BULLETIN OF THE ALLYN MUSEUM

Published by
THE ALLYN MUSEUM OF ENTOMOLOGY
Sarasota, Florida

Number 40 10 November 1976

DIFFRACTION STRUCTURES IN THE WING SCALES OF *CALLOPHRYS (MITOURA) SIVA SIVA* (LYCAENIDAE)

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In preparing color photographs of several species of the genus *Callophrys* we encountered difficulty in obtaining an acceptable reproduction of the green color of ventral surfaces. In several cases, we could obtain little, if any, green color on photographs even though it was visually quite prominent.

Previous scale studies (see Downey and Allyn, 1975), together with continued research in Pieridae and Lycaenidae, indicate at least two types of scale structures which produce discreet frequencies through interference or diffraction pheonomena.* Only one of these is found in the Nearctic *Callophrys siva*. Morris (1975) reported the green iridescence of the Palearctic *Callophrys rubi* was caused by a porous element in the scale lumen, which has a mosaic of polygonal grains having an ultrastructure of a cubic network. Our previous work using scan electron microscopy had revealed similar porous elements in other Lycaenidae.

PROCEDURES

Samples of the ventral surface of wings of *Callophrys (Mitoura) siva siva* (W. H. Edwards) were examined with a Beckman DB-GT spectrophotometer and a JEOL-SMU-3 scanning electron microscope. The spectrophotometer was equipped with a reflectance attachment and reference beam attenuator. A small attachment was also devised which permitted the sample to be placed on the attenuator at various angles. Dried wings were coated for scanning in a Varian V-10 vacuum coater to approximately 50 angstroms with 60/40 gold palladium.

*Numerous investigations have dealt with the general subject of iridescence which need not be reviewed here. Such studies include: Anderson & Richards, 1942; Gentil, 1935 through 1964; Ghiradella, 1974; Ghiradella *et al*, 1972; Lippert & Gentil, 1952, 1959; Mason, 1926, 1927; Onslow, 1921; Suffert, 1924.

OBSERVATIONS

Light microscopy indicated the green scales in *siva* produced also a light brown color. This color was similar to the coloration of the ventral forewing scales, and is assumed to be melanin deposited in the scale structure. Therefore it seemed reasonable that, to more precisely determine the exact output of the green portion of the scales, we could produce spectophotometric curves of both the green hindwing scales and the brown forewing scales, and subtract the data of the brown from that observed from the green scales. The two curves produced in this manner further indicated the reasonableness of this approach. The resulting curve (Fig. **1**) indicates a very tight peak of response at 515 nm. The intensity varies slightly with the viewing angle, but there is no wavelength shift. This was confirmed both visually and spectrophotometrically. Essentially no reflection in the ultraviolet was observed.

Upon SEM examination we located a dislodged scale from which the ventral (bottom or adwing surface) side had been peeled back, revealing for the first time the mosaic of polyhedral grains in great detail (Fig **2** and **3**). The dorsal side of a typical green scale is shown in Figure **4**.

Internal examination of these grains indicates that their structure is more hexagonal in form than it is cubic and most closely resembles a honeycomb from all planes. A honeycomb-like formation would permit a more uniform thickness throughout the lattice than would a cubic form as postulated by Morris (1975).

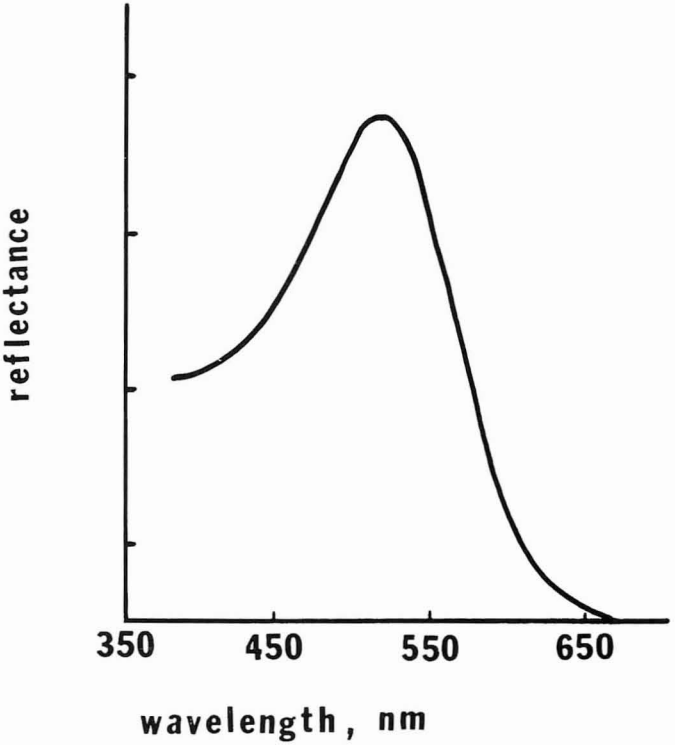
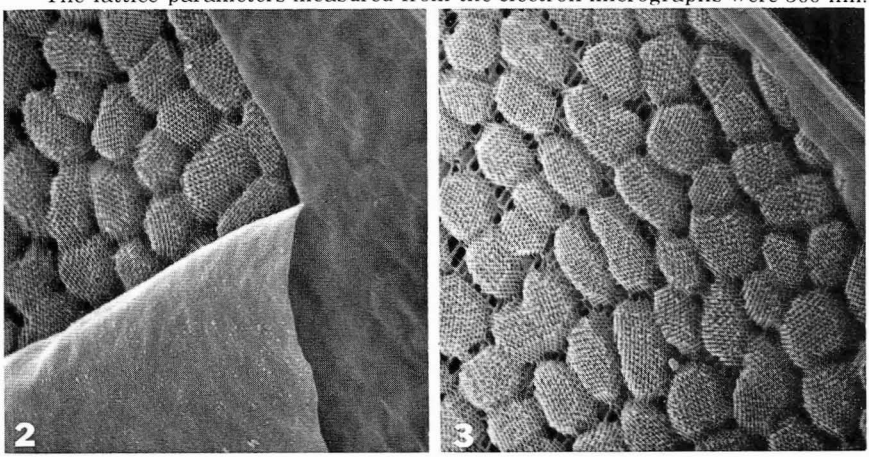


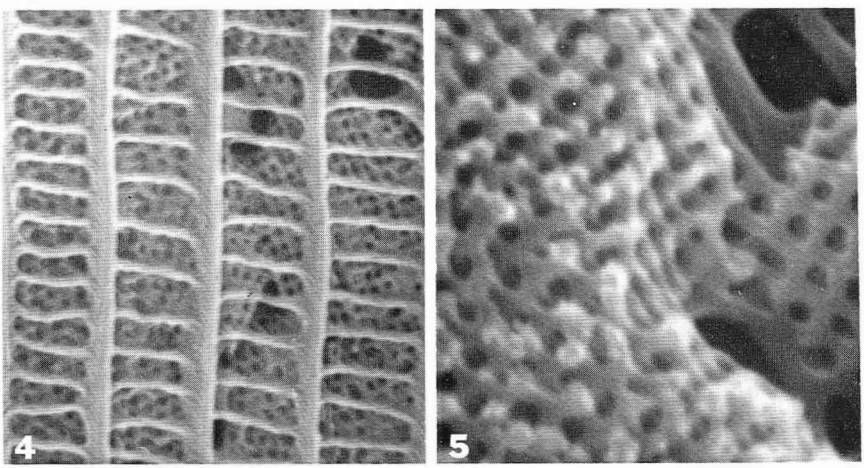
Figure 1. Spectrophotometric curve derived from ventral hindwing surface of *Callophrys siva*.

In cross section the grains appear to be composed of perforate layers four to seven deep, and connected by minute trabeculae (pillars). This could account for earlier observations (W. Schmidt, 1942a: 199; Schmidt and Paulus, 1970: 235) on layering of this structure. As indicated by both Figure **5** and the stereo pairs (Fig. **6**), the structure is a uniform lattice perforated in the vertical and both horizontal planes, and having uniform lattice thickness in all directions. Such a formation would permit the constant color seen from all viewing angles. This uniformity contrasts sharply with the color variation with viewing angle as observed in the ridge-line and ridge-shelf interference phenomena of the Morphidae scale structure.

The lattice parameters measured from the electron micrographs were 300 nm.



Figures 2 & 3. 2: Ventral hindwing scale of *Callophrys siva* with adwing surface peeled back (1930x). 3: Porous elements in scale lumen (1930x). The differling horizontal orientation of the elements may be noted.



Figures 4 & 5. 4: Dorsal view of ventral surface green scale of *Callophrys siva* (6430x). The porous elements may be seen below the ridges and cross ribs which partially obscure their true form and shape. 5: Detail of structure of a porous element (19300x). The lighter knob-like protuberances are the pillars connecting the element to the adwing membrane.

The density correction factor derived following Morris (1975) is 1.162. Using this factor, the lattice parameter yields a theoretical frequency of 516 nm. The observed peak output of 515 nm is within reasonable limits of the theoretical.

The grains were highly variable in size and orientation appeared to be random. This latter fact would also permit a uniform output at approximately 515 nm when viewed from any direction or by diffused light.

The general form of the scales throughout the expanse of the ventral surfaces of *C. siva* was quite uniform. Other than the presence or absence of the diffraction grains the only difference noted was a wider spacing of the ridges in the green scales of the hindwing and the light brown scales of the forewing. (Figs. **7, 8, 9**).

The hole sizes of the grains in *M. siva* is between those observed in certain blue scales and copper scales of other species of Lycaenidae. This conforms with the postulated volume diffraction method of color production.

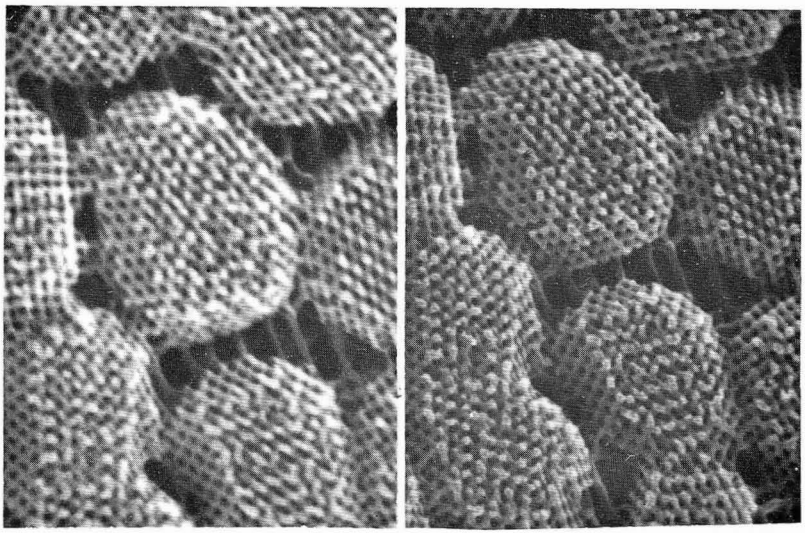
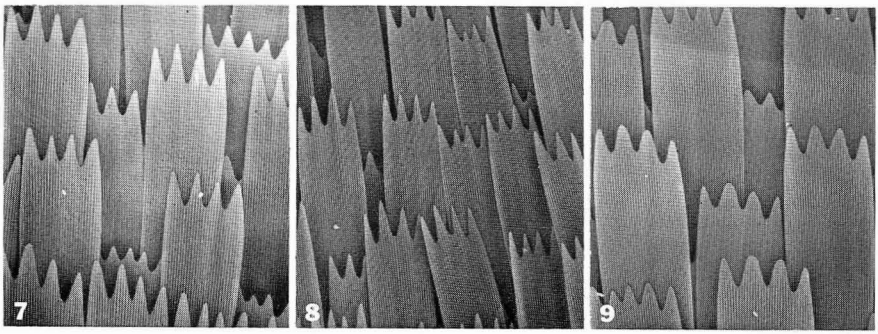


Figure 6. Stereo-pair of porous elements (6000x). The four to five layered depth of the elements can be seen.



Figures 7, 8 & 9. Ventral surface scales of *Callophrys siva* showing general similarity of form (185x). Porous elements occur only in the green scales. 7: Green hindwing. 8: Brown hindwing. 9: Brown forewing.

CONCLUSIONS

1. The green color of the ventral side of the hindwings of *Callophrys siva* is produced by a volume diffraction grating (porous elements) situated within the scale.

2. The shape of the entire porous element is irregular and scattered in a close order random manner in the scale lumen. The horizontal orientation of each porous element is also random.

3. The extraordinarily narrow wavelength in the green (515 nm peak) from the diffracting porous elements accounts readily for the difficulties encountered in color reproduction since most color film has a relatively low sensitivity at this frequency.

4. The wavelength differences between *siva* and *rubi* (Morris, 1975) are compatible with the observed differences in lattice parameters of the porous elements.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. Tyler Estler of the Physics Department of New College for his verification of the physics of the observed phenomena. Special thanks to our associate, Dr. Lee D. Miller, for his many cogent suggestions and proofing of the manuscript.

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