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CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY
(*Continuation of Contributions from the Museum of Geology*)
UNIVERSITY OF MICHIGAN

VOL. III, No. 6, pp. 109–150 (5 pls.) FEBRUARY 20, 1930

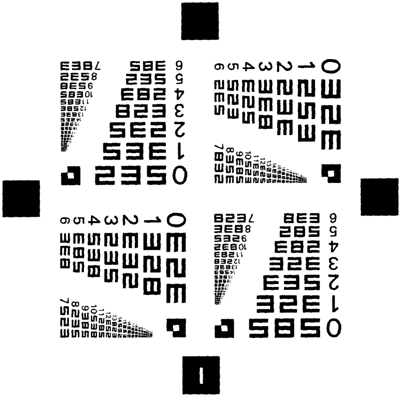
THE COLOR PATTERNS OF FOSSIL CEPHALOPODS AND BRACHIOPODS, WITH NOTES ON GASTEROPODS AND PELECYPODS

BY
AUG. F. FOERSTE

UNIVERSITY OF MICHIGAN
ANN ARBOR

ROCHESTER INSTITUTE OF TECHNOLOGY, ONE LOMB

MEMORIAL DRIVE, ROCHESTER, NEW YORK 14623



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(Continuation of Contributions from the Museum of Geology)

UNIVERSITY OF MICHIGAN

Editor: EUGENE S. MCCARTNEY

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By AUG. F. FOERSTE

CONTENTS

ACKNOWLEDGMENTS

THE incentive toward the studies recorded in this paper was furnished by the loan from Professor E. C. Case of the University of Michigan of several specimens showing color patterns. Two of these were specimens of *Orthoceras* showing transverse zigzag color lines and one was a fragment of limestone retaining parts of two valves of a terebratuloid brachiopod, both of which showed concentric color lines. These were supplemented by a loan from Professor Carl Dunbar of Yale University of

several specimens of *Orthoceras*, belonging to two species, both of which showed color markings, one of these having zigzag lines, and the other, relatively straight transverse ones. Finally, Dr. H. Hedström of the Geological Survey of Sweden loaned me two specimens of a small erect cyrtoceroid in which the steeply inclined color lines formed a zigzag pattern only on the ventral side of the conch. I had previously been permitted by Dr. Jan Koliha to study the unrivaled collection of cephalopods described by Barrande, a considerable number of which show color markings; similar markings occur also on specimens formerly borrowed from Dr. Rudolf Ruedemann and Professor T. E. Savage. To all of these I here express my appreciation of the favors so generously granted.

The following studies are concerned chiefly with color markings in cephalopods and brachiopods, but a few notes on gasteropods and pelecypods are added, enough to give some notion of the relative number of color-marked species known at present and their stratigraphic distribution. The bibliography at the end includes all the more important papers bearing on this subject, especially those listing species from the widely scattered literature. Among these the papers by Deecke, Leidhold, Newton, Oppenheim and Richter will be found very useful.

I. Introduction

Fossils retaining evidences of former coloration are always of interest, especially when they belong to the remote past. In fossils of more recent age the original colors are frequently preserved, but in earlier fossils, especially those of Paleozoic age, the former presence of colors is usually indicated only by varying shades of light and dark. Sometimes these traces of color are in the form of dots or blotches, irregularly scattered, or arranged according to some definite pattern. At other times they may take the form of radiating or concentric lines or bands, or of combinations of the two. Occasionally the lines are of a zigzag form, or the patterns may be even more intricate.

In the more recent fossils all the colors at present known from animals of a similar type are to be expected, but in fossils from

Paleozoic strata the colors usually found are confined to various shades of brown or are nearly black. Occasionally the browns verge on red.

In some cases there is evidence that the color shown by a particular fossil is determined in some manner by the mineral matter present in the inclosing matrix. Occasionally this may be indicated by a single individual. For instance, specimens have been found which possessed brownish color markings where preserved in whitish limestone, but which had almost black markings where extending into a blackish matrix.

All traces of color tend to disappear with the increasing age of a deposit of fossils, especially during the recrystallization of the calcareous components of the shell. Hence color patterns are retained more frequently by the more recent species. This is shown especially by the gasteropods. A total of 293 species of gasteropods has been recorded as retaining color markings. Of these, 224 species occur in the Tertiary, 25 in the Mesozoic, and 44 in the Paleozoic. Even among Paleozoic strata great differences are shown, the Carboniferous retaining 33 species of gasteropods with color markings; the Devonian, 5 species; the Silurian, 3 species; and the Ordovician, also 3 species.

In cephalopods, on the contrary, almost all color-marked species belong to the Paleozoic. This is readily understood when it is remembered that color markings are extremely rare among all the strongly coiled cephalopods, both nautiloid and ammonoid. They are not numerous among straight conchs, and they appear to occur most frequently among the breviconic cyrtoceroids, which are known only from Paleozoic strata.

In a similar manner, only two brachiopods preserving color patterns have been recorded from the Tertiary. But this type of life was much more abundant in Paleozoic and Mesozoic times, from which a larger number of species with color patterns is reported.

The general vertical distribution of the different types of shell-bearing animals is indicated on the following page.

The very imperfect character of the data secured so far is shown by the fact that of the 33 color-marked species of gastero-

pods recorded at present from the Carboniferous of the entire world, 15 were discovered by J. Brookes Knight only recently, and at a single horizon, in the Pennsylvanian division of the Carboniferous, near St. Louis, Missouri. In a similar manner, of the 25 color-marked species of cephalopods known so far from the Silurian of the entire world, 22 were found in a relatively small area north of Prague, formerly in Bohemia, now a part of Czechoslovakia. Similar rich but isolated localities probably await discovery elsewhere.

NUMBER OF SPECIES RECORDED AS COLOR-MARKED

	Tertiary	Mesozoic	Paleozoic	Total
Brachiopods ..	2	10	11	23
Pelecypods ...	6	12	7	25
Gasteropods ..	224	25	44	293
Cephalopods ..	1	1	39	41
Total	233	48	101	382

The imperfection of our knowledge regarding color markings in fossil shells is shown also by the irregular vertical distribution of the gasteropods in the Tertiary and Mesozoic. Of the 293 species recorded as showing color markings, 16 occur in the Pliocene, 75 in the Miocene, 10 in the Oligocene, and 72 in the Eocene; 2 additional ones are recorded as from the Tertiary, without any statement of their more exact horizon. The abundance of color-marked species of gasteropods in the Eocene should be contrasted with the small number of 5 species recorded from the Cretaceous, 11 from the Jurassic, and 9 from the Triassic. It is evident that the sudden increase of recorded color-marked species from 5 in the Cretaceous to 72 in the Eocene does not indicate that color-marked species were relatively scarce during Cretaceous times, but either that the conditions for the preservation of the colors of Cretaceous species, for some unknown reason, was less favorable, or that by some chance certain localities unusually favorable to the preservation of color markings have

been found in Eocene strata, while similar good localities of Cretaceous await future discovery.

II. Brachiopods

Recently a terebratuloid brachiopod shell showing black concentric lines and bands on an otherwise light gray field was found by Professor E. C. Case in the Alpena member of the Traverse group, in the Middle Devonian of eastern Michigan. Its exact horizon was about 90 feet below the top of the quarry of the Michigan Alkali Company, at Alpena, Michigan. This horizon is between 22 and 30 feet above the present base of the quarry, where the limestone is dark and fine-grained, irregularly bedded, and with streaks of black. At one point within this zone were found the cephalopods *Acleistoceras casei*, *Acleistoceras nummulatum*, *Alpenoceras ulrichi* and *Nephriticerina alpenensis*, described in *Contributions from the Museum of Geology, University of Michigan*, in 1927. In addition, this horizon contains a species of *Acervularia*, a long form of *Favosites*, various cyathophylloids, and large, flat, fan-shaped stromatoporoids. The *Acervularia* occurs also in abundance in a zone 10 feet thick at a horizon 16 feet above this cephalopod horizon.

The terebratuloid species with color markings is referred provisionally to *Cranaena*, but its exact generic relationship cannot be determined until specimens are secured permitting the discovery of the structure of the interior of their valves in the vicinity of their beaks, according to the methods recently used by Bielanski on Iowan Devonian material. The Alpena species is described here as new. At least no terebratuloid species with concentric color markings has yet been described from Middle Devonian strata of America. The name **Cranaena casei** is proposed. To judge from fragments of *Cranaena* in the matrix of other specimens from the same locality and horizon, further search will no doubt result in securing better material for specific description, though probably lacking the color markings. At least, to judge from occurrences elsewhere, even where color-marked species are unusually frequent, the number of specimens of any species actually

retaining color markings forms only a small part of the total number of specimens of that species occurring at the same horizon. The following description gives a more detailed account of the color-marked specimens of *Cranaena* from Alpena.

Cranaena casei, sp. nov. (Plate II, Fig. 5). — Two valves, their interiors facing each other, evidently not belonging to the same individual, since the color patterns on the two valves do not match. Their lateral displacement is about 5 mm. The width of the valve best preserved is about 25 mm., and the other is of about the same size. Their lateral outlines appear to have been similar to those of *Cranaena calvini* (Hall & Whitfield), but the valves of the latter are spotted, instead of marked with concentric lines and bands. The posterior half of the better preserved valve is almost smooth, as seen without a lens, but its anterior half is striated distinctly, though not strongly, in a concentric direction, and very faint radiating lines can be detected if the shell is illuminated transversely. The surface of the shell is minutely punctate, with the punctae arranged in diagonal rows which cross each other at an angle of approximately 45 or 50 degrees. There are about 15 punctae within a length of 1 mm., counted along one of the diagonal rows. The punctae are elongated distinctly in a radial direction from the beak. Concentric black lines cross the otherwise gray surface of the shell. The different black lines vary in width from about 0.66 mm. to fully 0.7 mm. They occur at irregular intervals and in an irregular order of succession, broader and finer bands and lines being intermingled. In fact, under a lens some of the broader black bands may be seen to be made up of a series of very narrow but closely crowded black lines, separated by still finer intermediate lighter-colored lines. In other specimens the broader black bands are not interrupted by lighter-colored lines, but appear continuous even under a lens. In the two valves here under consideration the black lines and bands are more distant from each other posteriorly, but more closely crowded anteriorly.

The relative scarcity of concentric lines in fossil brachiopods is shown by the following list, which includes all known fossil brachiopods retaining color markings; also a brief indication of the character of the color markings presented.

LIST OF SPECIES

Pliocene

Terebratula ampulla; spotted

Eocene

Terebratula sp. (from Säntis); spotted

Cretaceous

Rhynchonella octoplicata; spotted
Terebratula biplicata; with radial lines

Jurassic

Terebratula eudesi; with radial lines
Terebratula maxillata; with radial lines
Terebratula subovoides; with radial lines
Terebratula umbonella; spotted
Waldheimia perforata; with concentric lines

Triassic

Terebratula falsani; with radial lines
Terebratula potieri; with radial lines
Terebratula vulgaris; with radial lines

Carboniferous

Dielasma elongatum; with radial lines
Dielasma hastatum; with radial lines
Martinia glaber; with radial lines
Schizophoria resupinata; with radial lines

Devonian

Cranaena calvini; spotted
Cranaena navicella; spotted
Cranaena morsii; with radiating rows of dots and spots
Cranaena (?) *sp.;* a species from Arctic America, evidently incorrectly referred to *Terebratula;* spotted
Cranaena casei (from Alpena, Michigan); with concentric lines and bands
Newberria cimex; with concentric bands
Pugnax pugnus (often still cited under *Rhynchonella*); spotted

This list includes 23 species of brachiopods retaining color markings. Of these, 18 belong to the terebratuloids (*Terebratula, Dielasma, Cranaena, Newberria*); 1 is a terebratelloid (*Waldheimia*); 2 are rhynchonelloids (*Rhynchonella, Pugnax*); 1 is a spiriferoid (*Martinia*), and only 1 is an orthoid (*Schizophoria*). Among these species the forms with punctate shells predominate greatly; they include the 18 terebratuloids and 1 terebratelloid. Rhynchonelloids, spiriferoids and orthoids are relatively few. Eleven of these

species have radiating lines. In 8 species there are dots or spots irregularly arranged; in 1 species the dots are arranged in radiating series. In 3 species the lines or bands are concentric.

The Devonian brachiopod brought back from Arctic America by Sir John Richardson, and now preserved in the British Museum of Natural History, was cited in 1854 by Forbes [1] under the generic name *Terebratula*. That genus does not occur, however, in Paleozoic strata, and it is more likely to be a *Cranaena* or to belong to some genus closely related to *Cranaena*. Forbes described this specimen as being beautifully spotted. According to Suess,[2] this spotting was irregular. The specimen is mentioned also by Kayser.[3] It is of interest especially on account of the presence of *Cranaena calvini* and *Cranaena navicella* in the Hackberry stage of the Upper Devonian in Iowa. This Hackberry fauna is regarded as of northern origin, a view which finds support in the occurrence of an apparently closely related species in the American Arctic. The general color of *Cranaena calvini* is described by the Fentons [4] as brownish to olive-brown, with touches of purple and chocolate, one specimen being olive-brown with dots and longitudinal splotches of purple. The color of *Cranaena navicella* is described by them as brown or olive-brown, with purplish-brown mottlings.

The Alpena limestone fauna also may be of northern origin. The terebratuloid *Cranaena casei* from this limestone differs, however, from any other known species of this genus in having concentric color lines and bands instead of irregularly arranged dots and splotches of color.

The presence of concentrically arranged lines and bands in the Alpena limestone is of interest, moreover, because concentric lines

[1] Forbes, E., "Note on an Indication of Depth of Primaeval Seas, Afforded by the Remains of Colour in Fossil Testacea," *Proc. Royal Soc. London*, Vol. 7, pp. 21–23, 1854.

[2] Suess, Ed., "Über die Wohnsitze der Brachiopoden," *Sitzungsberichte der k. Ak. Wiss., Math.-nat. Kl.*, Vol. 37, pp. 185–248, 1859.

[3] Kayser, E., "Notiz über Rhynchonella pugnus mit Farbenspuren aus dem Eifler Kalk," *Zeitschrift der deutsch. geol. Gesell.* (Berlin), Vol. 23, pp. 257–265, 1871.

[4] Fenton, C. L. and M. A., *The Stratigraphy and Fauna of the Hackberry Stage of the Upper Devonian* (Macmillan Co., New York), pp. 132–133, 1924.

and bands are extremely rare in fossil species, and are relatively rare even among living forms. Among fossil forms, they occur in *Waldheimia perforata* (Piette), from the Lower Liassic of Gloucestershire, in England; the transverse or concentric bands deviate but slightly from the course of the lines of growth. They occur also in *Newberria cimex*, in which, however, the concentric bands deviate conspicuously from the lines of growth. Among living brachiopods the following species are listed by Richter,[5] on the authority of Professor Blochmann of Tübingen, as having concentric color lines: *Terebratula coreanica* Ad. & Reeve, *Terebratula cruenta* Dillw., *Terebratula rubicunda* Sow., *Krausina rubra* Pallas, *Laqueus rubellus* Sow. and, with some deviations, also *Waldheimia grayi* Davidson. In these living forms, however, the concentric lines follow the lines of growth closely. In this respect, the Alpena specimens of *Cranaena* correspond more closely to the living terebratuloids than to *Newberria cimex* from the Devonian of western Europe, its concentric lines and bands being strictly parallel to the lines of growth.

III. Pelecypods

Fossil pelecypods with color markings are known at present only in small numbers, with the following stratigraphical distribution: Miocene, 3 species; Oligocene, 1; Eocene, 2; Cretaceous, 9; Jurassic, 1; Triassic, 2; Carboniferous, 8; a total of 26 species.

Of the Carboniferous species, Forbes cited 4 as occurring in the collections of the Geological Survey of Great Britain; namely, *Aviculopecten elongatus*, *Aviculopecten intercostatus*, *Aviculopecten sublobatus*, and an unnamed species of *Aviculopecten* with spotty markings on the ribs. The species called *Aviculopecten sublobatus* by Forbes is referred at present to the genus *Streblopteria*. To this list given by Forbes, Oppenheim added the three species *Aviculopecten rugulosus* McCoy, *Syncyclonema colorata* Koninck and *Syncyclonema sowerbyi* McCoy. Recently J. Brookes Knight found a pelecypod with color markings in the Pennsylvanian part of the Carboniferous, in the vicinity of St. Louis, Missouri, thus

[5] Richter, Rudolf, "Zur Färbung fossiler Brachiopoden," *Senckenbergiana*, Vol. 1, no. 3, p. 84, 1919.

raising to 8 the total of Carboniferous pelecypods known to have color markings. The discovery of 15 color-marked species of gasteropods and of the single peleycpod in the St. Louis area was announced to the Paleontological Society of America at its meeting in New York city in December, 1929 (*Bull. Geol. Soc. Am.*, 40: 212. 1929), but the details have not yet been published.

IV. Gasteropods

As already noted on a preceding page, the total number of species of fossil gasteropods recorded as retaining color markings equals 293, of which 224 occur in the Tertiary, 25 in the Mesozoic, and 44 in the Paleozoic. Of the Paleozoic species, 33 occur in the Carboniferous, 5 in the Devonian, 3 in the Silurian, and 3 in the Ordovician. These Paleozoic species, as far as published, are recorded in the following list:

LIST OF PALEOZOIC SPECIES

Carboniferous

Capulus margarita Boulanger
Euomphalus (Solarium) pentangulatum Sowerby
Glyptobasis marshalli Roundy
Holopea proutana Hall
Macrocheilus maculatus Koninck
Mourlonia (Pleurotomaria) carinata Sowerby (= *flammigera* Phillips)
Natica (Naticopsis?) lirata Phillips
Naticopsis cf. *altonensis* McChesney
Naticopsis picta Girty
Naticopsis plicistria Phillips
Patella retrorsa Phillips
Patella solaris Koninck
Pileopsis (Capulus) pileus Phillips
Platyostomella (Littorina) scotoburdigalensis Etheridge
Pleurotomaria conica Phillips
Pleurotomaria rotundata Sowerby
Trochus sp., in the collection of the Geological Survey of Great Britain
Turbo cryptogrammus Koninck
Fifteen additional species found by J. Brookes Knight near St. Louis, but not yet published.

Devonian

Platyceras repletum Barrande
Pleurotomaria beaumonti Archiac & Verneuil
Pleurotomaria limbata Phillips
Pleurotomaria orbignana Archiac & Verneuil

Turbonitella (*Naticopsis*) *subcostata* Archiac & Verneuil (= *harpula* Sowerby)

Silurian

Cyrtolites Pharetra Lindström
Platyceras nobile Barrande
Polytropina (*Oriostoma*) *helicina* Lindström.

Ordovician

Cyclonema (*Turbo*) *rupestris* Eichwald, from the Bala of Chair of Kildare, near Dublin, Ireland
Holopea symmetrica Hall, from the Trenton of New York and New Jersey
Holopea (*Straparollina*) *harpa* Hudson, from the Valcour member of the Middle Chazyan of New York

All the Silurian gasteropods in the preceding list belong to the Gotlandian division of the Middle Silurian, as exposed in Europe. Among the few Ordovician species here listed *Holopea harpa*[6] is the oldest. The next oldest probably is the *Holopea symmetrica.*[7] The age of the *Cyclonema rupestris*[8] from the Chair of Kildare is not known definitely. The exposures here consist of the Middle and Upper Bala. I have been unable to determine from the literature from which of these two horizons the Kildare specimen was obtained, but it was from the equivalents of either the Trenton or the Cincinnatian.

V. Cephalopods

Among cephalopods retaining color markings a total of 41 species has been recorded, all of which are discussed on the following pages. Among these, 1 ranges from the Eocene into the Miocene, 1 occurs in the Middle Liassic, 1 is found in the Pennsylvanian part of the Carboniferous in America, 3 occur in the Carboniferous limestone division of the Carboniferous of western Europe, 3 occur in the Middle Devonian, 25 are found in the Middle Silurian, and 7 are known from the Ordovician.

Among these 41 species the following 9 occur in America:

[6] Raymond, Percy, "An Ordovician Gasteropod Retaining Color Markings," *Nautilus*, Vol. 19, p. 101, 1906; also *Annals Carnegie Mus.*, Vol. 4, p. 212, 1908.

[7] White, Theodore G., "The Faunas of the Upper Ordovician Strata at Trenton Falls, Oneida Co., N. Y.," *Trans. New York Acad. Sci.*, Vol. 15, p. 85, 1896.

[8] Forbes, E., *op. cit.*, pp. 21–23.

LIST OF AMERICAN SPECIES

Orthoceras dunbari; from the Ochelata formation in the Pennsylvanian of Oklahoma
Orthoceras anguliferum alpenense; Alpena limestone, Middle Devonian of Michigan
Orthoceras trusitum; Guelph, Middle Silurian of New York
Sactoceras manitoulinense; Waynesville member of Richmond, Manitoulin island in southwestern Ontario
Rizoceras coronatum; Shamattawa member of Richmond; west of Hudson Bay
Sactoceras westoni; Lorraine, northwest of Toronto, in southwestern Ontario
Geisonoceras tenuitextum; Trenton, New York
Orthoceras tenuistriatum; Trenton of New York and New Jersey.
Orthoceras sp.; Plattin, in northeastern Missouri

1. BREVICONIC ORDOVICIAN, SILURIAN AND DEVONIAN CEPHALOPODS

From the Silurian of Bohemia, now included in Czechoslovakia, Barrande [9] figured the following eighteen species as preserving color markings. All these he referred to the genus *Cyrtoceras*, though none of them show the internal structure of the siphuncle characteristic of the genotype, *Cyrtoceras depressum.* In this list the name of the species is followed by the number of the plate or plates on which this species is illustrated, and by the page in the text where it is described. Those numbers which are followed by the letter *S* refer to pages in the supplement to the text published in 1877. The remaining page numbers refer to the first part of the text, published in 1867. The words "black" and "white" indicate merely whether the color designs on the shell are lighter or darker than the general body color of the latter. The word "erect" is used for those conchs which are straight, or nearly straight; usually their curvature is very small, and in some species it is confined to the apical part of the conch. The word "curved" is used for those conchs in which the lengthwise curvature is more conspicuous. Conchs in which the siphuncle is located on the convexly curved side of the conch are called "exogastric"; those in which it is located on the concavely curved side are called

[9] Barrande, Joachim, *Systeme silurien du centre de la Boheme,* Text: pt. I (1867); pt. II (1870); pt. III (1874); pt. IV (1877); pt. V, including Supplement (1877).

"endogastric." In some of these conchs, as already stated, the lengthwise curvature may be confined to the apical part of the conch. In those erect conchs in which both the siphonal and the antisiphonal outlines of the conch are slightly convex, one side is usually more convex than the other. In those cases the conch is called endogastric if the siphuncle is located near the less convex side. Strictly speaking, the ventral side of a conch is known definitely only when the location of its hyponome can be determined. In the fossil shell this is shown by the location of the hyponomic sinus. In the ellipochoanoidal nautiloids this is usually on the convexly curved side of the conch, at least during early stages of its growth. The cross-sections of most of the conchs here listed are circular, but in two species they are slightly compressed laterally; in one this lateral compression is more conspicuous.

LIST OF BOHEMIAN SILURIAN CYRTOCEROIDS

1. *Cyrtoceras cyathus;* pls. 153, 481, 507; pp. 542, 22–S, 134–S. Black, erect, exogastric, with circular cross-section
2. *Cyrtoceras intricans;* pl. 514; p. 149–S. White, curved, exogastric, with circular cross-section
3. *Cyrtoceras sinuatulum;* pl. 153; p. 566. White, erect, exogastric, with circular cross-section
4. *Cyrtoceras zebra;* pls. 168, 481; pp. 632, 49–S. Black, erect, exogastric, with circular cross-section
5. *Cyrtoceras bonum;* pl. 167; p. 651. White, erect, endogastric, slightly compressed laterally
6. *Cyrtoceras gentile;* pl. 505; p. 144–S. White, erect, endogastric, with circular cross-section
7. *Cyrtoceras haesitans;* pl. 505; p. 147–S. White, erect, endogastric, with circular cross-section.
8. *Cyrtoceras iridis;* pl. 153; p. 554. White, curved, exogastric, with circular cross-section
9. *Cyrtoceras parvulum;* pls. 177, 481, 504, 505; pp. 689, 39–S, 168–S. White, curved, endogastric, with circular cross-section
10. *Cyrtoceras veteranum;* pls. 208, 514; pp. 571, 190–S. White, moderately curved, exogastric, with circular cross-section
11. *Cyrtoceras chrysalis;* pl. 506, p. 121–S. White, erect, endogastric, with nearly circular cross-section
12. *Cyrtoceras pseudomorphum;* pl. 506; p. 174–S. White, erect, probably endogastric, with slightly compressed cross-section
13. *Cyrtoceras eurus;* pl. 506; p. 142–S. White, erect, endogastric, with circular cross-section
14. *Cyrtoceras jubatum;* pl. 506; p. 151–S. White, erect, exogastric, with circular cross-section

15. *Cyrtoceras vittatum;* pl. 153; p. 572. White, erect, exogastric, with circular cross-section
16. *Cyrtoceras decurio;* pl. 240; p. 545. Black, curved, exogastric, with laterally compressed cross-section
17. *Cyrtoceras jugale;* pl. 506; p. 152–S. White, erect, exogastric, with circular cross-section
18. *Cyrtoceras maculosum;* pl. 155; p. 556. Black, moderately curved, probably exogastric, with circular cross-section

All the species here listed have short conchs. These enlarge rapidly and have relatively large living chambers. They differ from the typical *Rizoceras* of Hyatt,[10] of which the genotype is *Orthoceras indocile* Barrande (his Plate 185), in having more or less distinctly curved conchs, instead of conchs which are almost strictly orthoconic, though usually showing a slight lengthwise curvature, at least at the apical end of the conch.

The color pattern shown by these Bohemian forms varies in the different species.

In *Cyrtoceras cyathus, Cyrtoceras intricans, Cyrtoceras sinuatulum* and *Cyrtoceras zebra* the color lines are transverse and wavy, with the sinuations numerous within the circumference of the conch.

In *Cyrtoceras bonum* the transverse color lines show a chevron pattern, zigzagging up and down so as to produce 6 or 8 chevrons within the circumference of the conch. In *Cyrtoceras gentile, Cyrtoceras haesitans, Cyrtoceras iridis* and *Cyrtoceras parvulum* the chevrons arch evenly upward and meet laterally at acute, downward pointing angles. In these species the number of chevrons within the circumference of the conch appears to be 6 in some species and 8 in others. In *Cyrtoceras veteranum* the transverse color lines zigzag up and down, but curve at the turning points. The number of chevrons within the circumference of the conch is 6. In all these 6 species one of the chevrons occupies the median part of the siphonal side of the conch, and this chevron arches upward. This curvature of the median chevron is shown in *Cyrtoceras bonum* by Figure 20 on Barrande's Plate 167; in *Cyrtoceras gentile* by Figures 23 and 30 on Plate 505; in *Cyrtoceras*

[10] Hyatt, Alpheus, "Genera of Fossil Cephalopods," *Proc. Boston Soc. Nat. Hist.*, Vol. 22, p. 276, 1884.

haesitans by Figure 19 on Plate 505; in *Cyrtoceras iridis* by Figure 21 on Plate 153; in *Cyrtoceras parvulum* by Figures 4, 5, 11 and 12 on Plate 481, and also by various figures on Plate 504; and in *Cyrtoceras veteranum* by Figure 21 on Plate 208. In the type of the species last named the chevron along the median part of the convexly curved siphonal side of the conch rises. A similar rising chevron is shown along the median part of the opposite or antisiphonal concavely curved side in Figure 15 on Plate 504.

The five species, *Cyrtoceras chrysalis*, *Cyrtoceras pseudomorphum*, *Cyrtoceras eurus*, *Cyrtoceras jubatum* and *Cyrtoceras vittatum*, show a similar upward arching of the chevrons, but the upper side of each chevron is fringed by short branches having the same color as the chevron itself. In three of these species one of the chevrons occupies the median line of the siphonal side of the conch. This is well shown in *Cyrtoceras pseudomorphum* by Figure 8 on Barrande's Plate 506; and in *Cyrtoceras jubatum* by Figure 23 on Plate 506. In *Cyrtoceras eurus* it is indicated very vaguely by Figure 18 on Plate 506. It may be present on *Cyrtoceras chrysalis*, but nothing is known of the color lines on the ventral side of *Cyrtoceras vittatum*.

In *Cyrtoceras decurio* the transverse color lines are replaced by broad color bands. On the lateral side of the type only a single chevron is preserved, which rises to an angular point, two of its sides meeting along the median part of the conch at a point which is directed downward. According to Barrande there is a possibility that an additional series of chevrons once occupied the convexly curved side of the conch, but no trace of such a series remains.

In *Cyrtoceras jugale* there appear to be several vertical series of short horizontal color lines, the individual members of which are somewhat yoke-shaped.

In *Cyrtoceras maculosum* the shell appears ornamented with irregularly arranged black blotches irregular in shape.

Regarding a specimen of *Cyrtoceras parvulum* Barrande in the British Museum of Natural History, Foord [11] stated that about

[11] Foord, Arthur H., *Catalogue of the Fossil Cephalopoda in the British Mus.*, pt. 1, pp. 292, 297, 1888.

seven upward arching chevrons occur within the circumference of the conch. On the septate part of one of the specimens of *Cyrtoceras expandens* (Barrande, Plate 167, p. 659), in the same museum, Foord observed light-colored zigzag bands resembling those of *Cyrtoceras iridis*, as illustrated by Figure 21 of Barrande's Plate 153.

Zigzag types of color patterns have been observed also in areas other than Bohemia. For instance, in the Shamattawa limestone, on the Shamattawa river, west of Hudson Bay, Savage and Van-Tuyl found a small, erect, rapidly enlarging rizoceroid conch, later described by Foerste and Savage [12] as *Rizoceras* (?) *coronatum* (Plate II, Fig. 3). The number of waves within the circumference of this conch is estimated at about fifteen. The pattern of these color lines differs, however, from that shown by the Bohemian cyrtoceroids described above in the direction of curvature of their chevrons; the latter curve moderately downward instead of arching strongly upward. The siphuncle is close to the ventral wall of the conch and consists of narrow, fusiform segments. The Shamattawa limestone in which this specimen was found is regarded as of Richmond age.

Of *Cyrtoceras depressum* Bronn, Foord [13] stated that "zigzag bands of colour are seen upon the cast in one of the specimens in the Museum Collection" (No. 66380, British Museum of Natural History). From this brief description it cannot be determined to what extent these zigzag colors are likely to have been visible on the exterior of the shell.

The cyrtoceroid described by Barrande under the name *Cyrtoceras bolli* (Barrande's Plate 119, pp. 485, 20–S) differs strongly from the rizoceroids described in the earlier paragraphs of this paper in the much slower rate of enlargement of the conch and in its dorso-ventral depression. The siphuncle is located on the convexly curved side of the conch and its segments enlarge slightly within the camerae. The transverse color lines are narrow and black. Their course is wavy, and that wave which occupies

[12] Foerste, Aug. F., and Savage, T. E., "Ordovician and Silurian Cephalopods of the Hudson Bay Area," *Denison Univ. Bull., Journ. Sci. Lab.*, Vol. 22, p. 50, pl. 5, fig. 7, 1927.

[13] Foord, Arthur H., *op. cit.*, p. 266.

the median part of the ventral side of the conch curves more strongly downward than do the waves ventro-laterally. These waves are preserved only on the ventral side of the conch, but it is estimated that, if they extended in the same manner also around the dorsal side of the conch, their number would be six or seven within the circumference of the conch. This Bohemian species is of Devonian age, occurring in Barrande's horizon Gg3.

Another breviconic cyrtoceroid showing color markings is the species here named *Hedstroemoceras haelluddenense* (Plate I, Figs. 3 A, B; Plate V, Figs. 1, 2 A, B; Plate III, Figs. 3 A, B). In this species there are 14 almost vertical color bands, of which 12 slope downward in a ventral direction at an angle of about 12 degrees with the vertical axis of the conch. The remaining 2 rise in a ventral direction at about the same angle, thus forming a zigzag pattern across the median part of the ventral side of the conch. The rising chevron of the zigzag pattern has its angle along the median line of this side. It is assumed that a similar rising angle is formed by the 2 bands nearest the median line of the dorsal side, but, if so, this angle is not preserved in the two specimens at hand. Since these specimens are types of both a new species and a new genus, a more detailed description of the conch here follows.

Hedstroemoceras haelluddenense, gen. et sp. nov.

Conch small, erect, dorsal outline faintly convex, ventral outline more distinctly convex. Cross-section nearly circular, slightly compressed laterally. Living chamber enlarging but slightly. Siphuncle located near the ventral side of the conch, but not in contact with it; its segments fusiform in outline.

The length of the larger specimen (Plate I, Fig. 3 A; Plate V, Figs. 2 A, B; Plate III, Figs. 3 A, B) is 46 mm., of which 22 or 23 mm. belongs to the living chamber. The phragmacone enlarges dorso-ventrally from a diameter of 10 mm. at its base to 15 mm. at the base of the living chamber 23 mm. farther up, the diameter at its aperture being 16 mm. The lateral diameter at the base of the living chamber is 14.3 mm. The cast of the interior of the living chamber contracts to within 5 or 6 mm. of the aperture and

then expands again. This is probably due to a thickening of the interior of the walls of this chamber; no corresponding contraction of the exterior of the shell is noted. The number of camerae in a length equal to the dorso-ventral diameter of the conch at the base of the living chamber is a little more than 6; the uppermost camera is a little shorter than those immediately beneath. The sutures of the upper septa rise distinctly ventro-laterally and curve downward both ventrally and dorsally. The ventral lobe is distinctly narrower and slightly deeper, but the dorsal lobe is broad and shallow and tends to be straight and directly transverse along its median part. Within the third camera beneath the living chamber, where the dorso-ventral diameter is 14.2 mm., the center of the siphuncle is 2 mm. from the ventral wall of the conch. The segment of the siphuncle is fusiform in outline, with a maximum diameter of 1.3 mm., narrowing to 0.8 mm. at its passage through the septum. The dorsal vertical outline of this segment is faintly convex, but the ventral outline is distinctly convex, with the maximum convexity above its mid-height.

The length of the second specimen (Plate I, Fig. 3 B; Plate V, Fig. 1) is 32 mm., 18 mm. of which belongs to the living chamber. Its dorso-ventral diameter at the base of the living chamber is 14.5 mm.; its lateral diameter is about 13 mm. The number of camerae within a length equal to the dorso-ventral diameter of the conch is eight. The sutures of the septa are almost straight, with very faint undulations that cannot be asserted to be strictly conformable to those of the preceding specimen. This suggests that the undulations of the septa in the preceding specimen are not to be considered diagnostic. Both specimens are from Haelludden, on Oeland, southeast of Sweden, in the gray *Endoceras vaginatum* limestone.

Hedstroemoceras is distinguishable from the following genera.

In *Clinoceras* Mascke the siphuncle is located dorsad of the center of the conch and its segments are almost cylindrical, though distinctly contracted at the passage of the siphuncle through the septa. Moreover, the conch is distinctly depressed dorso-ventrally.

In *Cyrtactinoceras* Hyatt the conch also is depressed dorso-ventrally. Its siphuncle, however, is ventrad to the center of the

conch. At earlier stages of growth its segments are obliquely globular or slightly nummuloidal in form, but later the siphuncle moves nearer the center of the conch though remaining ventrad to the latter, and its segments become narrowly elongated, enlarging only slightly within the camerae.

In *Wetherbyoceras* Foerste the siphuncle is near the ventral wall of the conch, but not in actual contact with it. Its segments are obliquely globular, and are strongly constricted at the septal necks. The interior of the siphuncle is occupied by ten to twelve converging vertical lamellae which do not reach its center.

In *Chicagooceras* Foerste the conch is only slightly depressed dorso-ventrally, and the siphuncle is located slightly ventrad of the center of the conch.

2. PHRAGMOCEROIDS

One of the phragmoceroids described by Barrande under the name *Phragmoceras panderi* (Barrande's Plate 429, p. 236–S) is marked with numerous vertical and transverse black lines, of which the vertical ones tend to be more distinct, more regularly spaced, and more widely separated, with about fifty occurring within the circumference of the conch. The transverse lines, on the contrary, are fainter, more irregularly spaced, and more numerous. These specimens, however, differ from typical *Phragmoceras panderi* (Plates 48, 50, p. 232) in being more strongly curved lengthwise, and in the stronger dorso-lateral divergence of the median dorsal lobes of the aperture. These lobes are longer and the included median dorsal crest is much broader than in the type of the species. It belongs, however, to Hyatt's genus *Hexameroceras*, of which typical *Phragmoceras panderi* (Barrande's Plate 48, p. 278) is the genotype. For the color-marked specimens figured on Barrande's Plate 429 the term **Hexameroceras barrandei** is proposed. They were found at Grosskuchel, Bohemia, in the Middle Silurian.

Hedström [14] described four species of Phragmoceras with black

[14] Hedström, Herman O., "Über die Gattung Phragmoceras in der Obersilurformation Gotlands," *Sveriges Geologiska Undersökning, Uppsatser och avhandlingar* i 4: o, Ser. C a, n: o 15, 1917.

shells. This black color is ascribed to the retention of the chitinous layer which once covered the entire surface of the conch. It is evenly distributed, and therefore did not make a color pattern as in the species forming the subject of this paper. Hedström's species include *Phragmoceras costatum*, *Phragmoceras munthei*, *Phragmoceras fasciatum* and *Phragmoceras convolutum*. All were obtained in the Middle Silurian of Gotland.

3. ORDOVICIAN AND SILURIAN ORTHOCEROID CEPHALOPODS

Barrande figured five specimens under the name *Orthoceras pellucidum* and one under the name *Orthoceras pellucidum* var. *contrahens*, all of which have white vertical color bands or lines on a general brown field. On his Plate 261 the bands are broad but irregular in width and arrangement. They appear to occur on all sides of the conch. This conch is gently curved lengthwise, with the siphuncle slightly ventrad of the center of the conch. On his Plate 400 the whitish bands are relatively few and far separated. In one specimen on Plate 420 the bands appear to be few, but on the other, they are relatively numerous, approximately of the same size and equally spaced. Apparently they become narrower toward the right side of the second specimen. In the specimen figured on Plate 452 the color bands consist of paired white lines, the pairs being equally spaced around the circumference of the conch. The specimen figured on Plate 266 under the name *Orthoceras pellucidum* var. *contrahens* differs from the five specimens figured under the name *Orthoceras pellucidum* in having numerous vertical white lines alternating with similar narrow brown lines. In *Orthoceras pellucidum* the segments of the siphuncle are globular (Plate 420, Fig. 3), as in *Orthoceras richteri* (Plates 318, 349), the genotype of Hyatt's genus *Sactoceras*,[15] to which genus it should be referred.

Several conchs with vertical color bands similar in width, number and arrangement to those of *Orthoceras pellucidum* were described from the Waynesville member of the Richmond at Clay Cliff, on the eastern margin of Manitoulin Island, in the northern part of Lake Huron, under the name *Sactoceras manitoulinense*

[15] Hyatt, Alpheus, *op. cit.*, p. 273.

Foerste.[16] In these conchs (Plate II, Fig. 2) the black color bands appear to belong to a layer immediately beneath that forming the surface of the shell. A second species, with narrower and more closely arranged vertical black and white lines, similar in appearance to *Orthoceras pellucidum* var. *contrahens*, was described in the same publication from the Lorraine of the area northwest of Toronto, in southern Ontario, under the name *Sactoceras westonense* Foerste (Plate II, Fig. 1). In this second species the color banding is confined to one side of the conch, assumed to be ventral. In *Sactoceras manitoulinense* the color banding also appears to be confined to one side of the conch, but whether this side is ventral or dorsal was not determined at the time this specimen was studied.

In a specimen of an unknown species of *Orthoceras* found in the top of the Plattin limestone in Ralls County, in northeastern Missouri,[17] vertical color banding is present. These colors are merely lighter and darker shades of the light brownish tint characterizing the inclosing rock. The specimen is 22 mm. wide and the color bands equal or slightly exceed 1 mm. in width; the intermediate lighter-colored intervals are 1 mm. or slightly less in width.

Angelin and Lindström [18] figured from the Silurian of Gotland, under the name *Orthoceras columnare* Marklin, a part of the surface of a conch showing vertical color lines. These lines are half a millimeter or less in width and 1 mm., or moderately more, apart. They are distinctly darker than the remainder of the shell, which is whitish.

Blake [19] figured, under the name *Orthoceras annulatum*, a specimen from the Middle Silurian of Great Britain, from 28 to 29 mm. in diameter, showing on one side vertical color bands, alternately

[16] Foerste, Aug. F., "Upper Ordovician Faunas of Ontario and Quebec," *Geol. Surv. Canada, Memoir 138*, pp. 224, 226, 1924.

[17] Foerste, Aug. F., "The Kimmswick and Plattin Limestones of Northeastern Missouri," *Denison Univ. Bull., Journ. Sci. Lab.*, Vol. 19, p. 212, 1920.

[18] Angelin, N. P., and Lindström, G., *Fragmenta Silurica*, p. 7, pl. 10, fig. 1, 1880.

[19] Blake, J. F., *A Monograph of the British Fossil Cephalopoda*, pt. 1, p. 91, pl. 4, fig. 4, 1882.

light and dark. According to Blake, these bands are one eighth of an inch (3 mm.) wide, but his figure indicates only five bands on the side of the conch illustrated. The lateral outlines of these bands do not appear to be sharply defined, as in the orthoceroids described in the preceding pages. *Orthoceras annulatum* is the genotype of *Dawsonoceras*. For a note on *Orthoceras pictum* Blake, see Addendum, p. 146.

Clarke [20] figured, under the name *Orthoceras tenuistriatum* Hall, a specimen from the Platteville member of the Black River formation in Minnesota which is ornamented by narrow, vertical, opaque or dull lines crossing the otherwise shining surface of the shell. These vertical lines are assumed to correspond to original color lines. According to the figures published by Clarke, these color lines are about one tenth of a millimeter wide, and at least fifty occur within the circumference of the conch. It is possible that these lines represent differences in the texture of the shell rather than in color.

Vertical color lines are shown also by *Orthoceras trusitum* Clarke and Ruedemann,[21] from the Guelph member of the Middle Silurian of New York. In the specimen represented by Figure 2 on their Plate 13, there are nine or ten vertical light brown lines in a width of 3 mm. These lines are confined to one side of the specimen. In the specimen represented by Figure 9 on the same plate, the structure usually accompanying color banding is present, but no distinctive coloring remains. Those vertical lines which correspond to the color bands consist of denser material and weather less rapidly than the intermediate parts of the shell. In a more recent paper Doctor Ruedemann has pointed out that the specimen illustrated by Figure 4 on Plate 12 of the publication by Clarke and Ruedemann also belongs to the species *Orthoceras trusitum*, and not to *Kionoceras darwini*.[22] In this specimen the

[20] Clarke, John M., "The Lower Silurian Cephalopoda of Minnesota," *Geol. Surv. Minnesota, Final Report*, Vol. 3, pt. 2, p. 788, 1897.

[21] Clarke, John M., and Ruedemann, Rudolf, "Guelph Fauna in the State of New York," *New York State Museum, Mem. 5*, p. 77, pl. 13, and also pl. 12, fig. 4, 1903.

[22] Foerste, Aug. F., "American Arctic and Related Cephalopods," *Denison Univ. Bull., Journ. Sci. Lab.*, Vol. 23, p. 99, pl. 14, figs. 3 A, B, 1928.

surface of the shell is smooth, but the vertical brown color lines are preserved distinctly, though here again on only one side of the shell. Dr. Ruedemann suggests the possibility that this restriction of the vertical color lines to one side of the conch may have been a part of the original color scheme, but he cautiously abstains from asserting definitely that this is the fact.

In the case of *Geisonoceras tenuitextum* (Hall), however, from the Trenton of New York, Dr. Ruedemann [23] was convinced not only that the vertical color lines were restricted to one side of the conch in the present state of preservation of the specimens, but that they had never been present on that side where now they are absent. This is indicated by the following facts. In the specimen illustrated by Ruedemann's text Figure 21 there are seventeen vertical brown color lines 0.5 mm. wide, separated by intervals of 0.4 mm. along the median part of the ornamented area, but by a much wider interval, 0.9 mm., at the lateral margin of this area. Moreover, the intervals between the vertical brown lines are decidedly darker (light brown) than the general color on the opposite side of the conch (whitish), where no vertical color lines appear. In the specimen represented by his Figure 22 the vertical color lines again are confined to one side of the conch. This is true also of the specimen represented by his Figure 23. In that case the color of the vertical lines is light brown where the interior of the conch is filled with crystalline calcite, and black where it is filled with black calcareous mud. In the specimen represented by his Figure 24 there are only ten vertical dark color bands. From the restriction of these vertical color lines and bands to one side of the conch Dr. Ruedemann concluded that in the species in question the conch usually occupied, during the life of the animal, an approximately horizontal position, with the side ornamented with color lines facing upward and the lighter-colored side facing downward. The species *Geisonoceras tenuitextum*, here under consideration, is that originally described by Hall under the name *Endoceras proteiforme* var. *tenuitextum*. According to Dr. Ruedemann, the

[23] Ruedemann, Rudolf, "On Color Bands in Orthoceras," *New York State Mus. Bull.*, Nos. 227, 228, p. 79, 1921. (*Orthoceras trusitum*, pp. 81, 86. *Geisonoceras tenuitextum*, pp. 81–84.)

species *Orthoceras strigatum* Hall belongs to the same species as *Geisonoceras tenuitextum;* the types happen to be specimens in which the surface of the shell was weathered so as to leave the color bands more or less distinctly elevated, the intermediate parts being reduced to furrows.

It is customary in studies of the color markings of fossil shells to cite the statement by Marsh (*Proc. Am. Assn. Adv. Sci.*, 17th meeting, p. 325, 1869), that he noted in a specimen of *Endoceras proteiforme*, from the Trenton of New York, distinct traces of color arranged in a delicate cancellated pattern. Unfortunately the specimen so described apparently can no longer be located, and therefore its generic reference cannot be confirmed. This generic reference, however, must be very doubtful, in view of the fact that very heterogeneous material was included by Hall himself under this name, so that the orthoceroids later separated as *Orthoceras lineolatum, Orthoceras tenuistriatum* and *Orthoceras tenuitextum* were originally described by Hall as varieties of his species *Endoceras proteiforme.* Under these circumstances it is evident that, in the absence of any knowledge of the siphuncle of the specimen so identified, it is unwise to accept the earlier identifications of orthoconic shells as *Endoceras proteiforme.*

4. DEVONIAN AND CARBONIFEROUS ORTHOCEROID CEPHALOPODS

The first known record of color design in a fossil cephalopod is that by D'Archiac and De Verneuil,[24] who in 1843 figured *Orthoceras anguliferum* from the Middle Devonian of Paffrath, in the Rhenish part of Germany, accompanied by the following description:

> Shell of an elongate cone shape, smooth, but covered with *chevrons* or zigzag coloured marks, of which the acute angles correspond regularly from the upper to the lower end of the cone. These angles, about 18 in number, are alternately turned toward the summit and the base. The little brown bands which form them are half a millimeter in width, and are separated by an uncoloured space of nearly equal width. If a line be passed through the successive summits of the upper and lower angles formed by the fracture of the same band an

[24] Archiac, d', and Verneuil, de, "On the Fossils of the Older Deposits in the Rhenish Provinces," *Trans. Geol. Soc. London*, Second Series, Vol. 6, p. 303, 1842.

oblique ellipse is obtained whose axis corresponds with a line passed through the siphon. Septa nearly flat and somewhat oblique. Siphon small, nearer to the centre than the edge. Paffrath: very rare.

Marsh [25] in 1865 secured another specimen of *Orthoceras anguliferum* from the Paffrath locality, where it was associated with *Natica subcostata*, also retaining color markings.

At present there are several specimens of *Orthoceras anguliferum* in the Peabody Museum, at Yale University, one of which was figured recently by Dunbar.[26] This specimen is illustrated as viewed from the side, and shows that the color lines are confined to the upper or ventral side of the conch, with the lower or dorsal side free from markings. Dunbar recognized the similarity between the restriction of the color markings to one side of the orthoconic shell in *Orthoceras anguliferum* and the restrictions in the species *Geisonoceras intertextum* and *Orthoceras trusitum*, as described by Ruedemann in the publication cited on page 131, and from this he drew the same conclusion: namely, that during the life of the animal the conch of *Orthoceras anguliferum* had been carried in a more or less horizontal position.

This opinion was further corroborated by the distribution of transverse color markings in a species of *Orthoceras* from a locality about 18 miles north of Tulsa, in Oklahoma, where it was found in the Ochelata member of the Middle Pennsylvanian. These transverse bands are confined to one side of the conch, assumed to be ventral; the dorsal side is free of color markings, thus again suggesting a horizontal position for the conch during the life of the animal. This specimen also belongs to the Peabody Museum, and the name **Orthoceras dunbari** is here proposed in honor of Professor Dunbar, a distinguished member of the force there in charge.

Since these specimens of *Orthoceras anguliferum* and *Orthoceras dunbari* offer conclusive evidence that at least some of the orthoceroids carried their conchs in an approximately horizontal posi-

[25] Marsh, O. C., "On the Preservation of Color in Fossils from Palaeozoic Formations," *Amer. Assn. Adv. Sci., Proc. of 17th Meeting*, p. 325, 1869.

[26] Dunbar, Carl, "Phases of Cephalopod Adaptation," in Thorpe, M. R., *Organic Adaptation to Environment*, p. 192, 1924.

tion, a more detailed description of their color markings is offered on page 139.

Of *Orthoceras angùliferum* the Peabody Museum contains three specimens, numbered 4132, 4129 and 4131, the order in which they are discussed.

Specimen No. 4132 (Plate I, Fig. 1; Plate III, Fig. 1) is 90 mm. long and enlarges from a diameter of 5.8 mm. at its base to 17 mm. at its top, the apical angle being 7.5 degrees. The ventral side is fairly well preserved, but the dorsal side is well preserved only along the upper third of the specimen; its middle and lower parts are crushed in. In its present condition the ventral outline of the conch has a convexity of 1 mm., but its original course, before the specimen was crushed, may have been nearly straight. Where the lateral diameter of the conch is 15.5 mm., its dorso-ventral diameter is 14.7 mm., again possibly due to crushing. The ventral side of the conch is marked by acutely angular zigzag brownish transverse lines, which are interpreted as consisting of three rising chevrons, as indicated at *A*, *B* and *C* of Figure 1 on Plate III. There are four descending angles, lettered *D*, *E*, *F* and *G*. The ascending chevron *A* and the descending angle *G* are interpreted as doubled. Of the ascending angles corresponding to *D*, seven consecutive ones can be recognized with confidence along the right side of the ornamented area; their lower points are located 5, 10, 15.5, 22, 29, 37 and 46 mm. above the base of the specimen, and the right arms of these angles (marked *y* in the figure) have a length of 1.5, 2, 2.5, 3, 3.5, 3.7, and 4 mm., respectively, each arm terminating abruptly, as seen in Figure 1 on Plate I, and as shown also by Figure 17 in the chapter on "Phases of Cephalopod Adaptation," published by Dunbar. The two chevrons *A* 1 and *A* 2 are preserved only by the uppermost two transverse color lines; the chevron *A* 1 is not distinguishable lower down, owing to cracking and crushing of the conch previous to fossilization. It is assumed, by analogy with several of the other specimens here illustrated, that the left end of each transverse line should terminate with a short ascending arm, such as is indicated at *x* in Figure 1 on Plate III, but the coloring of the specimen at this point is so indistinct that nothing definite can be learned regarding the charac-

ter of the terminations of the transverse lines here. Where the circumference of the conch is 47.5 mm., the width of the ornamented area is apparently 19 mm., or approximately four tenths of the circumference of the conch. Along the remaining six tenths of the circumference there is no trace of color lines. These lines are brown. They weather less readily than intermediate parts of the shell. The colored part evidently is very thin, and is measured only in hundredths of a millimeter. The shell itself is estimated to be 0.4 mm. thick at the upper end of the specimen. Its surface, where not weathered, is smooth. The dorsal side of the conch is slightly lighter in color than that part of the shell which is intermediate between the color lines. The color lines are merely of a darker tint of brown than the remainder of the shell.

Specimen No. 4129 (Plate III, Fig. 2) is 28 mm. long, and enlarges in this length from a diameter of 6.5 mm. at its base to 10 mm. at its top. The area marked by transverse zigzag color lines is 10.75 mm. wide where the circumference of the conch is 25.5 mm., the ratio of the former to the latter being 42 per cent. The ascending chevrons and descending angles are more symmetrical in form and arrangement than in any other specimens studied and have been adopted here as a standard. Of the right arms corresponding to *y* in Figure 2 on Plate III, three are defined clearly on the specimen, their lengths in ascending order being 3, 4 and 5 mm. The two left arms, corresponding to *x*, are respectively 3 and 4.5 mm. long; the uppermost one of this series is not defined distinctly. Here, again, the dorsal side of the conch has a lighter shade of brown than the general ground color of the ventral side. The septum at the top of the specimen has a concavity of 1 mm. The siphuncle is 3.2 mm. from the dorsal wall of the conch, where the diameter of the latter is 10 mm. The passage of the siphuncle through the septum is 1 mm. in diameter. Five camerae occupy a length of 8 mm., corresponding to six in a length equal to the diameter of the conch.

Specimen No. 4131 is 43 mm. long and enlarges from 3 mm. at its base to 7.25 mm. at its top. The area marked by transverse zigzag lines is estimated to be 7.4 mm. wide where the circumference of the conch is 18.3 mm.; the ratio of the former to the latter

is 40 per cent. There are three series of upward directed chevrons corresponding to *A*, *B* and *C* of the other diagrams, and the two downward directed angles corresponding to *E* and *F* are preserved distinctly. Along the lower part of the right side of the color-marked area there are also traces of the angles corresponding to *D*, with the right arms *y* scarcely one third of a millimeter in length. This specimen is of interest because its lower end cannot be far removed from the original apical end of the conch.

These three specimens of *Orthoceras anguliferum* are from Paffrath, in the Rhenish part of Germany, and came from the *Stringocephalus* or Givetian division of the Middle Devonian. Evidently they were obtained from some soft argillaceous layer which permitted their being cleaned without the slightest injury to the surface of the shell. The color of the body of the shell shades very gradually from the darker tint between the zigzag color lines to the slightly lighter tint on the opposite or dorsal side of the shell. The right and left arms corresponding to the parts marked *x* and *y* on the accompanying diagrams terminate so abruptly, and yet at such exact agreement with the rate of enlargement of the conch, that, in the absence of a corresponding abrupt change in color on the general surface of the conch, it seems impossible to regard this absence of color lines on the dorsal side of the conch as due merely to the exposure of this side to weathering previous to fossilization. If, however, the color lines were already confined to the ventral side of the conch during the life of the animal, this is in favor of the more or less horizontal position of the conch during this period of its existence. Further evidence is presented by the two specimens of *Orthoceras anguliferum alpenense* next described.

Recently two specimens of *Orthoceras* showing zigzag transverse color lines almost identical in pattern with those of *Orthoceras anguliferum* were found in the Alpena limestone of the Traverse group in the quarry of the Michigan Alkali Company at Alpena in eastern Michigan. Only Alpena limestone occurs in this quarry and the specimens were found about 90 feet below the top of the quarry. According to Irwin Pohl, the entire Traverse group, of which the Alpena limestone is a member, is of later age than the Onondaga and of earlier age than the Hamilton. Its fauna occu-

pied northwest Ohio, southwest Ontario, and all of the southern peninsula of Michigan, connecting by way of James Bay and Hudson Bay with the Arctic. The group thins out southward and overlaps the Onondaga eastward.

Specimen No. 10775 (Plate I, Fig. 2; Plate IV, Fig. 1), from the Alpena limestone, is 82 mm. long, but of this length only 58 mm. belongs to the conch; the remainder belongs to that part of the matrix which extends beyond the upper end of the conch. The specimen enlarges from a diameter of 10 mm. at its base to 17 mm. at a point 45 mm. farther up; the apical angle is 9 degrees. One side of the specimen is ornamented by conspicuous transverse zigzag lines, tinted medium brown, which are defined sharply from the much lighter colored intervening spaces, which are light brown. Where the circumference of the conch is 50.3 mm., the width of the ornamented area is almost 24 mm., or 45 per cent of the circumference. The zigzag lines vary from 0.25 to 0.6 mm. in width; the intervening spaces vary from 0.5 to 1.0 mm. in width. The longest straight courses of the zigzag lines are 14.5 mm. long; the included angles vary from 28 to 32 degrees. The middle part of the color pattern is well preserved. The left arms x can be recognized only with difficulty. The right chevrons $C1$ and $C2$ and the right arm y are distinctly shown by the two uppermost transverse lines; the corresponding parts of the lower transverse lines are not exposed.

Specimen No. 10776 (Plate IV, Fig. 2) is 57 mm. long, enlarging from a diameter of 11.3 mm. at its base to 17 mm. at a point 40 mm. farther up, the apical angle being 8.3 degrees. Where the circumference of the conch is 50.3 mm., the width of the ornamented area is 22 mm., which is equivalent to 41 per cent of the circumference. Within this area the zigzag lines are not colored as strongly as in the preceding specimen, but their course can be traced distinctly, especially along the upper part of the specimen. Nothing is known of the structure of the interior of the conch beyond the fact that the concavity of the septum is 4 mm. where the diameter of the conch is 17 mm. No trace of the siphuncle remains.

The only difference that can be detected between the Michigan

specimens and those of typical *Orthoceras anguliferum* from Paffrath, Germany, is that the ascending and descending angles of the former tend to be slightly broader, with the sides forming these angles correspondingly shorter. Moreover, the concavity of the septa in the former appears to be greater. On this account the Michigan specimens are here designated as **Orthoceras anguliferum alpenense;** the differences are evidently of a minor character. It is possible, however, that, when the structure of the interior of the Michigan specimens becomes better known, other differences may be noted.

Special attention is called to the doubling of the rising chevron *C* on the right side of the two specimens from Alpena, Michigan, and the corresponding doubling of the rising chevron *A* in one of the specimens from Paffrath. This doubling is known at present only from lateral parts of the color pattern, and is opposed to the opinion that the absence of color lines on the dorsal side of the conch is due to their removal by exposure to weathering previous to fossilization, rather than to the confinement of the color pattern to the ventral side of the conch during the lifetime of the animal. Attention is called also to the relative constancy of the ratio between the width of the color-marked area and the entire circumference of the conch in the different specimens here described from Paffrath and Alpena. In the three specimens from Paffrath this ratio is 40, 42 and 40 per cent, respectively. In the two Alpena specimens it is 45 and 41 per cent. This comparative constancy in the ratio between the width of the color-marked area and the entire circumference of the conch can hardly be a matter of chance, but favors the view that the restriction of the color-marked area to the ventral side of the conch is original, and not secondary, resulting from the weathering away of former color markings on the dorsal side of the conch.

Another specimen (Plate II, Fig. 4; Plate V, Fig. 3) bearing on the problem of the horizontal position of some orthoceroid conchs is the one from the Pennsylvanian of Oklahoma, briefly mentioned by Dunbar in his chapter on "Phases of Cephalopod Adaptation." This specimen, already referred to in an earlier paragraph, is from the Ochelata formation, near the middle of the Pennsylvanian as exposed in Oklahoma. It was found 15 miles

north of Tulsa, and is numbered 10549 in the Peabody Museum, Yale University. For this specimen the name **Orthoceras dunbari** is here proposed, although further information is needed about the location and structure of its siphuncle. This specimen is 74 mm. long, and is strongly crushed in an obliquely dorso-ventral direction. In its present state the conch enlarges from a maximum diameter of 15 mm. at its base to 22 mm. at a point 67 mm. farther up, suggesting an apical angle of 6 degrees. The middle of the ventral area of the shell is crossed at regular intervals by dark transverse lines. The area crossed by these lines varies in width from 6 mm. at the lower end of the specimen to 15.5 mm. at its upper end. The lines consist merely of a deeper shade of brown than the general color of the shell. In a length equal to the present maximum diameter of the conch their number is sixteen. Along the upper part of the conch these darker lines vary in width from 0.6 to 0.8 mm.; the lighter brown intervening spaces vary from 0.4 to 0.7 mm. in width. Along the upper and lower parts of the specimen the lines are almost directly transverse, but near mid-length there appears to have been a break, above which they at first slope strongly downward from left to right, gradually becoming less oblique along a vertical interval of 10 to 15 mm. Both sides of the transversely lined vertical area are margined laterally by vertical areas in which a blackish color predominates. Along the right side of this area the blackish vertical band is quite constant in width, increasing from 4 mm. at its base to 5 mm. at its top. The vertical black band on the left side of the transversely lined area is about 12 mm. wide along the upper part of the specimen, but its preservation is very irregular farther down, since only a small part of its original width is preserved at the base of the specimen. It is estimated that the transversely lined area occupied about 30 per cent of the circumference of the conch, and that, including the two vertical black bands, the entire more or less ornamented area formed about 52 per cent of the entire circumference. The black vertical color bands forming the lateral margins of the transversely lined area are confined to a very thin film on the surface of the shell, possibly less than one hundredth of a millimeter in thickness. Apparently this film was rubbed

off or weathered off readily, or was not deposited evenly over the vertical band. The shell itself is half a millimeter thick and its surface is smooth. The color of the dorsal side of the conch is medium brown, faintly lighter than the general color of its ventral side.

In the preceding specimen the area covered by transverse color lines is definitely limited laterally. The transverse banding does not continue beneath the black film forming the lateral border of the transversely banded area, as may be seen readily where this film is removed. This fact, again, suggests that the color-lined area was already restricted to the ventral side of the conch during the lifetime of the animal, and that it was never present on its dorsal side. Apparently the living animal carried its conch in an approximately horizontal position, as already suggested by Dunbar.

There is no evidence, however, that all orthoconic cephalopods, or even a great number of them, ever carried their conchs in this position. Such a conclusion is premature and based on too little evidence. In the specimen of *Orthoceras pellucidum*, for instance, figured by Barrande on his Plate 261, the conch is distinctly curved lengthwise, and yet the vertical color bands occur on both the ventral and dorsal sides of the conch. The evidence is not as conclusive in the specimens illustrated on Plates 420 and 452, since it is not known how the figures of them were oriented, but in the variety *contrahens*, figured on Plate 266, the slight lengthwise curvature of the conch again makes it possible to determine which side is ventral and which is dorsal, so that here, again, the even distribution of the vertical color bands both ventrally and dorsally can be confirmed. This even distribution certainly does not suggest a horizontal position for the conch.

Possibly the horizontal position of the conch was adopted by only a few of the smaller species of orthoconic cephalopods. At least the restriction of the color patterns to the ventral side of the conch is known so far only in the case of a few species, none of which attained a large size.

5. CARBONIFEROUS CYRTOCEROID CEPHALOPODS

Transverse color lines are shown also by a conch found in the upper part of the Carboniferous limestone at Vise, Belgium, where it was identified by De Koninck [27] as *Cyrtoceras unguis* Phillips. By Phillips [28] this species was referred to *Orthoceras*, and this procedure was followed by Foord,[29] probably owing to the central location of its siphuncle. The specimen figured by De Koninck is about 105 mm. long. Its lower part, for a length of 20 mm., is curved distinctly on both sides of the conch, the convex side being assumed as ventral. Above this lower part the dorsal side is straight and the convexity of the ventral side becomes very faint. The cross-section is circular near the base of the specimen, but becomes oval farther up. The siphuncle is located slightly ventrad of the center of the conch and is narrowly cylindrical. The surface of the shell is smooth, but is marked by transverse color bands. These bands are alternately light and dark. Those near the lower part of the conch are relatively broad, but along the upper half of the shell they are much narrower and more numerous. They slope downward from the dorsal toward the ventral side of the conch, with several sinuations along their course.

An entirely different type of ornamentation is shown by *Cyrtoceras acus*, from the Carboniferous limestone at Tournai, Belgium. This species originally was identified by De Koninck [30] as *Cyrtoceras unguis* Phillips, but later was recognized as distinct from it. The form of this species is very similar to that of *Cyrtoceras unguis*, having a similar moderately curved apical end, the conch becoming straight farther up. The siphuncle, however, is located much nearer the ventral side of the conch, which is somewhat depressed dorsoventrally; and the transverse color lines, alternately light and dark, are strongly zigzag, resembling those of *Orthoceras anguli-*

[27] Koninck, L.-G. de, *Faune du calcaire carbonifère de Belgique*, p. 170, pl. 34, fig. 2, 1880.

[28] Phillips, John, *Geology of Yorkshire*, pt. 2, p. 238, pl. 21, fig. 2, 1836.

[29] Foord, Arthur H., *op. cit.*, p. 116, 1888.

[30] Koninck, L.-G. de, *Descr. des anim. fossiles de Belgique*, p. 524, pl. 47, fig. 8a, 1844; also *Faune du calcaire carbonifère de Belgique*, p. 180, pl. 35, figs. 6, 6a, 1880.

ferum, but they occur on the dorsal as well as on the ventral side of the conch. It is not known how many upward pointed chevrons occur within the circumference of this conch, but apparently their number is five, the odd one being located along the median part of the ventral side of the conch.

It is not likely that either *Cyrtoceras unguis* or *Cyrtoceras acus* carried their conchs in a horizontal position. It has already been noted by Ruedemann [31] that none of the breviconic cyrtoceroids are known to have carried their conchs in this position.

6. SILURIAN TROCHOCEROID CEPHALOPOD

The trochoceroid described by Barrande (Plate 28, p. 113, 1867), under the name *Trochoceras pulchrum*, from the Silurian of Bohemia, differs from the genotype *Trochoceras davidsoni* (Plate 27, p. 89) in having the siphuncle a short distance ventrad of the center of the conch, instead of in contact with its ventral wall; there are no lateral wing-like protuberances; the surface of the shell is ribbed transversely; these ribs curve much more strongly downward and they are crossed by relatively fine striae which are parallel to the longitudinal axis of the conch. In addition to these markings there are longitudinal brick-red color bands which appear equally distributed on all sides of the conch. In the areas between these bands the general color of the shell is whitish.

7. COILED CEPHALOPODS FROM CARBONIFEROUS, LIASSIC AND TERTIARY STRATA

Among the nautiloid cephalopods Foord cited *Coelonautilus paucicarinatus* Foord,[32] from the Carboniferous limestone of Cork, Ireland, as having, in one specimen, very distinct color markings, arranged in spots or irregular bands of a blackish hue.

A much more recent representative of the Nautiloidea is *Aturia aturi* Basterot,[32] from the Eocene and Miocene of southwestern France and Italy. Regarding this species Foord stated that the surface of its shell is ornamented with semicircular,

[31] Ruedemann, Rudolf, *op. cit.*, p. 87.
[32] Foord, Arthur H., *op. cit.*, pt. 2, pp. 116, 361, 1891.

transverse, approximate zones or bands of a reddish color, beginning in the umbilical depression and extending to the edge of the periphery, upon which they break up into little patches which follow the direction of the striae.

Among the goniatite members of the Ammonoidea, *Goniatites striolatus* Phillips [33] was cited by Oppenheim as being represented in his collection by a specimen having brown, and rather thick, markings along the suture lines, as seen through the translucent shell. This coloring, however, probably belongs to the interior of the conch, but the color patterns here under consideration occur close to the exterior surface of the shell, where they are confined to an extremely thin layer just beneath the surface. Moreover, Dr. L. F. Spath kindly called to my attention that the specimen described by Oppenheim could not have been a typical specimen of *Goniatites striolatus*, since that species, now known as *Homoceras striolatum*, came from the Sabden shales of Yorkshire, which belong to the Middle Carboniferous, but Oppenheim's own specimen came from the Carboniferous limestone, a different horizon, and therefore likely to contain species distinct from those known from the Sabden shales.

A more typical representative of the Ammonoidea is *Amaltheus (Paltopleuroceras) spinatus*, from the Middle Liassic division of the Lower Jurassic. In this species Schindewolf [34] recently noted the presence of dark, transverse lines, approximately parallel to the lines of growth of the conch.

VI. Crinoid and Trilobite

Remains of color markings are confined chiefly to the various types of shells. Bather [35] noted, however, the presence of dark spots also on the arms of a crinoid, *Cyathocrinus acutitubus*, from the Middle Silurian at Tividale, in England, stating that these

[33] Phillips, *op. cit.*, pt. 2, p. 234, pl. 19, figs. 14–18, 1836.

[34] Schindewolf, O. H., "Über Farbstreifen bei Amaltheus (Paltopleuroceras) spinatus (Brug)," *Palaeontologische Zeitschrift*, Vol. 10, pp. 136–143, 1928.

[35] Bather, F. A., British Fossil Crinoids, VIII, p. 215. Annals and Mag. Nat. Hist., Ser. 6, Vol. 9, p. 215, 1892. See also *The Crinoidea of Gotland*, pt. 1, p. 151; *Kongl. Svenska Vet.-Akad. Handl.*, Stockholm, Vol. 25, no. 2, 1893.

dark spots "may possibly be the relic of some original colouring, since similar ornament is found in recent forms."

Moreover, Raymond[36] recently discovered a specimen of *Anomocare vittata*, a trilobite from the Conasauga shale member of the Upper Cambrian in Cherokee County, Alabama, which retained three transverse bands on its pygidium. These bands were dark gray, almost black, and alternated with light gray. They were approximately parallel to the pleural elements of the pygidium. See also Addendum on page 146. There were also many small irregularly placed spots of a yellowish hue.

VII. Earliest Appearance of Color Markings in Different Groups of Animals

The oldest known fossil retaining color markings is the Upper Cambrian trilobite *Anomocare vittata*, just discussed. Furthermore, it appears to be the only trilobite in which color markings are known to occur.

Apparently the next oldest is the cephalopod described in this paper as *Hedstroemoceras haelluddenense*, from Haelludden, on the island of Oeland, off the southeastern coast of Sweden. Here it was found in the gray *Endoceras vaginatum* limestone, which belongs to the Kunda formation of Raymond.[37] Nothing strictly comparable to this formation is known on the American continent, and it is regarded either as belonging very low in the Chazyan or as intermediate between the Chazyan and the Canadian.

The oldest gasteropod retaining color markings is the *Holopea harpa* discovered by Raymond in the Middle Chazyan of Valcour Island, in Lake Champlain, New York.

No brachiopods retaining color markings are known from strata older than the Middle Devonian; and no pelecypods retaining color markings are known from strata older than the Carboniferous.

[36] Raymond, Percy, "A Trilobite Retaining Color Markings," *Am. Journ. Sci.*, Vol. 4, pp. 461–464, 1 fig., 1922.

[37] Raymond, Percy, *Expedition to the Baltic Provinces of Russia and Scandinavia*, 1914, pt. 1: *The Correlation of the Ordovician Strata of the Baltic Basin with Those of Eastern North America*, pp. 192, 216, 1916.

Of course, this does not mean that the order of appearance of color markings in different types of animals is known. The retention of color markings in the older strata is so much a matter of chance and the number of specimens retaining color markings is so very small, especially among the more ancient forms, that no conclusions as to the order of appearance of color markings in different groups of animals can as yet be drawn.

VIII. Color Markings as an Index of Relatively Shallow Seas

Most colors of shells are not visible during the life of the animal. In many shells, the prismatic layer, which carries the color markings at or immediately beneath its surface, is covered by a horny layer of conchiolin, which conceals these colors during the life of the animal. In those not covered by a horny layer the prismatic layer, with its color markings, is concealed by reflections of the mantle. Of course, the horny layer or the mantle itself may show colors, but they are not the colors retained by shells in their fossil form, and therefore have nothing to do with the present study.

Notwithstanding this fact there evidently is an intimate connection between the presence of color markings on shells and their access to light during the life of the animal. Forbes [38] has called attention to the fact that in shallow waters shells present more varied colors and more distinct color designs. At greater depths the colors tend to become uniform over the entire surface of the shell, so that color patterns disappear. Moreover, at these depths the the variety of colors is restricted more and more to various shades of dull red or of reddish brown. Newton [39] stated that in the Mediterranean only 1 out of 18 shells showed colors below the 100-fathom line; between 35 and 55 fathoms, 1 out of 3; and at depths of only 2 fathoms or less, more than half.

[38] Forbes, E., "Report on the Mollusca and Radiata of the Aegean Sea, and on Their Distribution, Considered as Bearing on Geology," *Rept. of 13th Meeting of the British Assn. for Adv. of Science*, London, pp. xxiii, 130, 1844; also pp. 21–23 of article cited in note 1.

[39] Newton, R. B., "Relics of Coloration in Fossil Shells," *Proc. Malacozool. Soc. of London*, Vol. 7, p. 280, 1907.

From the vividness of the color patterns of the Carboniferous limestone specimens studied by him, Newton concluded that the Carboniferous limestone was deposited in water less than 50 fathoms deep. The relatively numerous species of gasteropods with color patterns found by J. Brookes Knight in a single horizon of the Pennsylvanian division of the Carboniferous, in the vicinity of St. Louis, Missouri, suggests deposition in an equally shallow sea. By a similar line of reasoning, it seems probable that the portion of the Alpena limestone which retained color markings in a species of cephalopod and also in a species of brachiopod (both discussed above) was deposited in relatively shallow waters.

Addendum

Another orthoconic cephalopod with vertical color bands is described by Blake (*British Fossil Cephalopoda*, p. 144, Pl. 13, Fig. 5 *bis*) from the Bala shales at Bala in northern Wales under the name *Orthoceras pictum* Blake. It has "longitudinal bands of colour, alternately white and brown, some wider and some narrower, about 12 per diameter. The colour bands are variable in their distance and breadth, the dark colour being as broad as the light." See page 130.

In the list of papers to be presented before Section E of the American Association for the Advancement of Science, at Des Moines, Iowa, December 30–31, 1929, is one by James S. Williams, entitled: "An Indication of a Color Pattern on a Mississippian Trilobite." Hitherto only one species of trilobite retaining color markings has been known, and that is the Cambrian form found by Professor Raymond. See page 144. This trilobite is a new species of *Proetus*, which Professor Williams has named *Proetus tenuituberculus*. He informs me that it is very close to *Proetus missouriensis* Shumard.

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PLATE I

FIG. 1. *Orthoceras anguliferum* D'Archiac and De Verneuil. — Lateral view of conch with ventral outline on left, showing the abrupt termination of the zigzag color lines along the middle of this lateral side. A part of this color pattern across the entire circumference of the conch is represented by Figure 1 on Plate III. The two rising chevrons of this pattern correspond to angles *B* and *C* on the latter plate. The descending angle *F* is readily identified only along the upper left margin of the figure. The left part of the color pattern is out of view. Angle *B* of each zigzag line lies along the median line of the ventral side of the conch. This conch is slightly curved lengthwise, but has been turned so as to expose a little more than half of the color pattern. From Paffrath, in the Rhenish part of Germany; in the *Stringocephalus* or Givetian division of the Middle Devonian. Specimen No. 4132, Peabody Musuem, Yale University. Magnified 2 diameters.

FIG. 2. *Orthoceras anguliferum alpenense* Foerste. — Ventral view, with the left margin of the color pattern poorly preserved, and the right margin not exposed. A part of this color pattern across the entire circumference of the conch is represented by Figure 1 on Plate IV. The two rising chevrons of this figure correspond to angles *A* and *B* on Plate IV. Angle *B* of each zigzag line lies along the median part of the ventral side, but the specimen has been turned so as to show that part of the color pattern which is best preserved. From the quarry of the Michigan Alkali Company, at Alpena, Michigan; in the Alpena limestone. Specimen No. 10775, Museum of Paleontology, University of Michigan. Magnified 1.7 diameters.

FIG. 3. *Hedstroemoceras haelluddenense* Foerste. — *A*, ventral view of a specimen retaining the living chamber and the upper part of the phragmacone. The upper four camerae are outlined by the sutures of the septa. The lower one of this group of camerae was sectioned sufficiently to expose the siphuncle, as shown by Figure 3 on Plate III. The lower part of the specimen retains the shell with part of its color pattern. The latter, as far as preserved, is shown by Figure 2*A* on Plate V. *B*, lateral view of another specimen, exposing the living chamber and two camerae, beneath which the specimen retains the shell with its color pattern. The latter, as far as preserved, is shown by Figure 1 on Plate V. From Haelludden, on the island Oeland, Sweden; in the gray *Endoceras vaginatum* limestone. From Museum of the Geological Survey of Sweden, in the Riksmuseum, Stockholm. Magnified 2 diameters.

PLATE I

1

2

3A

3B

PLATE II

FIG. 1. *Sactoceras westonense* Foerste. — Ventral view, showing remains of vertical color bands. On the dorsal side, although the surface of the shell is well preserved, there is no color banding. From Weston, Ontario, in the Lorraine formation. Specimen No. 2174 in the Victoria Memorial Museum. Same specimen as that figured and described in *Upper Ordovician Faunas of Ontario and Quebec*, Foerste, Memoir 138, Geological Survey of Canada, p. 226, Plate 39, Figure 5; Plate 40, Figure 2, 1924. Figure enlarged 1.5 diameters.

FIG. 2. *Sactoceras manitoulinense* Foerste. — Ventral view, showing vertical color bands. From Clay Cliff, on the northeastern shore of Manitoulin Island; in the Meaford or Waynesville member of the Richmond. Specimen No. 8539, in the Victoria Memorial Museum. Same specimen as that described and figured in *Upper Ordovician Faunas of Ontario and Quebec*, p. 224, Plate 39, Figure 4a, 1924. Figure enlarged 1.5 diameters.

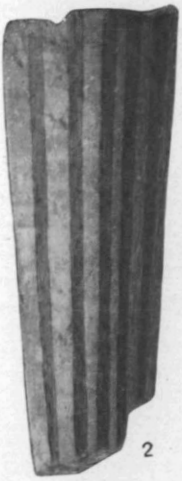
FIG. 3. *Rizoceras* (?) *coronatum* Foerste and Savage. — Ventral view, showing scalloped transverse striae on surface of shell. From Shamattawa River, southwest of Hudson Bay; in the Shamattawa member of the Richmond. Specimen No. 22 HB in the Savage collection. Same specimen as that described and figured in *Ordovician and Silurian Cephalopods of the Hudson Bay Area*, Foerste. Denison Univ. Bull., Journ. Sci. Lab., Vol. 22, p. 50, Plate 5, Figure 7, 1927.

FIG. 4. *Orthoceras dunbari* Foerste. — Ventral view, showing the area crossed by transverse color lines, bordered by a vertical black area on each side. From 15 miles north of Tulsa in Oklahoma, in the Ochelata member of the Pennsylvanian. Specimen No. 10549, Peabody Museum, Yale University. Magnified 2 diameters.

FIG. 5. *Cranaena casei* Foerste. — The right anterior quarter of the surface of a valve retaining black concentric lines of different width and distribution. The upper part of this specimen exposes also a part of the interior of a second valve, filled with matrix, but retaining a remnant of part of its interior structure in the vicinity of its beak. From the quarry of the Michigan Alkali Company, at Alpena, Michigan; in the Alpena limestone. Specimen No. 10775 in the Museum of Paleontology, University of Michigan. Magnified 2 diameters.

PLATE II

1



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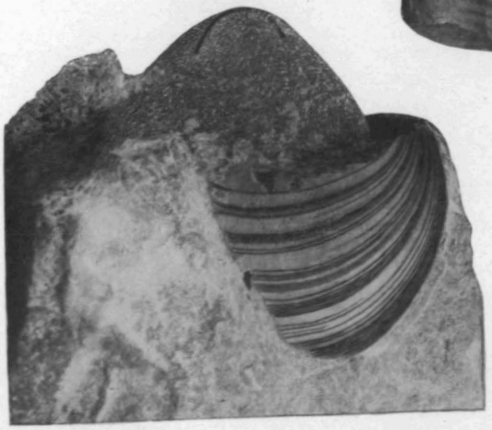
4



5

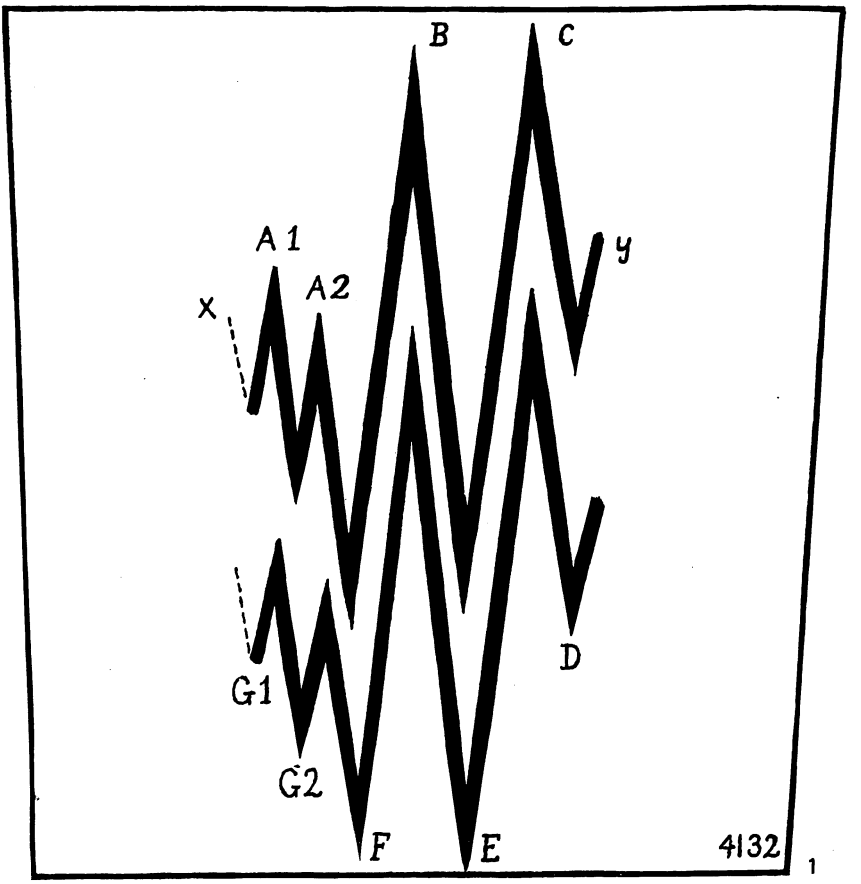
PLATE III

FIG. 1. *Orthoceras anguliferum* D'Archiac and De Verneuil. — Color pattern of the specimen represented by Figure 1 on Plate I. The figure represents the entire circumference of the conch, the blank parts represent the dorsal side of the latter where there is no color pattern. Magnified 3 diameters. *A*, *B* and *C* represent the upward directed chevrons; *D*, *E*, *F* and *G*, the downward directed angles. Angles *A* and *G* apparently are doubled. The letter *y* is the right arm of angle *D*, and *x* is the left arm of angle *G*. Specimen No. 4132, Peabody Museum, Yale University.

FIG. 2. *Orthoceras anguliferum* D'Archiac and De Verneuil. — Similar figure of the second specimen of this species described in the text. Magnified 3 diameters. Specimen No. 4129, Peabody Museum, Yale University.

FIG. 3. *Hedstroemoceras haelluddenense* Foerste. — *A*, vertical section of conch through the siphuncle, only the upper one of the two camerae figured being actually sectioned; *B*, cross-section showing location and size of siphuncle at its passage through the septum. Both figures magnified 2 diameters. Same specimen as that represented by Figure 3 A on Plate I. From Museum of Geological Survey of Sweden, in the Riksmuseum, Stockholm.

PLATE III



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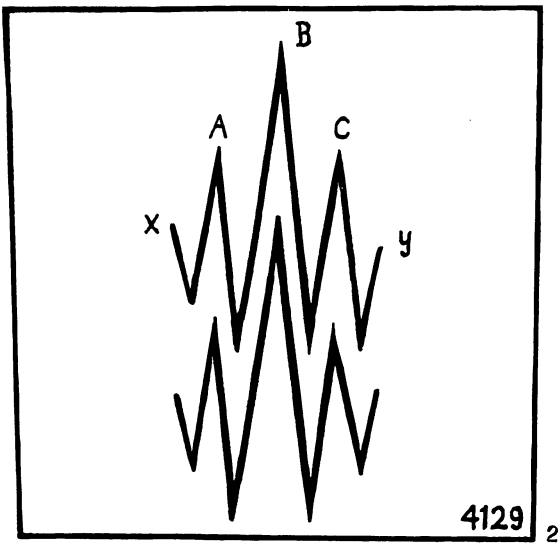

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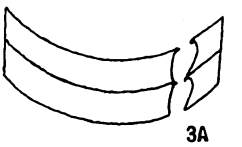

3A

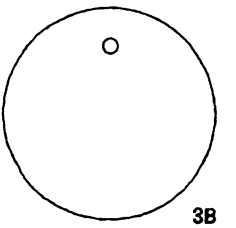
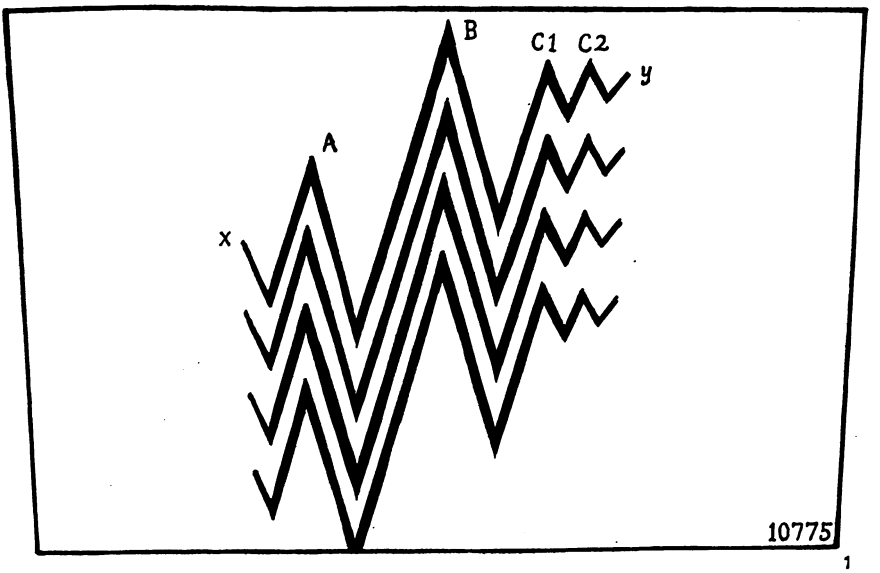

3B

PLATE IV

FIG. 1. *Orthoceras anguliferum alpenense* Foerste. — Color pattern of same specimen as that represented by Figure 2 on Plate I. In this specimen it is the angle *C* which is doubled. Magnified 2.4 diameters. Specimen No. 10775, Museum of Paleontology, University of Michigan.

FIG. 2. *Orthoceras anguliferum alpenense* Foerste. — Color pattern of second specimen described in the text. Magnified 2.4 diameters. Specimen No. 10776, Museum of Paleontology, University of Michigan.

PLATE IV



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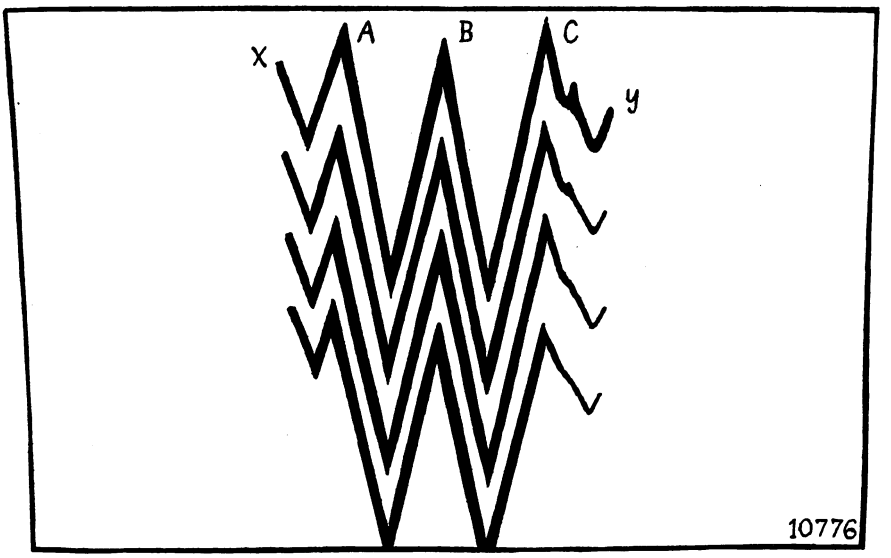

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PLATE V

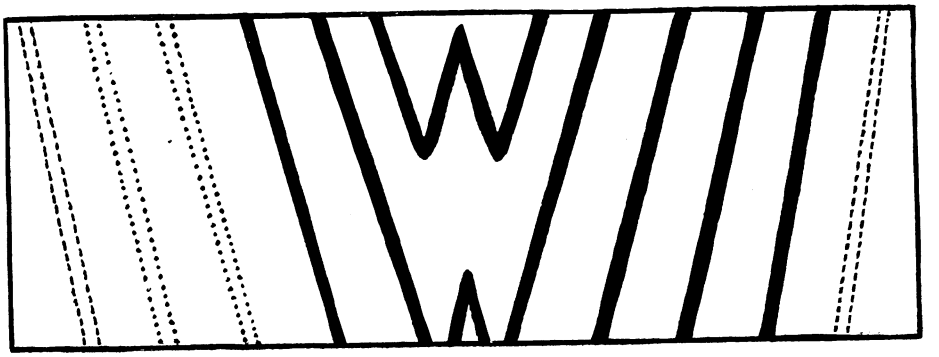
FIG. 1. *Hedstroemoceras haelluddenense* Foerste. — Color pattern of the same specimen as that represented by Figure 3B on Plate I. Magnified 3 diameters. The dotted lines represent the assumed location of color bands not preserved in the specimen. It is assumed that the two color bands nearest the median line of the dorsal side of the conch met at an upward directed angle. Along the median part of the ventral side they formed a pattern resembling the letter W, better shown in Figure 2A of this plate. Museum of the Geological Survey of Sweden, in the Riksmuseum, Stockholm.

FIG. 2. *Hedstroemoceras haelluddenense* Foerste. — *A*, color pattern of same specimen as Figure 3A on Plate I, magnified 3 diameters; *B*, diagram of suture at top of phragmacone, natural size. From *d* to *d* represents the entire circumference of the conch, *d* being the median line of the dorsal side; *v*, the median line of the ventral side; and *vl* the ventro-lateral parts of the conch. The suture rises ventro-laterally, and curves downward so as to form a ventral lobe narrower than the dorsal lobe. The median part of the dorsal lobe is flat and broader than the corresponding part of the ventral lobe. Museum of the Geological Survey of Sweden, in the Riksmuseum, Stockholm.

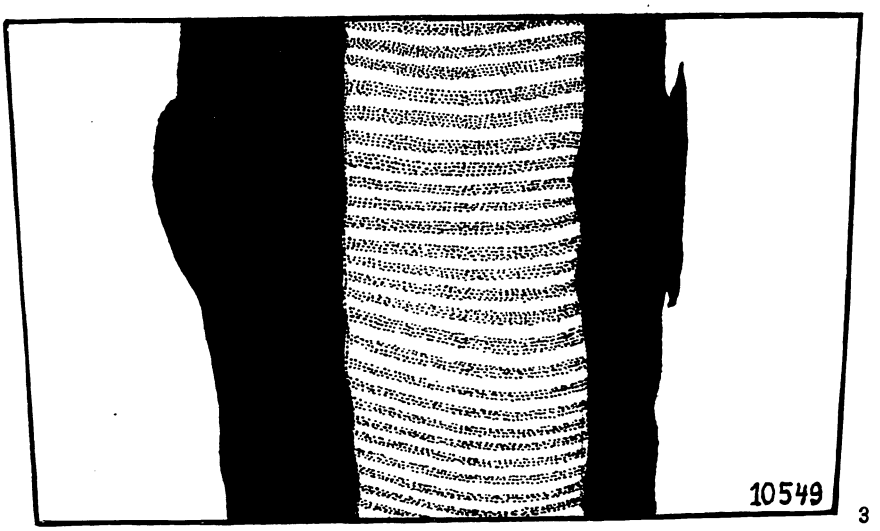
FIG. 3. *Orthoceras dunbari* Foerste. — Color pattern of same specimen as that represented by Figure 4 on Plate II, magnified 2 diameters. The dorsal side of the conch does not present any color pattern. Specimen No. 10549, Peabody Museum, Yale University.

PLATE V

1.



2A



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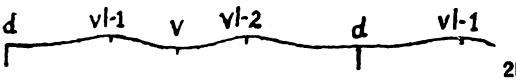

2B

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