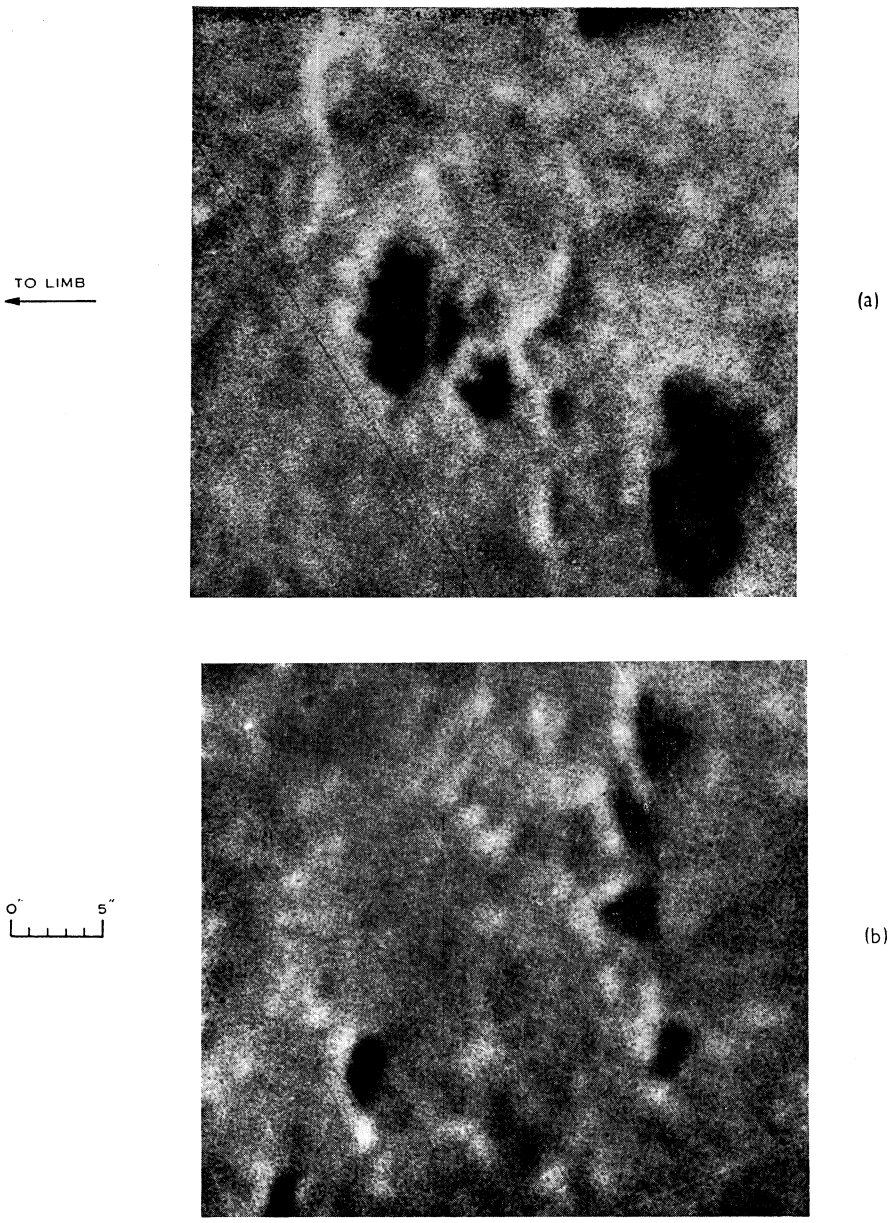

(*a*) Portion of an isolated group of small spots, photographed on January 10, 1958. Heliographic coordinates: 347° W., 23° N.; heliocentric angle, 58°.
(*b*) Small spots associated with a bipolar group, photographed on January 13, 1958. Heliographic coordinates: 298° W., 16° N.; heliocentric angle, 64°.
The spots are devoid of penumbrae and appear somewhat elongated in the vertical direction owing to foreshortening.

may well be a fruitful concept to consider spot and facula as two parts of a single physical system—the equivalent of a refrigerating engine (cf. Kiepenheuer 1953).

The authors are indebted to Miss M. McCabe and Mr. V. R. Burgess for supplying chromospheric photographs and to Mr. H. Gillett for processing the films and making the enlargements.

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