EUCONOSPIRA WITH COLOR MARKING FROM THE PERMIAN OF JAPAN

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(With 2 Plates)

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I. Introductory.

While examining late Paleozoic macro-fossils of Japan in the cabinet of the Department of Geology and Mineralogy, Hokkaidô University, the writer recently happened to come across with a trochiform gastropod with an almost flat base. It originated in the Permian limestone of Central Japan. Although the specimen is slightly deformed and partly damaged, most of the more important diagnostic characters are recognized quite clearly. A narrow selenizone buried between peripheral flanges is recognized though the latter are mostly broken off.

These features, although apertural part is lost, show that the fossil belongs to the genus *Euconospira* ULRICH and SCOFIELD which is widely distributed in North America ranging from Carboniferous to Permian.

The original work of ULRICH and SCOFIELD in which the genus was first introduced to science is beyond the reach of the present writer. However, it is briefly but exhaustively diagnosed by J. Brookes KNIGHT in "Index Fossils of North America", 1949. It reads as follows: "Conical shells with deep sinus in outer lip culminating just above periphery in a deep slit which generates selenizone deeply buried between two carinae; base flat, with narrow umbilicus; sutures linear"[1].

As the genotype of *Euconospira* what had been known as *Pleurotomaria turbiniformis* (MEEK and WORTHEN) was designated by KNIGHT in 1937[2]. Many species of the genus have been known almost exclusively from North America. Because of certain morphological features that seem to be characteristic, however, the Japanese species is regarded a new species. It is named *E. nipponica* and is described in the following pages.

Journ. Fac. Sci., Hokkaido Univ., Ser. IV., Vol. VIII., No. 4, 1953.

Another point of interest and importance of the Japanese fossil is the fact that it retains an unusual color marking on the surface of the conch. Paleozoic fossils with various color markings have been known in Europe and North America, though they have by no means been common. As far as the writer knows, the present specimen is the first fossil with color marking discovered in our country. Not only because of this, but also of the present situation of the problem of fossilized color patterns in general which seems to involve unanswered questions, it seems worthwhile to make a note on the observations on the fossil snail at hand.

II. Description of Species.

Euconospira nipponica nov. sp.

Pl. XX Figs. 1 and 2,

Conical, trochiform gastropod of rather large size, with an almost flat base which is slightly convex beneath about the last 1/3 of body whorl; concave toward umbilicus which is shallow. Shell thin. Periphery angular, with a narrow selenizone just above peripheral edge, bounded on both sides by projecting flanges or carinae though the latter are broken away from the major part of the shell. Shoulder of each whorl slightly convex ; just below suture a narrow, steeply inclined zone which meets with a wide revolving ridge below to form a shallow groove in between. Similar revolving ridges tend to be added toward periphery as the conch grows, as is shown by symptomatic spiral relief on the shoulder of body whorl. Whole surface ornamented with fine, thread-like lirae or costulae that are retroambital and slightly convex forward ; they extend backward from suture to selenizone, making an angle of about 60 degrees with the former: they count about 5 in 2 mm on shoulder of body whorl. Beyond periphery, that is, on basal surface costulae are again retroambital, first making an angle of about 45 degrees with periphery and gradually becoming almost radial toward umbilical margin, thus prescribing a gentle curve convex backward.

Dimensions : –

Thickness of shell ··· ca. 1 mm after cleaning.
Apical angle ····· ca. 90 degrees
Height ····· ca. 90 mm (presumed from apical angle)
Width ····· 110 mm
Whorls preserved ··· 4 (possibly one more or two originally)

Umbilicus ····· ca. 25 mm wide
Selenizone ····· ca. 3 mm on body whorl

OBSERVATIONS: – The present Japanese fossil is extraordinarily large for a species of *Euconospira*. Perhaps the largest species hitherto recorded may be *E. taggarti* (MEEK) from the basal part of the Weber formation of Colorado[3]. Aside from the large size, however, these do not appear approximate, though in possessing low revolving ridges on the whorl they look alike. The American species seems to have higher whorls and consequently a smaller apical angle. But as both the species are represented by single specimens neither identification nor distinction is easy.

As to the enormous size of *E. nipponica* the writer has a few words to express at this place. The locality where the specimen is labelled to have occurred is the Nabeyama region, in the Kantô mountains. At and near the limestone quarry of Kadosawa in this region the writer collected and described a small brachiopod faunule consisting of many specimens of huge sizes[4]; they are preserved in a black limestone. In the similar bituminous zone of the limestone of Kinshôzan, Gifu Prefecture, an assemblage of gastropods and pelecypods of extraordinary sizes has long been known to occur[5]. It seems that certain brachiopods and molluscs, especially gastropods, behave similarly against certain change or changes of the environmental conditions. The conspicuous size of *E. nipponica* which is believed to have occurred in association with a number of gigantic brachiopod species, therefore, is not to be wondered at.

The genus *Euconospira* is quite popular in the Anthracolithic faunas of North America, but it had not been known outside, until its occurrence in southern China was reported by A. W. GRABAU some time ago. In his monograph on "the Permian of Mongolia", 1931,[6] a species of *Euconospira* which he named *E. permiana* was listed as one of the Permian species in the Maping limestone of Kwangsi Province. Subsequently, in 1936, this species was described and illustrated by him in a volume of Palaeontologia Sinica[7]. According to GRABAU this early Permian species from southern China is a small fossil and lacks spiral or revolving relief on the shell surface. The thread-like lirae on the surface, prescribing a gentle, forward curve make an angle of about 48 degrees with suture. "At the band (that is, selenizone) they become vertical, then passing over the shoulder angle, they curve gently forward to the umbilical margin" (p. 304). Because of these features and the fact

that the apical angle is smaller, this species is considered different from the Japanese species under consideration.

In point of the general outline of the shell *E. disjuncta* GIRTY, 1915[8], appears to closely resemble *E. nipponica* especially in having a low spire, though the species is very small. Except for the development of "several sharp revolving, thread-like lines" on the undersurface of the body whorl, that is, on the basal surface, *E. halliana* SHUMARD, 1859[9], may be comparable with *E. nipponica*, as is suggested by the description quoted from SHUMARD by GIRTY[10]. Perhaps *E. obsoleta* GIRTY, 1908[11], may be another species which closely resembles the Japanese species, although GIRTY himself is somewhat suspicious of calling it *Euconospira*. Morphologically they are very much alike. But *E. obsoleta* is described to lack revolving sculpture on the shell surface. Moreover, the thread-like costulae that are quite coarse, are directed backward from the selenizone though they are wavy or flexuous. In *E. nipponica* also the costulae curve back from selenizone, as stated above.

LOCALITY AND GEOLOGICAL HORIZON: – Kadosawa limestone quarry, Nabeyama region, Tochigi Prefecture. Lower Permian.

III. The Color Marking of *Euconospira nipponica*.

The specimen of *Euconospira nipponica* occurred in a black limestone as stated already. The relatively thin shell is turned into black perhaps by the impregnation of a bituminous matter. On the surface of the spire an unusual sort of color marking was found while cleansing the specimen with brushes and dilute acid. There had been no symptom of such until the surface was slightly worn off by etching and brushing: it seems as if the color marking was not exposed originally. DEECKE in his discussion on the coloration of molluscan and brachiopod shells remarks as follows. "Die Farbschicht bildet niemals die direkte Oberfläche, sondern gehört einer unter dieser liegenden Zone an, pflegt in vielen Fällen von einer starkglänzenden, durchsichtigen, glasartigen dünnen Lamelle von kohlensaurem Kalk bedeckt zu sein. Diese Lamelle ist ausserordentlich dünn und nicht kristallisierter kohlensaurer Kalk. Unter ihr, den obersten Faserschichten eingelagert und zwischen jenem äussersten Blatt reichert sich das Pigment an"[12]. Possibly this thin surface lamella, if it really exists, also was changed black in the case of *Euconospira nipponica*. Then, the absence of the color marking on the basal surface of the latter may not be that it is lacking there,

but that possibly the surface lamella is somehow still attached to the shell. The writer has applied the same manipulation of etching and brushing to the basal surface to trace the marking, but in vain. The fragments and patches of mother rock sticked might have prevented wearing of surface.

As is seen in the picture (Pl. 20, Fig. 2) there are seven gray radiating bands on the side of the spire. It is obvious that each of these bands or rays is not a continuous zone running between the apical region and the basal margin. On the contrary, each whorl has gray bands crossing the shoulder surface transversely and widening anteriorly, or toward periphery. These gray bands increase in width as the whorl grows; that is, the later band is wider. At the same time the distance between two bands also increase ambitally, so that the gray bands of succeeding whorls almost coincide in position, to the effect that they look like continuous rays at the first glance. Here we see that the formation of color marking is in an intimate relation with the growth of the shell: in other words, it is a part of life process.

The contrast between the black and gray becomes very distinct when the specimen is dipped in water or at least when its surface is wet. The pictures given (Pl. 20, Figs. 1, 2) are produced from photographs taken of the wet specimen.

In the foregoing lines the writer has described as if the gray bands are the remains of color marking. This is only an expression of his—and in all probability of most people's first impression obtained of the specimen. However, in all the cases hitherto known the color patterns in fossils are darker in color—either black, brwon or reddish brown—than the shells themselves. Discussions have always been why the fossil color markings are so dark while their Recent equivalents are of brighter tints. In *E. nipponica* the black areas between the gray bands may happen to be regarded as color marks instead of the reverse.

IV. On the Color Markings of some Paleozoic Fossils

Fossil color markings as paleobiological objects seem to have escaped from the notice of scientists for a long time. The oldest reference to the color marks accessible to the writer is PHILLIPS' "Geology of Yorkshire", part 2, 1936, in which *Pleurotomaria flammigera* PHILLIPS is described[13]: it is characterized in having "colour varied with zigzag flashes". An excellent picture is given. It is quite likely that PHILLIPS did not

pay a particular attention to the marks which might not have been very rare among the fossils he studied. In the Monograph of British Carboniferous Brachiopoda, 1857, by DAVIDSON, we find pictures of *Dielasma hastata* SOW. retaining color stripes radiating from beak[14]. These color stripes were correlated by DAVIDSON with the similar color markings of some Recent terebratulid brachiopods, and were assumed to be "in all probability of a red color, similar to those we find in several Recent forms, such as *T. rubellus, etc.*"

Fossil color markings are most frequently known in gastropods, being seconded perhaps by brachiopods. There are many papers dealing with such gastropods and brachiopods as well as some other forms of fossils. Regarding brachiopods RICHTER's investigations[15] are instructive. The color markings in fossil brachiopods known to him had been exclusively radiating stripes or radiating series of flecks, but he met with specimens of *Newberria*? *cimex* RICHTER, Devonian, with roughly concentric color bands almost conforming with growth-lines or growth-wrikles. It appears that this occurrence stimulated RICHTER to extend his observations and studies.

The color markings on the pedicle valves of *Newberria*? *cimex* are not exactly coincident with growth-wrinkles, nor do they show the bilateral symmetry with regard to form and number. In some specimens they are divided into more or less anastomosing veinlets on the visceral parts of the shell. These are the distinguishing features from some such comparable Recent forms as *Terebratalia coreanica* and the like. Both fossil and Recent forms in which color bands are symmetric and concentric suggest that the formation of such markings is in close relation with the growth of the animals. What RICHTER emphasizes in his paper is that the formation of the color bands, as is seen on pedicle valves, is "selbständig" (independent) of the process of shell growth. However, the color bands on the brachial valves of some specimens are symmetric and more regular.

En passant, the color bands of *Newberria*? *cimex* were examined by RICHTER[16] in a thin section vertical to the surface of the shell, and it was assured that the black bands are formed of a black pigment filling the concave zones between the concentric wrinkles: the pigment does not penetrate into the prismatic layer, but simply covers the surface.

In RICHTER's discussion we find many important data and suggestions for the consideration of the fossil color markings as a whole: they are very useful for the investigation of the similar phenomenon in other

groups of fossils.

In case of fossil gastropoda, color markings in many forms are seen to have an intimate relation with the growth process of shells. Namely, in some of them the color marking consists of revoloving band or bands, as is exemplified by the Pennsylvanian species *Holopea proutana* HALL (Pl. 21,Fig. 1) from Indiana[17]. In other cases color markings coincide with growth lines, as, for instance, in *Glyptobasis marshalli* ROUNDY (Pl. 21, Fig. 2)[18], also from the Pennsylvanian of Indiana. These correspond to the concentric bands seen in some brachiopods as were referred to above.

There is another group of color markings in fossil gastropods. Within the writer's access there are *Pleurotomaria flammigera* PHILLIPS from the British Carboniferous (Pl. 21, Fig. 3)[19], already quoted, and *Naticopsis picta* GIRTY from the Mississippian of Indiana (Pl. 21, Fig. 4)[20]. In these the color markings consist of a number of zigzag lines or bands, "independent" of the growth-lines. These are in a sense equivalents of the asymmetric color bands on the pedicle valves of *Newberria*? *cimex*, together making, as it were, a group of color markings that are "independent" of the growth of the respective animals. By the way, however, if the increase of width of bands, whether revolving, wavy or zigzag, is taken into account, all the color markings are not absolutely "independent" of the process of growth of shells of any kind of animals.

It is not easy to understand how such "independent" color patterns were formed. But these are not an unique phenomenon met with in these fossil gastropods alone. There are examples of similar or even almost identical patterns seen in some Recent shells. In the collection of Recent molluscan shells near at hand there are several species of *Cypraea* and *Conus*, for instance, that are ornamented with complicated and apparently irregular color stripes and flecks. Of these *Fulgoraria rupestrisa* (GMELIN) (Pl. 21, Fig. 5) is especially important, because it has a color marking consisting of delicate zigzag lines that are very much like those of the Carboniferous gastropods quoted above. To this group belongs *Euconospira nipponica* in point of the color marking as is evident in comparing the pictures. Moreover, in *Trochus conus* GMELIN we see another case of analogy (Pl. 21, Fig. 6). This species is ornamented with a number of red bands radiating from the apex downwards and reaching to the marginal zone of the basal surface: the radiality is obscured farther inwards toward umbilicus. If the narrow gray bands of *Euconospira nipponica* were originally coloar bands, then the affinity

between this fossil and *Trochus conus* appears very great. However, if the black area between these gray bands of the former are the color marks, the relation between these and the growth lines remains unaltered.

It seems very difficult, if not impossible, without many specimens for examination, to investigate into the way of formation of such "independent" color markings—in reality, of all kinds of color markings. Assuming that the fossil color patterns and the Recent ones are of the same origin and nature, as has been held by DAVIDSON, KAYSER[21], RICHTER and others, the problem can be solved only by the detailed investigations on the Recent shells. It is noteworthy that in certain gastropods—in *Astraea japonica* DUNKER (Pl. 21, Fig. 7), for instance—granulate ribs that transversely cross growth-lines are formed on the surface. It is evident, therefore, that there are in gastropods surface sculptures that are "independent" of growth-lines just like the color marks.

Our knowledge of the fossil color marks goes as far back as to the Ordovician age, as has been referred to elsewhere. Examples have been found in all the later formations through the Mesozoic to the Pleistocene: the younger the formation, the more frequent their occurrences, naturally. Throughout the geohistory, on the other hand, the most common among fossils retaining color markings are known to be gastropods as stated above. In this respect KAYSER's view in 1871 still proves true. In his discussion on the color marking of the Devonian "*Rhynchonella*" *pugnax* KAYSER summed up in a table all the occurrences of fossil color patterns then known to him from different formations[22]. Avoidingun necessary annoyance of mentioning the specific names listed by KAYSER, the distribution of various groups in different formations is given below.

	Gastropods	Brachiopods	Pelecypods	Cephalopod	Total
Carboniferous	8	4	2	—	14
Devonian	3	2	—	1	6
Silurian	1	—	—	—	1
Total	12	6	2	1	21

In this table we see not only that gastropods are most unmerous or frequent, but also that the fossils with color marks had been found most frequently in the Carboniferous formation. The same tendency

is evident even now when there are much more numerous records of occurrences. An interesting summary of our recent knowledge on the fossil color markings was given by Martin SCHWARZBACH in 1950[23]. Bringing together all the occurrences known to him he obtained the following table.

Frequency of Color Markings in Fossils

	Carboniferous	Paleozoic and Mesozoic
Brachiopods	6	23
Pelecypods	9	22
Gastropods	34	61
Cephalopods	4	41
Trilobites	1	1
Total	54	148

It is worthy of note, SCHWARZBACH remarks, that one third of all the known cases occurs in a single formation especially of the limited areas of the great coal basins of North America, and Western and Central Europe. Following the point of view current among paleontologists that fossil color marks and color patterns of Recent shells are of the same nature, and based on the fact that the bright colors of Recent shells are due to the influences of strong light which prevails along the coastal zones, especially on coral reefs, of tropical seas, SCHWARZBACH tries a paleoclimatological conclusion. Namely, the Carboniferous seas in our latitudes must have had the light and the water conditions like those of the present day warm seas. Such an idea seems to have been rather popular among scientists. DEECKE[24], for instance, discussed that the coloration and color patterns of Recent molluscan shells are mimic adaptations in warm seas, so that the fossils with color markings must have lived in the environmental condition similar to that of those colorful shells. As a matter of fact, the Recent shells the writer mentioned in the foregoing pages as the comparatives of the fossils, are all the warm water forms.

V. Concluding Remarks

The color markings retained by fossils are to be regarded as of the same nature as those of the Recent shells, both being a surface

phenomenon. The fossils with color markings, though exceptional cases of fossilization among respective kinds, are considered to have lived in warm, clear and shallow waters along the coast where light is strong, analogous to the abode of the Recent animals with bright colors and color marks. It is evident that the formation of the color markings has an intimate relation with the growth of the animals that bear them.

In both the fossil and the Recent color marks there are some consisting of stripes or bands that do not conform in trend with the growth lines or growth wrinkles of the shells.

How such could be produced is a question which paleontology can not solve with ease. Prof. K. HIRASAKA, Niigata University, on the writer's question, suggested him that the reflected mantle margin which may differ in form from the shell margin, may decide the shape of the color patterns by secreting pigment. Besides, the successive color bands or stripes appear to be formed at quite regular intervals,as has been seen in *Euconospira nipponica, Naticopsis picta, etc.* among fossil gastropods and in *Trochus conus* and *Fulgoraria rupestris* among Recent forms. Is it not possible that these color stripes represent certain periods, say, seasonal or annual?

As to the nature of the pigment of coloration, investigations have been made by some scientists, KAYSER, as early as 1871, carried out a detailed observation,[25] and found that there is some differences between the fossil and Recent pigments, and that the former must have been changed from the original material through the process of fossilization.

The color markings in brachiopods, both fossil and Recent, are known to be common in smooth forms, mostly in TEREBRATULIDAE. Among the Paleozoic examples mentioned by RICHTER[26], *Spirifer* (*Martinia*) *glaber* (MART.) is also a smooth form, but *Orthis* (*Schizophoria*) *resupinata* (MART.) is ornamented with fine radial striae, while "*Rhynchonella*" *pugnax* MART. is a form with radial plications. It seems there are some more examples of this among younger fossils. In gastropods also most of the species with color markings are smooth forms. *Euconospira nipponica* has a rather rough surface, but it is only an appearance due to the coarse growth lines: there is no strong relief on the shell surface. A Pennsylvanian spesies *Trachydomia wheeleri* SWALLOW from the coal Measures of Illinois, reported by KEYES[27] may be an unusual case. It may per-

haps be summed up that in gastropods fossil color markings are commonly expected in forms with a smooth surface.

For the solution of the problem of the fossil color markings, there remains much to be contributed by various lines of the biological investigations, as was pointed out even as early as in 1871 by E. KAYSER.

In concluding the writer desires to express his indebtedness to S. UOZUMI, post-graduate student of Hokkaidô University, for his favor of supplying him with necessary specimens of Recent shells and informations, and to S. HAYASAKA, assistant in Tôhoku University, by whose labor he could get copies of passages and pictures from some important paleontological works that had been inaccessible otherwise: photographs were prepared by S. KUMANO to whom also thanks are due.

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G. H. GIRTY who examined an imperfect specimen of *Euconospira bicarinata* MCCHESNEY from the Hermosa formation of San Juan region, Colorado, and compared it with "authentic specimen of *Pleurotomaria turbiniformis* from the original locality", came to the conclusion that "two forms are with but little doubt identical." Thus GIRTY maintains that the former specific name should be used for this fossil, because it antedated the latter by several months. Although MEEK retained the latter name by reason that *P. bicarinata* was preoccupied more than once, this reaon is "invalidated by the removal of that species to another genus." (GIRTY: The Carboniferous Formations and Faunas of Colorado: U. S. Geol. Surv. Prof. Paper 16, p. 454, 1903).

3) The original work of MEEK is not accessible, but GIRTY gave the reproduction of the original pictures of this species in his above cited work on the Carboniferous of Colorado, pp.453–451, pl. x, figs. 9 a, b. From these pictures it is seen that the Colorado species is not as large as the Japanese one, and the apical angle is a little narrower.

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19) See 14.
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22) *Ditto*, p. 265.
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Explanation

of

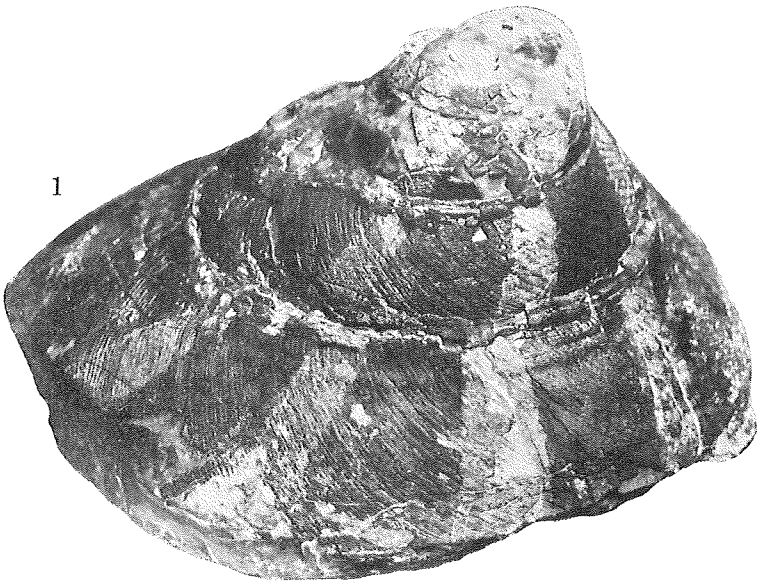
Plate 20

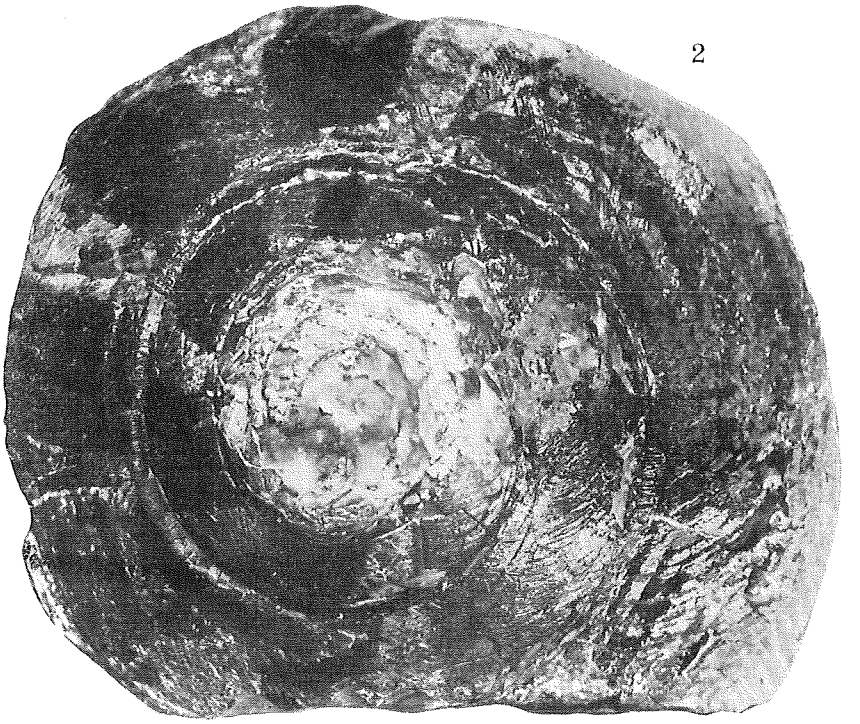
Plate 20

Euconospila nipponica HAYASAKA. Natural size.

Fig. 1. Lateral view. Development of selenizone is seen though somewhat obscurely: gray and black bands on each whorl are oblique to the thread-like costules or growth-lines.

Fig. 2. Apical view. Seven gray bands are recognized, radiating from apical region.





HAYASAKA: *Euconospira* KUMANO photo.

Explanation

of

Plate 21

Plete 21

Fig. 1. *Holopea proutana* HALL, Carboniferous. Copied from ROUNDY, *op. cit.*, 1914, pl. III. figs. 11, 12 and 13, designated here a, b and c, respectively.

a. "Specimen in which only the fourth band shows".

b. Color bands are seen on last two whorls. ROUNDY notices that there is a thin, thread-like color band above the third band, but it is not clear in the original picture.

c. Specimen with two revolving color bands. A thin, light-colored, thread-like line is seen above the lower color band: similar line above the upper band is not clear.

Fig. 2. *Glyptobasis marshalli* ROUNDY, Carboniferous. Copied from ROUNDY, *op. cit.*, 1914, pl. III, fig. 4 (a) and 5 (b).

a. Specimen with "the most regular color bands". These thin color bands are almost coincident with the growth-lines.

b. Specimen with color bands and dots in alternation: these marks also seem to conform with the trend of growth-lines.

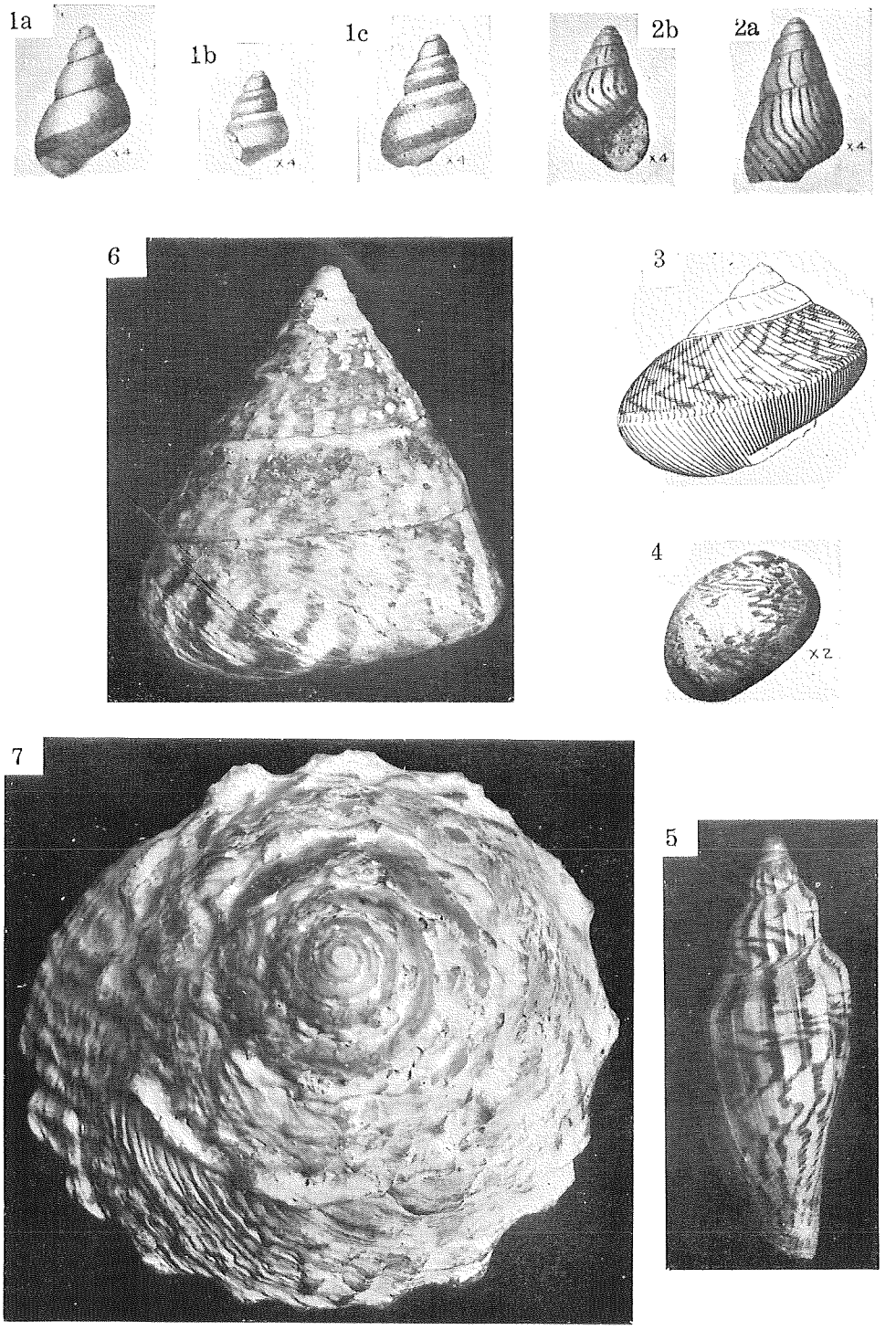
Fig. 3. *Pleurotomaria flammigera* PHILLIPS, Carboniferous. Copy of original figure in PHILLIPS, *op. cit.*, 1836, pl. XV, fig. 2. Color marking consists of zigzag bands.

Fig. 4. *Naticopsis picta* GIRTY, Carboniferous. Copy of the original picture in GIRTY, *op. cit.*, 1912, pl. fig. 9. Color bands are more strongly zigzag than in the preceding species.

Fig. 5. *Fulgoraria rupestris* (GMELIN), Recent. Natural size. This is to show zigzag color patterns that are comparable with those of the two preceding Paleozoic gastropods.

Fig. 6. *Trochus conica* GMELIN, Recent. Natural size. This species is ornamented with a number of radiating red bands that show a very striking resemblance to the color bands of *Euconospira nipponica*.

Fig. 7. *Astraea japonica* DUNKER, Recent. Natural size. This is to show the formation, during life, of granulated ridges oblique to growth-wrinkles, just like the color bands of *Euconospira nipponica* and *Trochus conus* are.



HAYASAKA: *Euconospira* KUMANO photo.