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FOSSIL CORALS OF THE GENUS TURBINOLIA FROM THE EOCENE OF CALIFORNIA

BY

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SAN DIEGO, CALIFORNIA

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INTRODUCTION

The first record of the genus *Turbinolia* in California was by Dickerson[1] who used it as the indicator of his "Turbinolia Zone." He made no attempt to classify the species systematically, but recorded "*Turbinolia* n. sp. (a) (long)"[2] and "*Turbinolia* n. sp. (b) (short)."[3] Dickerson's specimens have not been preserved and consequently his identifications cannot be checked.

Nomland[4] was the first who systematically named species of this genus from California, when he described *Turbinolia dickersoni* and *T. pusillanima.* He made no reference to Dickerson's "long" and "short" species. Nomland's types are, at present, missing from the University of California Museum of Paleontology and therefore were unavailable for the present study. From the literature, however, the two species appear to be valid.

Marcus A. Hanna[5] described *Turbinolia jollaensis* and *Balanophyllia imbulata.* The latter is a valid species of the genus *Turbinolia,* but the former is a synonym of *T. pusillanima* Nomland.

All the specimens available in the various museums and universities of the State have been studied for the preparation of the present paper and collections have been made from the type localities. This material has furnished additional information regarding the previously described species and has brought to light one species that is described as new.

For the loan of material I am indebted to Dr. B. L. Clark of the

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[1] DICKERSON, R. E., Note on Faunal Zones of Tejon Group, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 8, pp. 17-25, 1914.

[2] *Op. cit.* p. 20.

[3] *Op. cit.* pp. 20, 22.

[4] NOMLAND, J. O., Corals from the Cretaceous and Tertiary of California and Oregon, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 9, pp. 59-76, 1916.

[5] HANNA, M. A., An Eocene Invertebrate Fauna from the La Jolla Quadrangle, California, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, pp. 268, 269, pl. 24, figs. 1, 2, 3, 1927.

University of California; to Dr. J. E. Hoffmeister of the National Museum; to Dr. T. W. Vaughan of Scripps Institution of Oceanography; to Dr. H. G. Schenck of Stanford University; to Mr. C. H. Sternberg of San Diego and to Mr. Arthur Wrigley of London.

Acknowledgments are due especially to the late Professor J. P. Smith and to Professors W. K. Fisher, H. G. Schenck and G. F. Ferris of Stanford University for their personal interest and assistance.

For criticism of the manuscript and assistance in the geological correlations I am very greatly indebted to Dr. U. S. Grant, Dr. H. G. Schenck, Dr. B. L. Clark, Prof. A. Morley Davies, Royal School of Mines, London, and to Mr. Arthur Wrigley of London.

Dr. T. Wayland Vaughan has helped me in the systematic study, has furnished me with laboratory facilities, and has carefully corrected this manuscript. To him I wish to extend my sincerest thanks.

Phylum **COELENTERATA**

Class ANTHOZOA

Subclass HEXACORALLA Haeckel

Order **MADREPORARIA** Verrill

Suborder IMPERFORATA

Family TURBINOLIDAE Milne Edwards & Haime, in part

Genus **Turbinolia** Lamarack, in part

Turbinolia (in part) Lamarck, Hist. Nat. Anim. sans Vert., Vol. 2, p. 229, 1816; Milne Edwards & Deshayes Ed., 2nd ed., Vol. 2, p. 359, 1835.

Turbinolia Milne Edwards & Haime, Ann. Sci. Nat., 3ième sér. Zool., Vol. 9, p. 235, 1848; Brit. Foss. Corals, Introd. p. xvi, 1850; Hist. Nat. Corall., Vol. 2, p. 60, 1857. De Fromentel, Introduct., p. 91, 1861. Duncan, Journ. Linn. Soc. London Zool., Vol. 18, p. 18, 1885.

Diagnosis: Corallum simple, free, straight, and conical, with a circular calice. Wall a true theca. Costae always present and prominent, independent of each other, the principals opposite the septa. Intercostal furrows ornamented by a double or single row of pits, frequently with pores which perforate the wall, or in some species by transverse flutings near the base of the costae. Septa usually exsert in two, three or four

complete cycles, rarely incomplete in last cycle. Their margins usually entire, often folded or undulating along the inner margin. Their lateral faces more or less adorned with granulations. The primaries usually strongly fused to the columella. The secondaries weakly fused to the columella deep in the calice or free. Tertiaries often bending towards and fused to the included primaries or free. Quaternaries rudimentary and nearly always free. Columella essential, rising from the basal disc, styliform, stellate, compressed or granular.

Genotype (by subsequent designation, Milne Edwards & Haime, Brit. Foss. Corals, Introd. p. xvi, 1850) *Turbinolia sulcata* Lamarck, Eocene, Paris Basin. (See Plate 6, figs. 13, 14.)

Geological range: Eocene, Oligocene, and Recent(?).

Geographical distribution: Eocene, Europe and North America; Oligocene, North Germany and North America; Recent(?), Caribbean Sea.

Bathymetric range: 100 to 220 fathoms.

Remarks: With the new species, here described, there are nine species of *Turbinolia* recorded from North America as fossils and one as "perhaps fossil(?)."[6] There is nothing known of the habitat or life history of the genus, but Pourtalès' specimen would, if Recent, indicate warm water, a clear strong current and other conditions similar to those of the Gulf Stream along the north bank of Cuba at a depth of from 100 to 220 fathoms.

There is no indication of a basal attachment. The entire corallum appears to have been an internal skeleton, i. e. completely surrounded by the polyp. The individuals very likely lived like sea anemones partially embedded in sediment. The dead skeletons would accumulate by mechanical transportation with the small shells so often found associated with the fossils.

Only one of the American fossil species, *T. insignifica* Vaughan[7] from the Lower Oligocene Red Bluff beds of Mississippi, occurs in other than Eocene strata. The California species are confined to the Meganos and Domengine (including the Rose Canyon Shales of Hanna's La Jolla formation) and are valuable fossils for the correlation of these formations.

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[6] POURTALES, L. F. de, Bull. Mus. Comp. Zool., Vol. 5, no. 9, p. 203, pl. 1, figs. 12, 13, 1880.

[7] VAUGHAN, T. W., U. S. Geol. Surv. Mon. 39, pp. 16 and 92, 1900.

KEY TO THE NORTH AMERICAN SPECIES

1. Columella stellate, fig. 1 2

   Columella not stellate, figs. 7, 8, 9 5

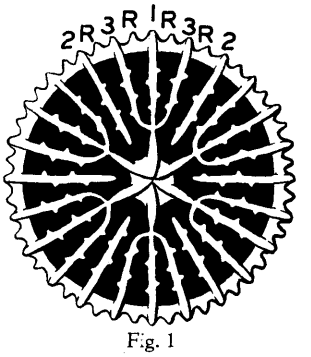

Fig. 1

2. (from 1) Rudimentary costae present opposite the interseptal loculi, fig. 1 (R, R.) 3

   Costae present only opposite the septa, fig. 2 4

Fig. 2

3. (from 2) Columella projecting well above the corallum wall, fig. 3 ..... *T. wautubbeensis* Vaughan

   Columella not projecting noticeably above the corallum wall, fig. 4 ..... *T. dickersoni* Nomland—p. 98

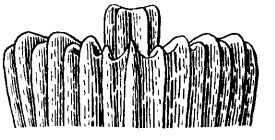
Fig. 3

4. (from 2) Twelve principal septa greatly swollen near the base, fig. 5 ..... *T. pharetra* Lea—p. 109

   Twelve principal septa not greatly swollen near the base, fig. 6 ..... *T. clarki* n. sp.—p. 100


Fig. 4

5. (from 1) Columella ending in a prominent style, fig. 7 6

   Columella more or less a granular irregular mass, not ending in a very prominent style, fig. 9 7

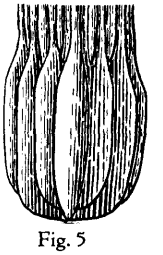
Fig. 5

KEY TO THE NORTH AMERICAN SPECIES—(Continued)

6. (from 5) Columella a hexagonal style, fig. 8; costal margins crenate, fig. 10 ..... *T. acuticostata* Vaughan

   Columella a round style, fig. 7; costal margins smooth and entire, fig. 11 ..... *T. insignifica* Vaughan

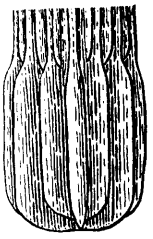

Fig. 6

7. (from 5) Twelve septa in two cycles ..... *T. corbicula* Pourtalès

   Twenty-four septa in three cycles, fig. 1 8

Fig. 7

Fig. 8

Fig. 9

8. (from 7) Costae much narrower than the intercostal spaces ..... *T. claibornensis* Vaughan

   Costae as wide as the intercostal spaces 9

9. (from 8) Septa thinner than the interseptal loculi, granules on septal faces sparse ..... *T. pusillanima* Nomland—p. 101

   Septa as wide as, or wider than, the interseptal loculi, granules numerous in close compact rows ..... *T. imbulata* (Hanna)—p. 103

Fig. 10

Fig. 11

Turbinolia dickersoni Nomland

Plate 6, figs. 1, 2, 3, 4, 5

Fifteen topotypes, three of which are complete specimens, furnish additional information regarding this species:

Turbinolia dickersoni Nomland, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 9, p. 61, pl. 3, figs. 5, 6, 7, 8, 1916. Dickerson, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 9, pp. 372, 378, 385, 426, 430, 1916. Clark, Journ. Geol., Vol. 29, p. 158, 1921. Palmer, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, p. 306, pl. 56, figs. 2, 4, 1923. Clark, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, p. 114, 1926.

Corallum conical, form varying from slender with a ratio[8] of .413:1, to stout with a ratio of .589:1. In fully mature specimens there are forty-eight costae, the twenty-four principals are very prominent and oppose the twenty-four septa. They extend from the margin of the calice to within one and one-half millimeters of the base, three-fourths to four-fifths the length of the corallum, where the twelve tertiaries end. The secondaries and primaries are equal along the basal quarter of the corallum, the secondaries not quite reaching the tip which is formed by the primaries. Where well preserved they are not flattened at their outer margin, and they are considerably wider at the thecal wall than near the margin. In cross-section they are roundly pointed. At the base of the corallum the primaries and secondaries are but slightly thickened. Their upper margin is entire and smooth. The rudimentary costae, twenty-four in number, begin, as the "low ridges" described by Nomland, at about four-fifths of the height of the corallum from the base, but attain the proportions of rudimentary costae near the calicular margin. The intercostal furrows are almost twice as wide as the costae and contain prominent double rows of pores which, in sectioned specimens, are, in many instances, seen to pass through the thecal wall. The wall is a true theca. There are twenty-four septa. The primaries and secondaries are equal, broadly arched at their upper margins which are entire and smooth. They are exsert above the calicular margin of the wall from five to seven tenths of a millimeter. The primaries are united to the rays of the columellar star at about the level of the calicular wall. The secondaries join it deeper in the calice. Their inner margins are transversely fluted. These flutings appear on the lateral faces as swellings which extend horizontally about one-fourth the distance from the inner margin toward the wall. In many instances, but not always, they coincide with the diagonal rows of granules. The tertiaries are a little less exsert than the members of the two higher cycles. Along their inner margins they bend toward, and are fused with, the included primary septa at about two-thirds the distance from the wall to the columella. The lateral faces of all the septa are ornamented with small granules. Those on the first two cycles of septa appear, in a longitudinal section, in diagonal rows sloping from the wall at an angle of from 15° to 30° in Nomland's figure 8. The angle is less acute in the topotypes sectioned. The

[8] The diameter of the calice to the height.

granules are numerous and crowded along the rows which do not meet the marginal folds of the septa with exact regularity. In cross sections of the septa they appear on the primaries as small spinules, three or four in number, arranged alternately. The columella is stellate, solid, and prominent. It occupies almost one-third of the calice. Its surface does not extend to the upper margin of the primary and secondary septa, but stands a little above the level of the calicular wall.

DIMENSIONS

	Holotype (Nomland)	*Plesiotype SDSNH 378*	*Plesiotype SDSNH 379*	*Plesiotype SDSNH 380*
Diam. of calice	2.8 mm.	3.3 mm.	3.1 mm.	2.6 mm.
Ht. of corallum	6.7 mm.	5.6 mm.	7.5 mm.	5.0 mm.
Ratio, diam. to ht.	.418:1	.589:1	.413:1	.520:1

Holotype: Said to be in the Univ. Calif. Museum of Paleontology.

Plesiotypes: Nos. 378, 379, 380, 381 San Diego Society of Natural History.

Topotypes: Nos. 32266, 32267 Univ. Calif. Museum of Paleontology. Nos. 371681, 371682 U. S. National Museum. Nos. 816, 817 Stanford Univ. Museum of Paleontology.

Type locality: U. C. locality 1817: "On branch of Salt Creek, near center of Sec. 15, T. 18 S, R. 14 E, M. D. B. & M., Fresno County, California, about 16 miles north of Coalinga." (University of California Locality Book.)

N. B. Nomland, *op. cit.*, erroneously gave Range "13" in citing the type locality.

Geological horizon: Meganos formation, Eocene.

Remarks: These topotypes correspond closely to Nomland's original description and figures. This species belongs, with *T. pharetra* Lea, *T. clarki* n. sp., and *T. wautubbeensis* Vaughan, to the group of *Turbinolia* possessing a prominent stellate columella. The presence of a fourth cycle of costae relates it closely to *T. wautubbeensis* Vaughan and separates it distinctly from *T. pharetra* Lea and *T. clarki* n. sp. It differs from *T. wautubbeensis* Vaughan by the less prominent columella which in the latter rises well above the upper margins of the principal septa.

The two specimens determined by Palmer[9] appear to be young and have not yet developed the fourth cycle of costae.

Moulds of this species were found in brown sandstone from the Meganos of Simi Valley, Ventura County, California, at. L. S. J. U. locality 2092. These are very slender with a ratio of .338:1.

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9 PALMER, *op. cit.*

Turbinolia clarki sp. nov.

Plate 6, figs. 6, 7, 8

Corallum elongate, conical, slender, the ratio of the diameter of the calice to the height in the syntypes being .400:1 (U.C. No. 32380) and .418:1 (U.C. No. 32381), simple and free. The wall is a true theca. Costae twenty-four in number, prominent, sharply rounded in profile, margins smooth and entire, equal in size at the calicular margin. Near the base the twelve costae corresponding to the primary and secondary septa are somewhat thicker and higher, the intermediate ones, the tertiaries, becoming very insignificant and eventually disappearing. Only the six primaries are prolonged to the basal tip, but the secondaries approach it closely. The intercostal furrows are about twice as wide as the costae and are ornamented by a double row of pits which in many instances are pores that pass through the corallum wall. The septa are moderately exsert, with entire margins, twenty-four in number, in three complete cycles. Their surfaces are moderately granulate on the half near the wall. Their inner margins are broadly undulating and the folds of the undulations extend half way to the wall where, usually, but not always, they coincide with the diagonal rows of granules. The granules, usually four or five in number, are arranged in parallel rows which descend from the wall at an angle of from 25° to 35°. The inner margins of the first cycle of septa are fused to the rays of the columellar star. The fused portion is broader than the intervening spaces and these points of fusion correspond in number to the folds along the inner margins. Occasionally in the lower portions of the corallum this fusion becomes solid. The inner margins of the second cycle of septa are more deeply fluted than are those of the first. Where the outer edges of the marginal fluting touches the sides of the columellar rays they are fused together. The inner margins of the third cycle of septa are invariably fused to the included member of the first cycle. The columella is essential, strong and stellate. The surface is very slightly below the upper margins of the septa.

DIMENSIONS

	Syntype U.C.Mus.Paleo. 32380	*Syntype U.C.Mus.Paleo. 32381*	*Average of nine Paratypes*
Diam. of calice	2.35 mm.	2.3 mm.	2.19 mm.
Ht. of corallum	5.87 mm.	5.5 mm.	4.81 mm.
Ratio, diam. to ht.	.400:1	.418:1	.455:1

Syntypes: Nos. 32380, 32381 Univ. Calif. Museum of Paleontology.

Paratypes: Nos. 356, 357 San Diego Society of Natural History. Nos. 32261 to 32265 Univ. Calif. Museum of Paleontology. Nos. 371672, 371673 U. S. National Museum.

Type locality: U. C. locality 672: "SE¼ of NW¼ sec. 24, T. 18 S, R. 14 E, M. D. B. & M., Parsons Peak, 0-10 ft. below white shale. Domengine Ranch and Creek, Coalinga Quad., Fresno County, California." (University of California Locality Book).

N. B. This locality description should be modified to prevent misinterpreta-

tion regarding the very prominent white Oligocene (?) shales above the salmon colored and brown shales which weather out white and which rest directly above the Domengine sands in which the specimens of *Turbinolia* occur.

Geological horizon: Domengine formation, Eocene.

Remarks: Comparison of a series of eleven perfectly preserved specimens of this species with twenty-four typical specimens of *T. pharetra* Lea from Claiborne, Alabama, shows that their resemblances are extremely close. However, the columella is less exsert, and the twelve principal costae are consistently less swollen at the base, the angle formed by the rows of granules on the septal faces with the wall is more acute, 25° to 40°, the swellings on the inner margins of the septa are not as horizontal but slope a little upwards, and the transverse fluting, which causes these swellings, is more broadly undulating than in *T. pharetra* Lea. From *T. dickersoni* Nomland, the only other California *Turbinolia* with a stellate columella, it is readily distinguished by the total lack of rudimentary costae—the thin ridge between the rows of pores in the intercostal furrows is not a costal ridge—by the less acute angle formed by the rows of granules on the septal faces with the wall, by the fewer number of these granules, and the more prominent fluting of the inner margins of the septa, and the more prominently swollen costae near the base.

It is very probable that this species has been called *T. dickersoni* because of their general resemblance. The two species seem to be confined to different horizons as indicated in the accompanying correlation table.

Named in honor of Dr. B. L. Clark of the University of California.

Turbinolia pusillanima Nomland

Plate 6, figs. 9, 10

Turbinolia pusillanima Nomland, Univ. Calif. Publ. Dept. Geol. Sci., Vol. 9, p. 62, pl. 3, figs. 9, 10, 1916.

Turbinolia jollaensis Hanna, Univ. Calif. Publ. Dept. Geol. Sci., Vol. 16, p. 269, pl. 24, fig. 1, 1927.

Ten topotypes of this species furnish additional information which, for the sake of unity, is given in a redescription:

Corallum conical, slightly stout, the ratio of the diameter of the calice to the height being .500:1. Calice subcircular. Wall a true theca. The principal costae are twenty-four in number opposite the septa, with an equal number of rudimentary costae present in the upper third of the corallum opposite the interseptal loculi. Twelve of the principals end one-third of the height from the base. The primary and secondary cycles reach nearly to the base but only the six primaries form the basal tip. They are acute, almost sharp, their margins entire and smooth

except for irregular incisions which appear to be due to weathering. Along the central third of the corallum they are just about as wide as the intercostal furrows. In the basal third they are somewhat broader than the furrows. In the marginal third, where the rudimentary costae are present, they are thinner than the furrows. The rudimentary costae are considerably thinner than the principals but almost equal in height. In the intercostal furrows a double row of pits is present except between the rudimentary and principal costae where there is but a single row. The four cross sectioned specimens show these pits as distinct pores that perforate the wall. The septa are twenty-four in number, three complete cycles, arranged in six groups. They are fairly straight in two weathered-out specimens which are badly worn, but in the four cross sectioned specimens they have a wavy appearance near their inner margins. The lateral faces of the septa reveal no marked ornamentation, although a few minute granules occasionally occur in the cross sections and, in the longitudinal section, these can be detected in the upper region near the calice. Their alignment in rows is vaguely suggested. In the longitudinal section the folds of the inner margins of the septa, near their fusion with the columella, are regular and much more frequent than in the other California species of *Turbinolia*. The primary and secondary septa are weakly fused to the columella. The tertiaries are fused to the sides of the included primaries. The columella is very weakly developed. In the two weathered out calices it appears as a compressed granular mass that has not the remotest resemblance to a star. In the cross sections it is detectable as a small central column to which the six primary septa are irregularly fused.

DIMENSIONS

	Holotype (Nomland)	*Plesiotype SDSNH 377*	*Plesiotype SDSNH 376*
Diam. of calice	3.3 mm.	3.2 mm.	3.7 mm.
Ht. of corallum	5.8 mm.	5.8 mm.	7.4 mm.
Ratio, diam. to ht.	(broken)	(broken)	.500:1

Holotype: Of *T. pusillanima* Nomland, said to be in the Univ. Calif. Museum of Paleontology. Of *T. jollaensis* Hanna, No. 31163 Univ. Calif. Museum of Paleontology.

Plesiotypes: Nos. 376, 377 San Diego Society of Natural History.

Topotypes: No. 32269 Univ. Calif. Museum of Paleontology. Nos. 371674, 371675 U. S. National Museum. No. 820 Stanford Univ. Museum of Paleontology.

Type locality: Of *T. pusillanima* Nomland, U. C. locality 476: "SW$\frac{1}{4}$ of NW$\frac{1}{4}$ sec. 22, T. 1 S, R. 1 E, M. D. B. & M., elevation 1200 ft., in little wash near creek, below 1250-foot hill, Diablo Quadrangle, Contra Costa County, California." Of *T. jollaensis* Hanna, U. C. locality 5091: "Tecolote Creek about 0.25 mile north of its junction with its largest tributary." San Diego County, California.

Geological Horizons: Meganos formation (U. C. locality 476), and Rose Canyon shale (U. C. locality 5091), Eocene.

Remarks: The study of Hanna's holotype in comparison with the

figures and the topotypes of *T. pusillanima* Nomland is convincing that *T. jollaensis* Hanna is a synonym of Nomland's species. Hanna's specimen, No. 31163 Univ. Calif. Museum of Paleontology, is sectioned below the rudimentary costae and corresponds precisely to Nomland's fig. 10, *op. cit.*, as well as to two similar cross sections amongst the topotypes at hand.

T. pusillanima Nomland belongs to the group of the genus which is characterized by the columella being a more or less granular mass. This group includes *T. acuticostata* Vaughan, *T. claibornensis* Vaughan, *T. corbicula* Pourtalès, and *T. imbulata* (Hanna). The three complete cycles of septa separate it from *T. corbicula* Pourtalès which has but two cycles. The smooth and entire costal ridges distinguish it from *T. acuticostata* Vaughan which has crenate costal margins. It differs from *T. imbulata* (Hanna) by the much thinner septa with sparse granulations on their lateral faces and by the weakly developed columella. Its nearest resemblance is to *T. claibornensis* Vaughan, but it is separable from this species by the less prominent granules on the septal faces and the much wider costae which are as wide as the intercostal spaces.

Careful collecting at U. C. locality 1817 does not authenticate the presence there of this species, as reported by Nomland, *op. cit.*

Turbinolia imbulata (Hanna)

Plate 6, figs. 11, 12, 15, 16

Balanophyllia imbulata Hanna, Univ. Calif. Publ. Dept. Geol. Sci., Vol. 16, p. 268, pl. 1, figs. 2, 3.

Hanna's description is based upon two cross sections and is wholly inadequate. Three specimens, one of which is a topotype, and a study of the holotype and paratype furnish the following additional information regarding the species:

Corallum conical, elongate, slender, and large for the genus. Calice subcircular. Wall a true theca, rather thin near the calice. Costae forty-eight in number, alternating in size. The twenty-four principal costae opposite the septa extend throughout the incomplete specimen labeled "Rose Canyon," SDSNH No. 359. The rudimentary costae arise about one-fourth the distance from the broken upper end to the broken base of this specimen. In profile they are rather sharp, the principal costae rise vertically as high as they are broad, then flare out slightly to form a spearhead which is very nearly an equilateral triangle with the points rounded off. This odd appearance is brought about by the pores along the intercostal furrows which undercut the sides of the costae. These pores are irregular in shape and in several instances in the cross sections are seen to penetrate the wall into the interseptal loculi. They are arranged in a double row and

alternate in position in the exposed portion of the "Rose Canyon" specimen. The septa are twenty-four in number, three complete cycles arranged in six groups. The primaries are broadly and the secondaries are narrowly fused to the columella. The tertiaries curve toward and fuse with the sides of the included primaries near the outer edge of the columella. In cross section the septa are irregularly undulating, the granulations on their lateral faces accentuating this irregularity. In transverse section the granules are seen to be arranged in close compact straight parallel rows which slope down from the wall at an angle of from 35° to 45°. The space between them is about half the width of the rows. They extend fully two-thirds the distance across the faces of the septa. Each alternate row of granules with a few exceptions ends opposite a small swelling formed by the transverse fold of the septal margin. As many as eight granules are found in a row. The septal margins are fused rather solidly to the columella. The columella is a rather solid mass of stereoplasm in six irregular sections, corresponding to the groups of septa, fused around a small central column. There is no marked line of separation between the thickened inner margins of the primary septa and the columellar mass except in one group of the topotype. The secondary septa are usually narrower at their point of fusion with the columella. There is a slight indication in the topotype that the surface of the columella stood well up in the calice.

DIMENSIONS

	Topotype SDSNH 358	*Tecolote Canyon USNM 371683*	*"Rose Canyon" SDSNH 359*
Diam. of calice	4.1 mm.	3.6 mm.	2.4 mm.
Ht. of corallum	10.0 mm.	9.2 mm.	4.2 mm.
Ratio, diam. to ht.	.401:1	.390:1	(broken)

Holotype: No. 31166 Univ. Calif. Museum of Paleontology.

Paratype: No. 31167 Univ. Calif. Museum of Paleontology.

Plesiotypes: Nos. 358, 359 San Diego Society of Natural History.

Type locality: U. C. locality 5051: "At mouth of tributary to San Clemente Creek, due west of the "s" of Pueblo Lands [La Jolla topographic sheet of the U. S. Geological Survey], 40 ft. above the bottom of the creek. Elevation 225 feet." San Diego County, California.

N. B. A bed of hard indurated light brown sandstone containing a rich assortment of fossils and including this species occurs at the type locality.

Geological horizon: Rose Canyon shales, Eocene.

Remarks: A study of the holotype and paratype, which are cross sections only, proves that Hanna's *Balanophyllia imbulata* belongs to the genus *Turbinolia*. In the collection of the San Diego Society of Natural History there is a specimen, No. 359, collected by Mr. Frank Stephens, labeled "Rose Canyon." The matrix looks suspiciously like the San Clemente rock, but unfortunately the label is too general to allow this specimen to be considered a topotype. In cross section it is almost identical with the figure of *Balanophyllia imbulata* Hanna. From it the

costal and columellar characters have been described. In breaking up a piece of the hard indurated sandstone obtained at the type locality, Mr. C. H. Sternberg found the topotype and kindly donated it for this study. It is split longitudinally and reveals the septal faces and their ornamentation on both a primary and secondary septum. Another specimen, U. S. National Museum No. 371683, was collected by the writer from the type locality of *T. jollaensis* Hanna in Tecolote Canyon. It is also split longitudinally and reveals similar septal ornamentations.

T. imbulata (Hanna) is related to *T. claibornensis* Vaughan and to *T. pusillanima* Nomland by its granular, irregularly shaped columella and by the presence of rudimentary costae. It is separable from both species by its large size, the abundance of the granules on the septal faces and their arrangement in close compact rows, and by the thickness of the septa which are wider than the interseptal loculi and crowd the calice. In size it is equal to the larger of the European species of *Turbinolia* but none of these have the thick heavily ornamented septa nor the unique spearhead appearance of the costae when seen in profile or cross section.

DISCUSSION

There are no known records of the genus *Turbinolia* in Paleocene or older beds. The oldest species recorded is *T. acuticostata* Vaughan from the Pamunkey formation of Virginia and Maryland. The hexagonal style at the top of the columella in this species seems to place it as the possible ancestor of the American group with stellate and granular columella and of the European group with styliform, compressed or angular columella. The crenate margins of the costae connect it with *T. costata* M. E. & H. which has a compressed style at the top of the columella. This might well be considered an intermediate stage between the hexagonal style and the smooth round style of *T. sulcata* Lamarck and many other European species. The angular style of *T. forbesi* Duncan appears to have been derived from the compressed style or, possibly, from the hexagonal style. The accentuation of the angles opposite the six primary septa would develop the stellate columella from the hexagonal style. The granular columella has a noticeably hexameral arrangement that suggests a distortion of the hexagonal style or the stellate columella.

From this evidence the genus *Turbinolia* appears to have had its origin in the Tethyan sea during the interval subsequent to the deposition of Paleocene strata, near the Atlantic Coast of America where it first appeared in Lower Eocene time. From this center of distribution two distinct

groups diverged, the styliform columella group eastward to Europe and the stellate columella group westward to the Gulf Coastal Plain and California. No representative of the latter group seems to have reached the European continent, and only in the Oligocene did a member of the former group reach America.

The accompanying correlation table showing the distribution of the recorded species of the genus *Turbinolia* was compiled from the tables of Vaughan[10] and Clark[11] with changes suggested by letters from Prof. A. Morley Davies and Dr. H. G. Schenck. The divisions of the Lutetian, Calcaire Grossier, of France and the Barton beds of Great Britain were made for the purpose of giving the exact horizons recorded on the labels accompanying specimens received from Mr. Arthur Wrigley of London. This material contained topotypes of *T. sulcata* Lamarck, *T. costata* M. E. & H., *T. nystiana* M. E. & H., *T. dixoni* M. E. & H., *T. humilis* M. E. & H., *T. fredericiana* M. E. & H., and *T. exarata* Duncan. Prof. A. Morley Davies supplied the exact stratigraphical position of Milne Edwards and Haime's and Duncan's type localities. The material at hand lacks but two of their species, namely, *T. prestwichii* M. E. & H. and *T. minor* M. E. & H. Filliozat[12] records *T. dispar* Defrance and his species, *T. vaughani,* from Le Bois-Gouët, Campbon, which locality Prof. Davies says is Auversian. Milne Edwards and Haime[13] give the locality for *T. dispar* Defrance as "Eocene: Environs de Paris, Hauteville," which, according to Prof. Davies is Lutetian.

The columellar character of *T. prestwichii* M. E. & H. was indeterminable because hidden by the matrix in the only specimen ever recorded of that species.[14] The literature on the three Oligocene fossils from Germany and three of the Belgium species has not been accessible, but Duncan[15] records the former from the "Unter Oligocän" of Germany, and Mr. Wrigley writes me that *T. gerardi* Vincent is from Sables de Wemmel (Bartonian) and that *T. vincenti* Glibert and *T. nilensis* Glibert are from the Bruxellian (Lutetian). Felix[16] lists *Turbinolia octoscissa* Quenstedt from the middle Oligocene, "Osterweddigen bei Madgeburg."

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10 VAUGHAN, T. W., Spec. Publ. Bernice P. Bishop Museum No. 7, pp. 818-838, tables 1, 2, 1921; Bull. Geol. Soc. Am., Vol. 35, pp. 677-742, 1924.

11 CLARK, B. L., Bull. Geol. Soc. Am., Vol. 35, pp. 801-817, table 1.

12 FILLIOZAT, M., Bull. Soc. sc. nat. Ouest, 3e sér., t. IV, pp. 69-71, 1914.

13 MILNE EDWARDS & HAIME, Hist. nat. des. Coralliarires, Vol. 2, p. 65, 1857.

14 MILNE EDWARDS & HAIME, British Fossil Corals, Vol. 1, pp. 20-21, 1850.

15 DUNCAN, P. M., Supplement Brit. Foss. Corals, p. 56, footnote, 1866.

16 FELIX, J. Fossilium Catalogus Animalia, Pars 28, p. 169, 1925.

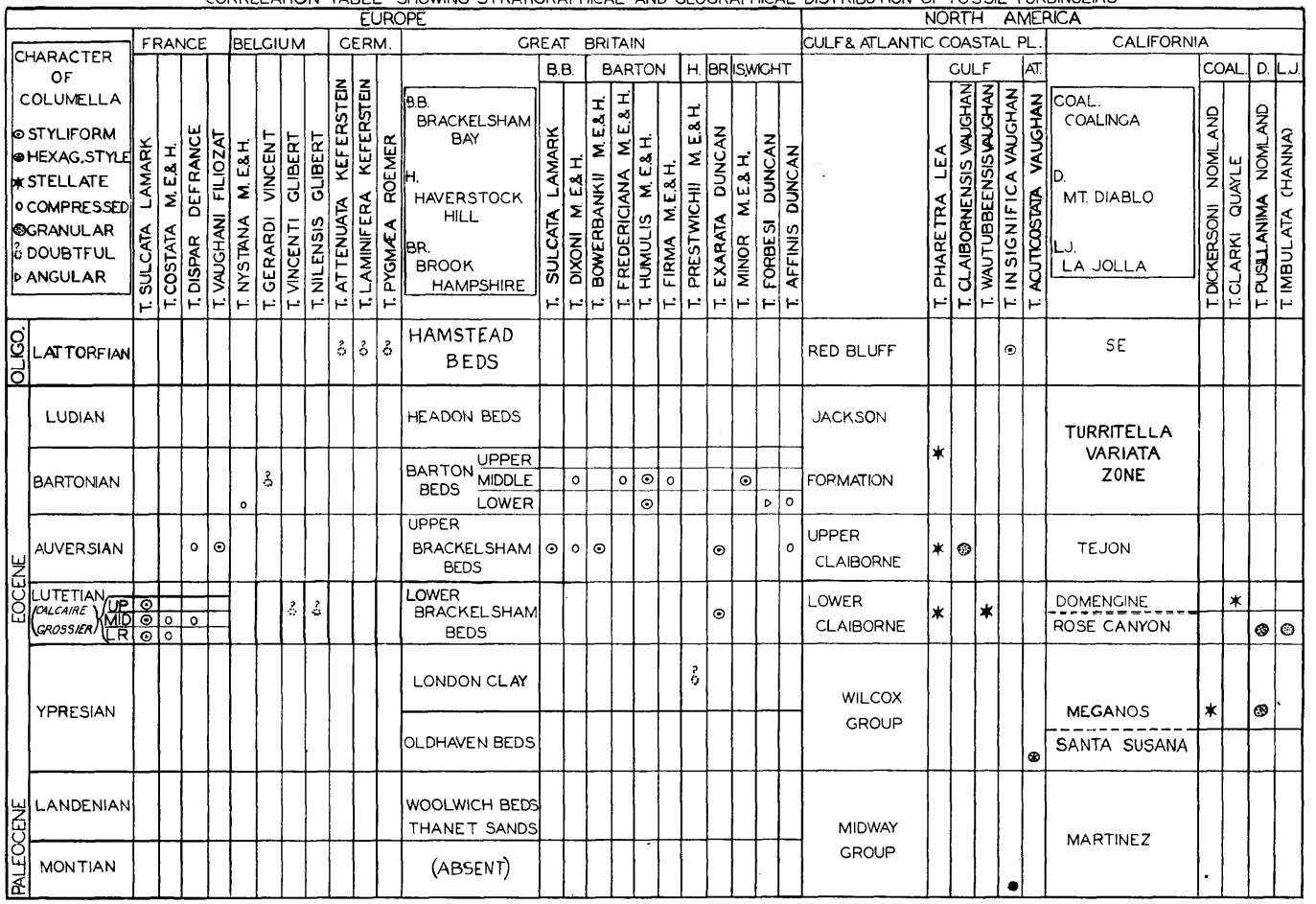

Fig. 12. Correlation Table. (Explanation of symbols in upper left-hand corner. SE indicates Sespe formation, non-marine.)

PLATE 6

Drawings by camera lucida

Line at lower right of specimen shows the natural size

Fig. 1. *Turbinolia dickersoni* Nomland
Plesiotype No. 379, S.D.S.N.H. type collection, from the type locality, U. C. locality 1817: "On branch of Salt Creek, near center of Sec. 15, T. 18 S, R. 14 E, M .D. B. & M., Fresno County, California, about 16 miles north of Coalinga."

Fig. 2. *Turbinolia dickersoni* Nomland
Plesiotype No. 381, S.D.S.N.H. type collection, from the type locality. Longitudinal section to show internal structure.

Fig. 3. *Turbinolia dickersoni* Nomland
Plesiotype No. 378, S.D.S.N.H. type collection, from the type locality. Short stout form.

Fig. 4. *Turbinolia dickersoni* Nomland
Plesiotype No. 379, S.D.S.N.H. type collection, from the type locality. View of the calice of fig. 1.

Fig. 5. *Turbinolia dickersoni* Nomland
Plesiotype No. 380, S.D.S.N.H. type collection, from the type locality. Showing pits in intercostal furrows.

Fig. 6. *Turbinolia clarki* Quayle, sp. nov.
Syntype No. 32381, U. C. Mus. Paleo. type collection, from the type locality, U. C. locality 672: "SE$\frac{1}{4}$ of NW$\frac{1}{4}$ sec. 24, T. 18 S, R. 14 E, M. D. B. & M., Parsons Peak, 0-10 ft. below white shale. Domengine Ranch and Creek, Coalinga Quad., Fresno County, California." Longitudinal section showing internal structure.

Fig. 7. *Turbinolia clarki* Quayle, sp. nov.
Syntype No. 32380, U. C. Mus. Paleo. type collection, from U. C. locality 672. Calicular view.

Fig. 8. *Turbinolia clarki* Quayle, sp. nov.
Syntype No. 32380, U. C. Mus. Paleo. type collection, from U. C. locality 672. Upright view of corallum.

Fig. 9. *Turbinolia pusillanima* Nomland
Plesiotype No. 376, S.D.S.N.H. type collection, from the type locality, U. C. locality 476: "SW$\frac{1}{4}$ of NW$\frac{1}{4}$ sec. 22, T. 1 S, R. 1 E, M. D. B. & M., elevation 1200 feet, in little wash near creek, below 1250-foot hill. Diablo Quadrangle, Contra Costa County, California." Cross section near the calice.

(*Continued on page 109*)