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ORTHAULAX, A TERTIARY GUIDE FOSSIL.

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INTRODUCTION.

Since the publication of Dall's "Tertiary fauna of Florida" in 1890,¹ when the genus *Orthaulax* was for the first time adequately described, much importance has attached to *Orthaulax* as a horizon marker. Twenty-five years later Dall² voiced current opinion when he said:

This genus is the most characteristic and typical of those belonging to the middle Oligocene of our southern Coastal Plain and the Antilles, including Middle America. It does not appear in the Vicksburgian fauna or the nummulitic Ocala beds of Florida; it seems to have become extinct before the development of the Oak Grove, Fla., fauna. So far it has been recognized in the middle Oligocene of Santo Domingo, Cuba, Antigua, the Canal Zone of Panama, the Tampa silex beds, the Oligocene of Bainbridge, Ga., and the lower bed at Alum Bluff, with its stratigraphically equivalent marl of the Chipola River, Fla. It is not known from the Bowden beds of Jamaica, which are doubtless younger than the Haitian Oligocene explored by Gabb, if indeed the latter be not divisible into several distinct horizons.

But the range in time appears so narrow and the genus so sharply characterized that, according to our present knowledge, the discovery of a species of *Orthaulax* in a Tertiary fauna may be taken as positive proof of its middle Oligocene age.

Since that statement was written the arbitrary boundary between the Miocene and the Oligocene has been shifted downward, so that the range in time of *Orthaulax* as then known straddles the greater part of the Oligocene and the lower Miocene of the present standard geologic time scale. The recent rediscovery of the genotype in an unsuspected stratigraphic position in Santo Domingo, as well as the attempt to identify another species from Santo Domingo, made necessary a critical study of all the available specimens of the genus. The facts assembled in this investigation appear to

me so interesting and important that it seems worth while to restate the old and to put the new on record.

THE GENUS.

Orthaulax is a marine stromboid gastropod resembling the common conch in many respects but curiously different from it in others. While still comparatively young the animal extends the outer lip of its shell to the tip of the spire, and continued growth envelops the entire spire in the domelike body whorl. The narrow space between the spire and the enveloping whorl soon fills with enamel. Some strombs exhibit a similar tendency to cover their spire with enamel and to carry the lip to the summit, but I know of none in which the process begins so young or proceeds so far as in *Orthaulax*. *Hippochrenes* also extends its lip to the spire, but this does not occur until the animal has attained maturity, so that its spire is not wholly involute as in *Orthaulax*. Figure 1, Plate II, representing a living species of *Strombus*, has been introduced for comparison. In all the known species of *Orthaulax* the outer lip lacks the prongs and knobs that characterize many species of *Strombus*, *Rostellaria*, and related genera. The Eocene genus *Calyptrophorus* bears a superficial resemblance to *Orthaulax*, but the covering of the spire of *Calyptrophorus* seems to be simply enamel spread over it after the animal attains maturity and is not an integral part of the shell.

The genus *Orthaulax* was defined in 1872 by Gabb, who used as genotype *Orthaulax inornatus*, from Santo Domingo. In 1887 Heilprin described a new species, *pugnax*, from the "silex bed" of Tampa for which he proposed the new genus *Wagneria*. Three years later Dall described a third species, *O. gabbi*, from the Chipola marl of Florida, and Maury has recently added a fourth species, *O. aguadillensis*, from

¹ Wagner Free Inst. Sci. Trans., vol. 3.

² Dall, W. H., A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Fla.: U. S. Nat. Mus. Bull. 90, p. 86, 1915.

Porto Rico. *Orthaulax caepa* from Cuba, here described as new, completes the list of known species of *Orthaulax*.

CRITERIA FOR DISCRIMINATION OF SPECIES.

In discriminating between species of *Orthaulax* several classes of criteria may be used:

The external form of the shell is of value but can not be relied on as infallible. Cross sections of *O. inornatus*, *O. aguadillensis*, and *O. caepa*, so far as we know, are always nearly circular, and *O. pugnax* and *O. gabbi* are usually subtriangular, but many immature specimens of *O. gabbi* are circular. *Orthaulax caepa* and *O. aguadillensis* each have two forms, a conical and a hemispherical, which possibly are secondary sexual characteristics. There may be a dome-shaped or hemispherical form of *O. inornatus* also, but it has not been discovered. The conical forms of *O. inornatus*, *O. caepa*, and *O. aguadillensis* may be discriminated from one another by the apical angle, which is most acute in *O. inornatus* and most obtuse in *O. aguadillensis*.

Of considerable value in discriminating between species is the cast of the interior. The casts show the altitude of the whorls and their rotundity or flatness, features which are concealed by the shell, and the outlines of the living chamber, which usually differ considerably from the external form.

Trustworthy identifications of some specimens can not be made without cutting. Axial sections through the apex disclose all the essential features of form and structure. The onion-like arrangement of the layers of shell and callus is laid bare, the outlines, both internal and external, of the whorls at all stages of growth can be traced, and the interrelations of shell substance, enamel, and cavities are plainly visible.

OCCURRENCE AND STRATIGRAPHIC POSITION OF SPECIES.

Orthaulax inornatus.—*Orthaulax inornatus* Gabb, the type of the genus, was first discovered in Santo Domingo. Specimens of this species were collected by Col. T. S. Heneken in 1848 or 1849, but they lay for many years undescribed in the collection of the Geological Society of London. The locality at which they were found is not known. One of Heneken's Dominican specimens was figured by Guppy in 1876,

and the figure is reproduced here (Pl. II, fig. 5). Gabb figured specimens of *Orthaulax inornatus* in 1872 from Santo Domingo, but as he was addicted to the labor-saving but highly reprehensible habit of stuffing his pockets with unlabeled specimens, the locality at which he found them is not recorded.

The stratigraphic position occupied by *Orthaulax inornatus* in Santo Domingo long remained unknown. Because of the presence of this species somewhere in Santo Domingo, presumably in the valley of Rio Yaque del Norte, Maury³ postulated an "*Orthaulax inornatus* formation" regarding which she says:

No one knows where Gabb found his *Orthaulax inornatus* because none of his Dominican fossils were labeled more precisely than "Miocene, Santo Domingo." We presume however, that it was collected from the basal blue clays in the eastern part of the Yaqui Valley, where the revolution prevented our securing sections and collections. For in the western part of the valley we have gone almost to the contact of the Tertiary with the older series, and although a special search was made for *Orthaulax* we did not find it. No doubt the *Orthaulax* zone represents an older horizon than [any] from which we collected.

Regarding the correlation of this hypothetical "*Orthaulax* formation" she says:⁴

The Dominican *Orthaulax* formation is older than those of Bordeaux and represents approximately the Rupelian Oligocene of Europe and the Tampa silex beds and White Beach limestone of Florida. It comes in just above the Vicksburg limestone.

The expedition to the Dominican Republic in 1919 headed by T. W. Vaughan was so fortunate as to procure a typical specimen of *Orthaulax inornatus* associated with so characteristic a fauna and in beds occupying so unmistakable a stratigraphic position as to dispel all doubt as to its age. The *Orthaulax* was collected on Rio Yaque del Norte at Baitoa from the lower part of the Baitoa formation (basal Miocene), which lies unconformably upon the tilted conglomerates and shales of the Tabera formation (middle Oligocene). The corals and mollusks with which the *Orthaulax* is associated have been studied by Vaughan and Woodring, who correlate them with the Burdigalian fauna of Europe and with the fauna of the Chipola marl member of the Alum Bluff formation of Florida.⁵

³ Maury, C. J., Bull. Am. Paleontology, vol. 5, pp. 456-457, 1917.

⁴ Idem, p. 458.

⁵ Vaughan, T. W., and Woodring, W. P., Tertiary and Quaternary stratigraphic paleontology: A geological reconnaissance of the Dominican Republic, p. 96, 1921.

In the United States *Orthaulax inornatus* has never been found in beds as young as the Chipola marl (lower Miocene), but it occurs in the "silex bed" of the next older formation, the Tampa, which is regarded as of upper Oligocene age. The species has also been listed by Dall⁶ from the Chattahoochee formation on Flint River, Ga., but the specimen so named in the collection of the United States National Museum (an impression of a fragment, U. S. Nat. Mus. catalogue No. 166787) appears to be *O. pugnax*.

The two large specimens of *Orthaulax* from Cuba which I figured as *O. inornatus*⁷ proved, on cutting, to be different, and they are here described under the name *Orthaulax caepa*.

Orthaulax gabbi.—The stratigraphic range of *Orthaulax gabbi* Dall appears to be very nearly the same as that of *O. inornatus*, but the two species have not yet been found in the same beds. *Orthaulax gabbi* has not hitherto been reported outside of Florida, where it is abundant in the Chipola marl member of the Alum Bluff formation, but it occurs also in the upper part of the Culebra formation and in the Emperador limestone at several places in the Canal Zone. Some of the Panaman specimens simulate very closely the external form of *Orthaulax pugnax*, and it is only in cross section that their true relationships become evident.

The known range of *Orthaulax gabbi* is upper Oligocene and lower Miocene.

Orthaulax pugnax.—The type of *Orthaulax pugnax* (Heilprin) comes from the "silex bed" of the Tampa formation. The species is common in the lower part of the Chattahoochee formation on Flint River, Ga., and it has been found also in beds of the same age in Alabama and Antigua. My identifications of specimens of *Orthaulax pugnax* from Anguilla⁸ and from Panama,⁹ which were based upon external form alone, are wrong; axial sections show the

first probably to be referable to *O. aguadillensis* and the second to *O. gabbi*.

The stratigraphic range of *O. pugnax* is therefore middle and upper Oligocene.

Orthaulax aguadillensis.—*Orthaulax aguadillensis* Maury is widely distributed in the West Indies but has not yet been reported from the continents. The type was taken by Reeds from the Aguadilla limestone at Aguadilla, P. R. It is probable that some of the specimens of *Orthaulax* collected by Hubbard¹⁰ elsewhere in Porto Rico belong to this species. Large casts of *Orthaulax* that appear to be referable to *O. aguadillensis* have been found on St. Croix (see Pl. III, fig. 4), and one poorly preserved specimen which seems to be *O. aguadillensis* comes from the upper Oligocene Anguilla limestone of Anguilla. In Santo Domingo this species has been collected at widely separated localities; it is fairly abundant but poorly preserved in the Cevicos limestone (upper Oligocene) near the east end of the Cibao Valley, and excellent specimens have been obtained from beds supposed to be of Miocene age at two localities in the valley of Rio Yaque del Sur.

The stratigraphic range of *Orthaulax aguadillensis* appears to be upper Oligocene and Miocene.

Orthaulax caepa.—*Orthaulax caepa* Cooke, n. sp., is known from only one locality, Consolacion del Sur, Pinar del Rio, Cuba. Specimens of this species, which I at first mistook for *Orthaulax inornatus*, proved, when cut, to be more closely related to *O. aguadillensis* but to be different from both. The age of the limestone at Consolacion del Sur is not known, but it is thought to be upper Oligocene.

Correlation table.—In order that the stratigraphic positions occupied by the species of *Orthaulax* may be more readily visualized, the accompanying correlation table has been prepared. The table is not complete but shows only those formations in which *Orthaulax* has been found and enough others to give a stratigraphic background.

⁶ U. S. Nat. Mus. Proc., vol. 51, p. 509, 1916. Plate 88, figure 9, represents a specimen from Ballast Point, Fla., U. S. Nat. Mus. catalogue No. 165099.

⁷ Cooke, C. W., Tertiary mollusks from the Leeward Islands and Cuba: Carnegie Inst. Washington Pub. 291, p. 116, pl. 2, figs. 1, 2, 1919.

⁸ Carnegie Inst. Washington Pub. 291, p. 115, pl. 2, fig. 3, 1919.

⁹ U. S. Nat. Mus. Bull. 103, p. 550, 1919.

¹⁰ Hubbard, Bela, Science, new ser., vol. 51, p. 396, 1920.

Known stratigraphic occurrence of *Orthaulax*.

Age.	Southeastern United States.	Dominican Republic.	Porto Rico and Jamaica.	Leeward Islands.	Cuba.	Panama.		
Miocene.	Upper.	Yorktown and Duplin formations.	Cerros de Sal formation.					
	Middle.	St. Marys formation. ^a Choptank formation. ^a Calvert formation. ^a	Mao clay. Mao Adentro limestone. Gurabo formation.	Bowden marl.	La Cruz marl.	Gatun formation.		
	Lower.	Shoal River marl member. Oak Grove marl member. Chipola marl member <i>O. gabbi</i> .	Cercado formation. Baitoa formation. <i>O. inornatus</i> .	Yaque group. <i>O. aguadillensis</i> (exact position not known).		Marl at Baracoa.		
Oligocene.	Upper.	Tampa formation. <i>O. pugnax</i> . <i>O. inornatus</i> .	Cevicos limestone. <i>O. aguadillensis</i> .		Aguadilla limestone. <i>O. aguadillensis</i> .	Anguilla formation and limestone in St. Croix. <i>O. aguadillensis</i> .	Limestone at Consolacion del Sur (position doubtful). <i>O. caepa</i> .	Emperador limestone. <i>O. gabbi</i> .
	Middle.	Chert beds on Flint River, Ga. <i>O. pugnax</i> .	Tabera formation.			Antigua formation. <i>O. pugnax</i> .		Culebra formation.
	Lower.	Vicksburg group.						

^a Faunal evidence is accumulating, according to T. W. Vaughan, that these formations classed by him in previous reports as Tortonian (upper Miocene), are of Helvetian (middle Miocene) age. This is return to the opinion stated by Dall in 1904.

SYSTEMATIC PALEONTOLOGY.

Family STROMBIDAE.

Genus ORTHAULAX Gabb.

- Orthaulax* Gabb, Acad. Nat. Sci. Philadelphia Proc., vol. 24, p. 272, 1872. Type *O. inornatus* Gabb, op. cit., pl. 9, figs. 3, 4. Miocene of Santo Domingo.
- Orthaulax* Gabb, Am. Philos. Soc. Trans., new ser., vol. 15, p. 234, 1873.
- Hippochrenes* (part) Zittel, *Traité de paléontologie*, vol. 2, p. 258, 1887.
- Wagneria* Heilprin, Wagner Free Inst. Sci. Trans., vol. 1, p. 105, 1887. Type *W. pugnax* Heilprin, op. cit., p. 106, pl. 15, figs. 36, 36a. Oligocene of Florida.
- Orthaulax* Dall, Wagner Free Inst. Sci. Trans., vol. 3, p. 169, 1890.
- Orthaulax* Dall, U. S. Nat. Mus. Bull. 90, p. 86, 1915.

The following description of *Orthaulax*, which is quoted from Gabb, 1873, differs from the original description of the preceding year only in a few unimportant verbal changes and alterations in punctuation which do not affect the meaning:

Shell rounded-fusiform, canal moderate, straight and regularly tapering; adult shell enveloped over the whole spire by the extension of the inner lip; posterior canal fissure-like, formed by the continued edge of the outer lip and running directly to the apex. Outer lip apparently sharp and simple; anterior notch oblique and broad.

The discovery of this genus fills an important break in the Rostellarias, uniting the true genus *Rostellaria* with Conrad's *Calyptrophorus*. Unlike both of these genera the canal is not styliform but robust and comparatively short, and its terminal notch is formed by an almost rectangular truncation of the anterior portion of the outer lip. Like *Rostellaria*, it has a straight posterior canal, prolonged, however, further than is common in that genus. The canal is similar in structure to that of *Calyptrophorus*, being formed by a squamose plate; but in the latter genus it curves over backwards, behind the spire, which it ascends to about half its height and then bends down to near the suture of the body whorl. Unlike the first and like the second of its congeners, it has the whole spire enveloped in a plate which should more properly be described as a posterior extension of the body whorl, carrying the suture to the extreme apex. The lines of growth run from the top of the spire to the anterior end of the shell. It carries none of the tubercles seen in *Calyptrophorus* and *Tessarolax* and seems, unlike most of the other genera of the family, to have had a simple outer lip, neither digitate nor notched.

The following excellent description of *Orthaulax* is taken from Dall's Tertiary fauna of Florida:¹¹

This group was described by Gabb from immature specimens, and no perfect specimen has hitherto been figured, for which reason a good deal of doubt has rested upon it.

At first, when I examined young specimens of a genuine *Orthaulax* I was struck by their resemblance to *Leiorhynchus* Gabb, and at once suspected that the latter was only a young specimen of the former. But on examining the type species of *Leiorhynchus* I found that this was not the case, since that shell bore evidences of maturity, has a thickened and lirate lip, is not self-enveloped by the last whorl, and has numerous varices. It is, in short, a form which permanently retains some of the external features of immature *Orthaulax* while adding to them others which are not found in *Orthaulax*.

The genus *Wagneria* of Heilprin is founded on characters which are simply part of the process of mineralization. The type of *Wagneria* is a siliceous pseudomorph; the very thick coating of the spire having been only partially replaced by silica, thus leaving a hollow, geodic dome analogous to nothing in the original shell.

A similar state of affairs is found in many of the fossils of that locality, which present a thickness too great to permit of solid silicification. All the corals, some of the *Turritellas*, etc., offer examples of this kind. For the rest, the relation of his shell to *Orthaulax* was not overlooked by Prof. Heilprin, though he was misled by the state of his material. The name *Wagneria* in any event was preoccupied, and if the genus had proved valid another name would have had to be substituted.

Orthaulax is almost intermediate between *Rostellaria* and *Strombus*. It differs from *Hippochrenes* Montfort, to which it was referred by Guppy and Zittel, in the following characters:

It has not the long, anteriorly produced pillar, nor the widely expanded outer lip; *Hippochrenes* has the last whorl, when adult, posteriorly extended to the tip of the spire, marking the conclusion of its growth; *Orthaulax* while very young has the whorls gradually ascending upon the normal juvenile spire by such an expansion, which, when developed, is continuous, enveloping the whole spire, coiling round and round it as the whorls grow, and completely concealing the whole of the spire, nothing but the outside of the last whorl being visible in an adult specimen.

The following additional remarks on the genus are added by Dall in the same volume, page 172, after his description of the species *O. gabbii*:

The essential difference between *Orthaulax* and *Hippochrenes*, *Calyptrophorus*, *Rimella*, etc., is that the involution of the spire, once commenced, is carried on by the posterior edge of the last or growing whorl continuously from the young condition in *Orthaulax*; while in the others the spire remains normal until the shell reaches its adult state and then, with the changes in the mantle, which incite the deposition of the thickened and enlarged outer lip, a process is developed at the posterior commissure of the aperture and mantle, which deposits enamel on the spire against which it lies, and it thus forms a gutter, sometimes straight, sometimes recurved, in which it is sheltered; apart from this the spire is enveloped, if at all, not by any expansion of the lip, but by a deposit of enamel which covers the whole, as frosting does a cake, without any relation to the coil of the shell considered as an organic product. Strip off the whole enveloping, continuous

¹¹ Wagner Free Inst. Sci. Trans., vol. 3, pp. 169-170, 1890.

enamel from *Calyptrophorus* and the whorls will remain intact; strip off the equivalent deposit in *Orthaulax* and the shell itself is destroyed. The latter, so far as its structure is concerned, is more nearly like an involute *Terebellum* (such as *T. sopitum* Brander, figured by Zittel) than like the enameled *Calyptrophorus* or winged *Hippochrenes*.

The latter wait until they have attained their majority and then spread their outer lips and lay down their enamel, once for all. In *Orthaulax* the involution, as in *Ovulum*, begins before maturity and continues with the growth of the shell without regard to its age or periodical resting stages. In this particular it is clearly distinguished from any other group included in the *Strombidae*, excepting the sufficiently distinct *Terebellum*.

All students appear to agree in referring *Orthaulax* to the family Strombidae. Guppy¹² emphasized its relation to *Rostellaria macrop-tera* (*Hippochrenes*) and Zittel¹³ refers it to *Hippochrenes*. Dall¹⁴ at first considered it a subgenus of *Rostellaria* but in later works¹⁵ returned it to generic rank. In the latter practice he is followed by the second English edition of Zittel's textbook of paleontology (1913) and by recent writers.¹⁶

Orthaulax inornatus Gabb.

Plate II, figures 2-6.

Orthaulax inornatus Gabb, Acad. Nat. Sci. Philadelphia Proc., vol. 24, p. 272, pl. 9, figs. 3, 4, 1872; Am. Philos. Soc. Trans., new ser., vol. 15, p. 234, 1873. Dall, U. S. Nat. Mus. Bull. 90, p. 86, pl. 11, fig. 4, 1915. Dall (part), U. S. Nat. Mus. Proc., vol. 51, p. 509, pl. 88, fig. 9, 1916. Maury, Bull. Am. Paleontology, vol. 5, p. 285, pl. 47, fig. 11, 1917.

Orthaulax inornata Guppy, Geol. Soc. London Quart. Jour., vol. 32, p. 520, pl. 28, fig. 8, 1876.

In 1873 Gabb described *Orthaulax inornatus* as follows:

Shell broadly rounded-fusiform. Young shell with the spire a little shorter than the aperture, suture impressed, whorls numerous, nuclear whorls three, the subsequent ones showing faint traces of occasional thickenings disposed like the varices of *Triton*; surface smooth; anterior end of body whorl marked by a few faint revolving lines, no posterior canal. Adult shell more distinctly fusiform, the spire covered by a longitudinally striated incrustation covering the sutures and extending to the extreme apex.

¹² Guppy, R. J. L., Geol. Soc. London Quart. Jour., vol. 32, p. 520, 1876.

¹³ Zittel, K. A. von, Handbuch der Palaeontologie, vol. 1, pt. 2, p. 260; Traité de paléontologie, vol. 2, p. 258, 1887; Textbook of paleontology (Eastman-Zittel), vol. 1, p. 472, 1900.

¹⁴ Wagner Free Inst. Sci. Trans., vol. 3, p. 169, 1890.

¹⁵ U. S. Nat. Mus. Bull. 90, p. 86, 1915; U. S. Nat. Mus. Proc., vol. 51, p. 509, 1916.

¹⁶ Cooke, C. W., Carnegie Inst. Washington Pub. 291, p. 116, 1919. Maury, C. J., Scientific survey of Porto Rico and the Virgin Islands, vol. 3, pt. 1, p. 58, 1920.

Aperture elongated, acute behind and prolonged into a very narrow posterior canal running straight to the apex; in advance it is gradually narrowed, the anterior notch broad and shallow; inner lip thinly incrustated; outer lip thin in all my specimens, and apparently thin, straight, and entire in the perfect adult. Size of largest specimen, length 3.75 inches, width 1.5 inches.

Orthaulax inornatus is the most slender of the known species of the genus. Its apical angle is about 60°, as compared with about 85° in *O. caepa* and about 95° in *O. aquadillensis*. Like those species, it has a circular outline in cross section. In axial sections its most obvious difference from them is in the thinness of the enamel, which in *O. inornatus* is scarcely perceptible but which in both *O. caepa* and *O. aquadillensis* attains a considerable thickness. In spite of the slenderness of the outside of the shell, the living chamber of *Orthaulax inornatus* is more rapidly tapering than that of either *O. caepa* or *O. aquadillensis*, but the whorls themselves are more compressed and flatter. These features, of course, can usually be made out only by cutting the shell or from casts of the interior.

Localities: Upper part of bluff of Rio Yaque del Norte at Baitoa, Province of Santiago, Dominican Republic, station 8668, Condit, collector, 1919; Ballast Point, Tampa Bay, Fla., Post, collector.

Geologic horizon: Baitoa formation, lower Miocene; Tampa formation, upper Oligocene.

Type: Philadelphia Academy of Natural Sciences, from Santo Domingo, Gabb.

Orthaulax pugnax (Heilprin) Dall.

Plate II, figures 7, 8; Plate III, figures 1a-4b.

Wagneria pugnax Heilprin, Wagner Free Inst. Sci. Trans., vol. 1, p. 106, pl. 15, figs. 36, 36a, 1887.

Orthaulax pugnax Dall, Wagner Free Inst. Sci. Trans., vol. 3, p. 170, pl. 8, figs. 5, 8, 1890; U. S. Nat. Mus. Bull. 90, p. 87, pl. 15, figs. 5, 10, 1915; U. S. Nat. Mus. Proc., vol. 51, p. 509, 1916.

Cooke (part), Carnegie Inst. Washington Pub. 291, p. 115, pl. 2, fig. 4, 1919.

Heilprin described *Orthaulax pugnax* as follows:

Shell irregularly oval, obconical, flattened, the flattened appearance being due to three irregular swellings or knobs, one of which immediately adjoins the anteriorly directed fissure of the aperture; aperture narrow, projected forward (in its upper course) as a closely compressed fissure, which in a crescental curve ascends to within a comparatively short distance of the apex of the spire; outer lip? (broken in specimen); inner lip largely developed, completely

concealing the whorls of the spire, and duplicating for a very considerable extent the outer lip; spire freely inclosed in a pointed superstructure, or dome, built over it by an extension of the mantle; surface covered with longitudinal lines of growth, which extend continuously from the apex to the base.

Length (of imperfect specimens, lacking probably upward of an inch), 2.7 inches; width, 1.75 inches.

What the precise relationship of the genus represented by this species may be I am not prepared to say.

Zittel (Handbuch der Palaeontologie, I, part ii, p. 260) unites *Orthaulax* with *Hippochrenes*, but in doing so this eminent paleontologist appears to have been misled by the rather imperfect diagnosis of the fossil given by Gabb. That its position is near to that genus I believe there can be no doubt.

As has been pointed out by Dall (see p. 27), Heilprin mistook a solution cavity in his specimen for a natural feature of the shell. Such a hollow dome would indeed be remarkable.

Orthaulax pugnax is so like *Orthaulax gabbi* that it seems surprising that the resemblances between them were not pointed out long ago. Young shells of both species are almost circular in outline, but older shells are strongly triangular. The outlines of the anterior part of the whorl as shown in figures of the type of *O. pugnax* can be matched perfectly by specimens of *O. gabbi*, but other specimens of *O. pugnax* appear to have proportionately longer and less top-shaped whorls than *O. gabbi*. The most conspicuous difference between the two species consists in the shape of the posterior end of the adult shell, which in *O. gabbi* is nearly always more or less rugose but in *O. pugnax* appears to be usually smooth. However, the range in variation in *O. gabbi* is so great that many specimens are as smooth as *O. pugnax*.

Because of the scarcity of authentic specimens of *O. pugnax* and the unfavorable state of their preservation, no axial sections of specimens from the type area have been cut, and it is not likely that attempts to cut the available material would yield satisfactory results. However, a small specimen from Antigua (Pl. II, figs. 3a, 3b), which seems to be *O. pugnax*, shows that the layers of callus are almost evenly lunate, as in *O. caepa*, but thicker than in *O. caepa* and not knobby, as in most specimens of *O. gabbi*. Another small specimen from the Canal Zone which I had previously identified as *O. pugnax*¹⁷ shows a tendency to knobiness in the callus and also possesses a

much more rapidly tapering living chamber like that in some specimens of *O. gabbi*. I have therefore referred it to *O. gabbi*.

Localities: Ballast Point, Tampa Bay, Fla., U. S. Nat. Mus. catalogue Nos. 112075, Burns, collector, 165100, E. J. Post, collector; Bailey's Mill Creek Sink, three-fourths mile northeast of Lloyds, Jefferson County, Fla., from clay overlying a limestone, L. C. Johnson, collector, U. S. Nat. Mus. catalogue No. 112521; Hales Landing, Flint River, Ga., 7 miles below Bainbridge, Vaughan, collector, 1900, station 3383, U. S. Nat. Mus. catalogue No. 166787 (labeled *O. inornatus*); Hales Landing, Flint River, Ga., Vaughan, Cooke, and Mansfield, collectors, 1914, station 7074, U. S. Nat. Mus. catalogue No. 166788; Blue Springs, Flint River, Ga., Pumpelly, collector, U. S. Nat. Mus. catalogue No. 115747; 1½ miles southwest of Geneva, Ala., Clapp, collector, station 8867; Antigua, Spencer, collector, U. S. Nat. Mus. catalogue No. 166984.

Orthaulax gabbi Dall.

Plate III, figures 5-7; Plate IV, figure 1.

Orthaulax gabbi Dall, Wagner Free Inst. Sci. Trans., vol. 3, p. 170, pl. 12, figs. 5, 5a, 5b, 1890; U. S. Nat. Mus. Bull. 90, p. 87, 1915.

Orthaulax inornatus Dall (part), U. S. Nat. Mus. Proc., p. 509, 1916.

Orthaulax gabbi has been well described by Dall as follows (1890):

Shell large, solid, many-whorled; in the very young smooth and polished, except for incremental lines and a few faintly impressed spiral lines anteriorly; nucleus small, polished, glassy, not differentiated from the rest of the shell; early whorls with a very distinct, not channeled suture; the whorl in front of it slightly turreted; each whorl after the third has three slightly elevated, narrow, rounded varices, somewhat irregularly spaced, so that they do not follow each other continuously down the slope of the spire; about the end of the eighth whorl the posterior edge of the outside whorl begins to be prolonged backward more and more as the shell grows, so that the suture thus formed makes an irregular spiral line ascending the spire over the antecedent whorls until by about the tenth turn the whole of the spire is enveloped, as well as any barnacles, vermetus, or other semiparasitic growth which may have become attached to the surface of the spire; the anterior part of the shell has the shape of *Leiorhynchus*; the pillar is rather thick and slightly recurved, with a moderately distinct fasciole; the canal moderately wide, shorter than the pillar; the outer lip simple, sharp, a little thickened at the resting stages, but not lirated internally; body with a moderate callus, which at the resting stages is considerably enlarged, so that when the whorl comes to grow over it (as it is not absorbed) it produces an irregularity

¹⁷ U. S. Nat. Mus. Bull. 103, pp. 550, 553, 1919.

somewhat like a varix; the whorls are ovately rounded, smooth, except for occasional transverse undulations due to irregularities of growth, and polished; no indications of color pattern have been observed.

The adolescent form a good deal resembles a *Strombus* except that the anterior sulcus of the outer lip behind the canal is absent or represented only by the faintest wave in the margin; the spire is entirely enveloped by the backward prolongation of the last whorl, except at the tip, where the envelope is usually a little eroded or defective; there appears to be a resting stage at every two-thirds of a revolution of the whorl around the axis, for which reason, looking down on the spire, the outline of the shell transverse to the axis is subtriangular or three-sided; the outer lip is simple, rather sharp-edged, and very slightly, if at all, recurved; it extends backward to the tip of the spire, near which it recedes somewhat from its parallelism with the axis; at the shoulder, also, it is slightly excavated and thickened; the body is smooth, with a moderate callus, which becomes thicker near the shoulder; at the shoulder, in front of the excavation above noted, it becomes very thick and is continued on to the spire parallel with the outer lip, and very near it, so that between the two is a narrow, flexuous groove of considerable depth; when the shell begins to grow again the whorl is carried over this ridge, which is not absorbed, and the surface is thus rendered, as it were, varicose; the canal is short, strongly recurved, with a remarkably deep siphonal sulcus, so that the end of the pillar stands forward in a marked way; on the shoulder, halfway around the shell, is an ill-defined narrow ridge, which ceases a little way behind the lip. The dimensions of the figured specimen are: Longitude, 68 millimeters; maximum latitude, 35 millimeters.

The adult form differs from the adolescent by the disproportionate strength of the ridge at the shoulder, by which the surface behind the ridge has become flattish, as in a *Cassis*, but more irregular, and the width at the shoulder has increased in proportion to the total length. No entirely complete specimen of the adult has been found, but from numerous fragments the proportions can be approximately determined. The maximum diameter is 74 millimeters, and the length about 11 millimeters, of which 15 millimeters are behind the shoulder, while, in the specimen only 68 millimeters long, there are 17 millimeters of length behind the shoulder.

This species appears abundantly, though in a poor state of preservation, in the lower bed at Alum Bluff and in the Chipola beds to the westward. The group in America would seem to be characteristic of the lower beds of the southern Miocene, as far as our present knowledge permits us to judge.

I have observed that, occasionally, the ridge on the shoulder in young specimens is represented by a nodule rather than a ridge.

The resemblance of *O. gabbi* to *O. pugnax* is noticed under the description of *Orthaulax pugnax*.

Localities: Tenmile Creek, 1 mile west of Bailey's Ferry, Chipola River, Fla., Burns, collector, station 2212; 1 mile below Bailey's

Ferry, banks of river above white limestone bed, Burns, collector, 1889, station 2213; right bank of Chipola River on McClelland farm, 1 mile below bridge at old Bailey Ferry, Calhoun County, Fla., Dall, collector, 1893, station 2564; same locality, Vaughan, collector, 1900, station 3419; lower bed at Alum Bluff, Apalachicola River, Fla., Burns, collector, 1889, station 2211; same locality, Cooke and Mansfield, collectors, 1914, station 7183; Panama Railroad, 2 miles south of Monte Lirio, formerly known as Mitchellville, Canal Zone, MacDonald, collector, 1911, station 5901; upper part of Culebra beds on west side of Paraiso, MacDonald, collector, 1913, station 6515; topmost limestone in Gaillard Cut opposite Las Cascadas, Canal Zone, MacDonald and Vaughan, collectors, 1911, station 6019-g (two casts of the interior, identification very doubtful).

Type: U. S. Nat. Mus. 112218.

Orthaulax aguadillensis Maury.

Plate IV, figures 2-6; Plate V, figures 1a, 1b.

Orthaulax aguadillensis Maury, Scientific survey of Porto Rico and the Virgin Islands, vol. 3, pt. 1, p. 58, pl. 9, fig. 4, New York Acad. Sci., 1920.

Orthaulax pugnax Cooke, C. W. (part), Carnegie Inst. Washington Pub. 291, p. 115, pl. 2, fig. 3, 1919.

Maury's description is as follows:

Shell large and heavy; form of spire short and blunt, like that of *Orthaulax pugnax*. This at once distinguishes the shell from the Dominican species *O. inornatus* Gabb, which is high-spined. A further characteristic of the shell is the evenly rounded form of the shoulder, which in cross section would be almost perfectly circular. This marks it off very decisively from the Floridian Chipolan species *Orthaulax gabbi* Dall, which is markedly triangular at the shoulder. The spire measures 45 millimeters in diameter.

A single specimen of this *Orthaulax* was collected by Reeds at Aguadilla. It is imperfect but undoubtedly a typical member of this very important index genus.

The shell was submitted to Dall, who compared it with the types of the various known species in the National Museum. He replied that "The *Orthaulax* is nearest to *O. pugnax*, but as the margin of the spire is gone it is impossible to be certain. I think it is new."

One might be criticized for describing so incomplete a specimen as new were this a less rare and less stratigraphically important genus. Moreover, no complete adult shell of either *O. inornatus* or *O. pugnax* has ever been found. Though heavy and apparently strong, the shells seem to go to pieces very easily, and usually one finds only heads, as in this case, or fragments of the heavy pillars.

No other molluscan shells were found associated with this *Orthaulax*, but an echinoderm occurred.

It is a little surprising that the nearest ally of this Porto Rican *Orthaulax* should be not Gabb's *O. inornatus*, from the adjacent island of Santo Domingo and in the Tampa and White Beach beds, Florida, but *O. pugnax*. The latter ranges geographically from the Tampa, Fla., beds and those of Bainbridge, on the Flint River, Ga., to Cuba, Antigua, and the Canal Zone, and geologically from the middle Oligocene of Antigua to the upper Oligocene of the Tampa and Flint River formations.

Orthaulax aguadillensis resembles *O. caepa* in size and appearance but differs from it in several respects: *O. aguadillensis* is blunter, the apical angle being a little greater than 90°, whereas that of *O. caepa* is a little less than 90°; some specimens of *O. aguadillensis* show faint grooves on the anterior part of the shell but no raised threads such as are found on *O. caepa*; most of the callus on *O. aguadillensis* is deposited just in front of the shoulder and is proportionately somewhat thicker than in *O. caepa*, on which the callus is more evenly distributed and is lunate in cross section.

Localities: Aguadilla, P. R., station 3, Reeds, collector; road from Cotui to Cevicos on east side of Arroyo Blanco east of Loma de los Palos, Dominican Republic, station 8598, Cooke and Ross, collectors, 1919; left bank of Rio Yaque del Sur at upper edge of Los Guiros, Province of Azua, Dominican Republic, station 8572, Condit, collector, 1919; west bank of Rio Yaque del Sur opposite Palo Copado, Province of Azua, Dominican Republic, station 8590, Condit, collector, 1919; Crocus Bay, Anguilla, station 6965, Vaughan, collector (identification doubtful).

Geologic horizon: Aguadilla limestone, Cevicos limestone, and Anguilla formation (?), upper Oligocene; Yaque group (?), Miocene.

Type: American Museum of Natural History.

***Orthaulax caepa* Cooke, n. sp.**

Plate V, figures 2a-3b.

Orthaulax inornatus Cooke, Carnegie Inst. Washington
Pub. 291, p. 116, pl. 2, figs. 1, 2, 1919.

Shell large, heavy, circular in cross section; first six whorls, more or less, bare in juvenile shell but completely enveloped by subsequent whorls; callus-filled spaces between whorls evenly lunate in axial sections through the apex; apex conical, with apical angle of about 85°, or hemispherical; whorl in front of the shoulder ornamented with fine raised revolving threads.

Orthaulax caepa is intermediate in shape between *O. inornatus* and *O. aguadillensis*. Its apex is blunter than that of *O. inornatus* but more acute than that of *O. aguadillensis*. It differs from both in the ornamentation of spiral threads in front of the shoulder. The cast of the interior appears to be more slender than that of either *O. inornatus* or *O. aguadillensis*, and the whorls of the cast to be more rounded than those of *O. inornatus* but very similar to those of *O. aguadillensis*. The callus in *O. caepa* is evenly lunate, but that of *O. aguadillensis* is asymmetric, the greatest thickness being in front of the shoulder, and is much thicker in proportion to its length than that of *O. caepa*; the callus is thin and inconspicuous in *O. inornatus*.

There are two forms of *O. caepa*, a pointed or conical form and a domed or hemispherical form. It is possible that these different shapes may be secondary sexual characteristics.

Locality: Consolacion del Sur, Pinar del Rio, Cuba, station 3474.

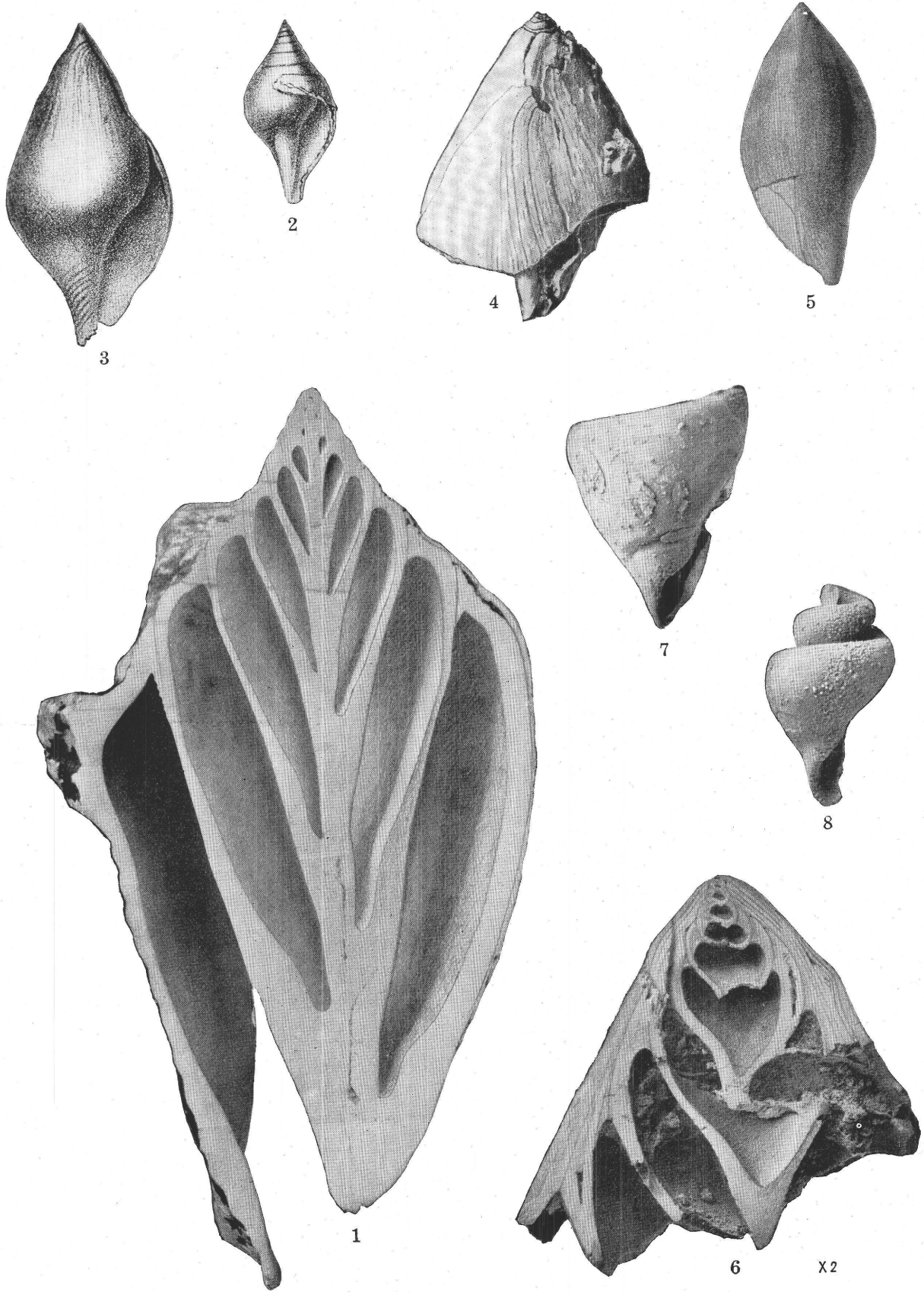
Geologic horizon: Oligocene (?).

Type: U. S. Nat. Mus. catalogue No. 166980.

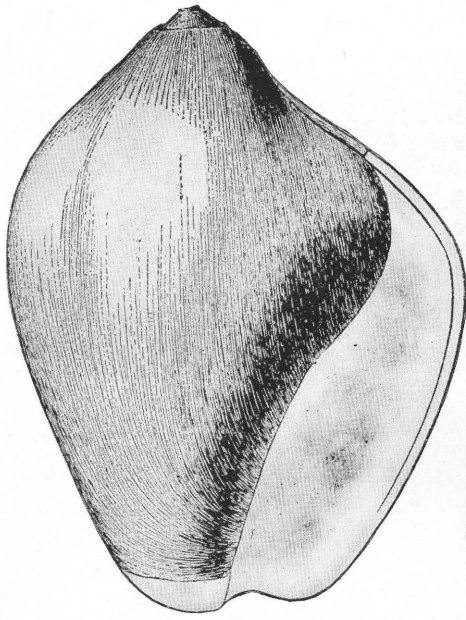
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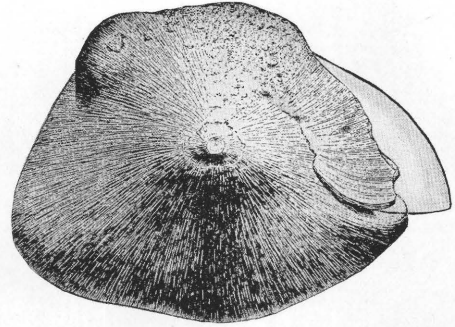
STROMBUS AND ORTHAULAX.



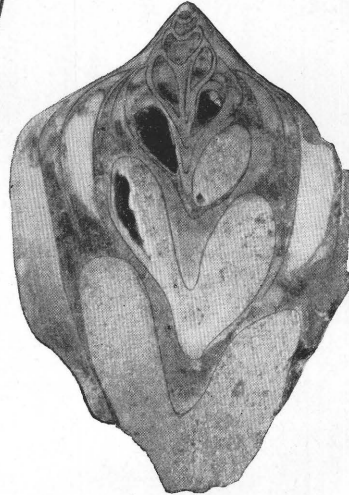
1a



3a

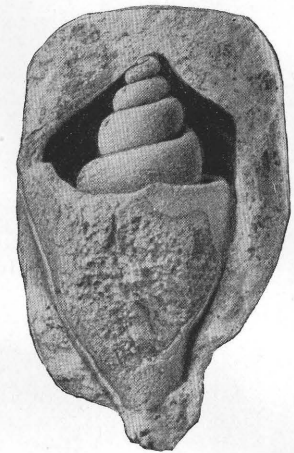


1b

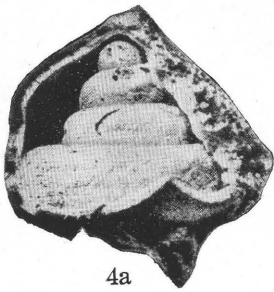


3b

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2



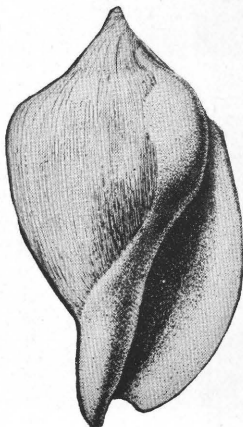
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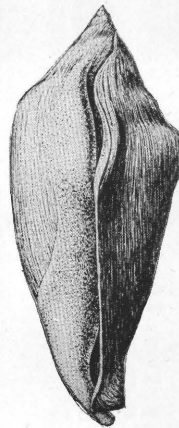
4b



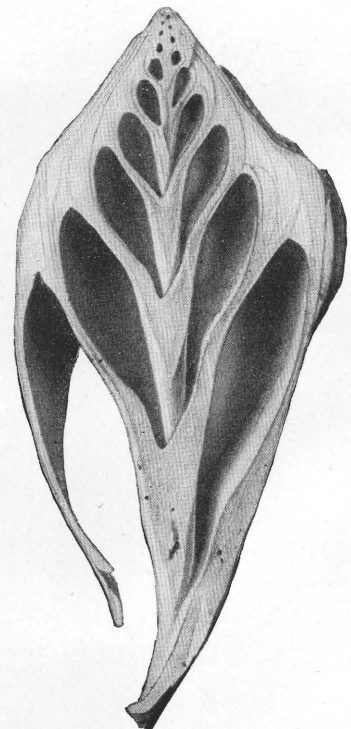
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6a



6b



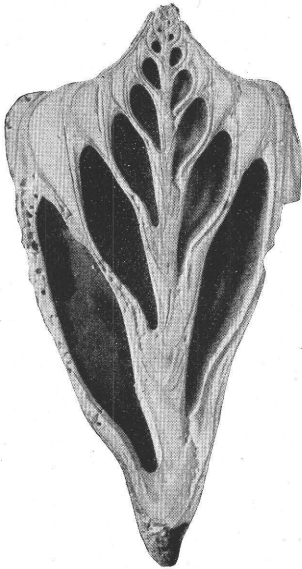
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PLATE III.

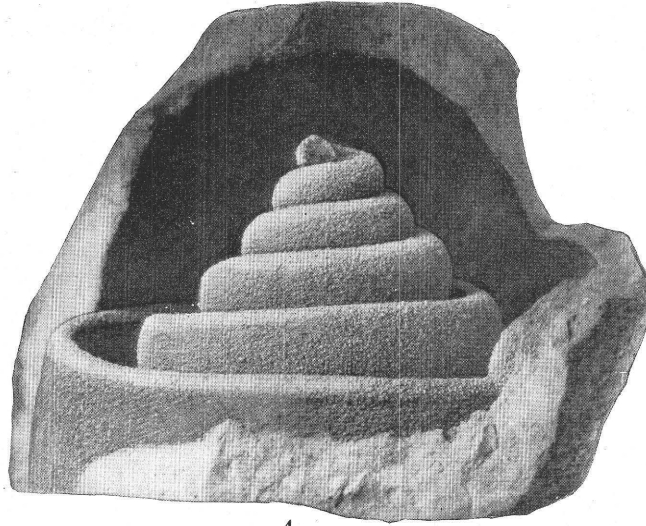
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7. <i>Orthaulax gabbi</i> Dall. Bailey's Ferry, Fla., station 3419.	

PLATE IV.

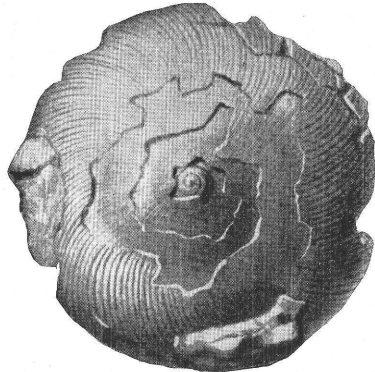
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6. <i>Orthaulax aguadillensis</i> Maury. Palo Copado, Dominican Republic. U. S. Nat. Mus. catalogue No. 328260.	



1



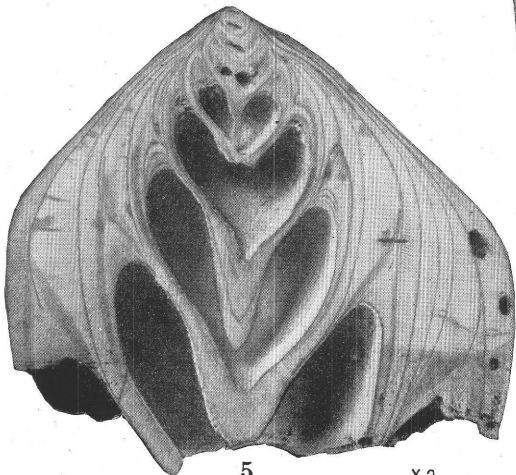
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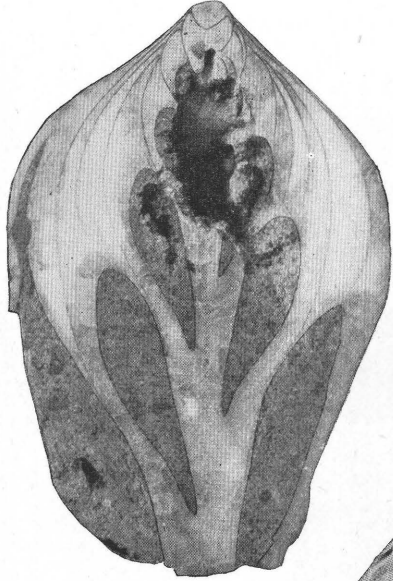
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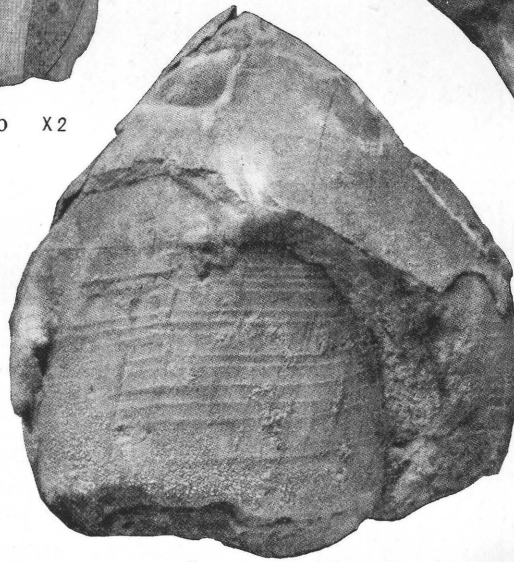
ORTHAULAX.



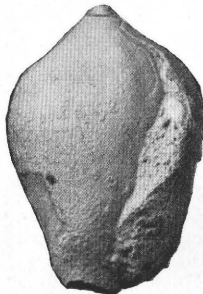
1b x2



3a



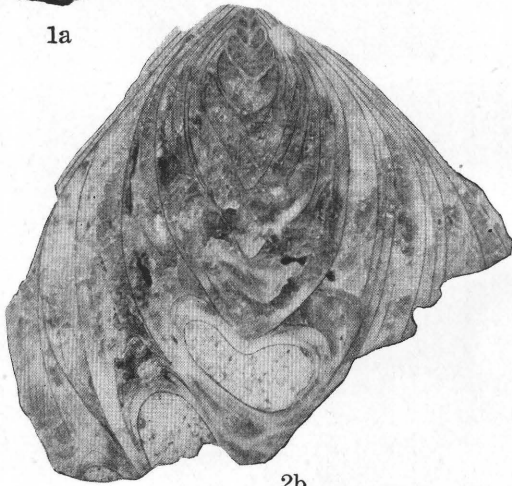
2a



1a



3b



2b

ORTHAULAX.

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