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THE SCLERACTINIAN GENUS *ACTINACIS* SYSTEMATIC REVISION AND STRATIGRAPHIC RECORD OF THE TERTIARY SPECIES WITH SPECIAL REGARD TO ITALIAN OCCURRENCES

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Key-words: Scleractinian corals, *Actinacis*, Tertiary, Italy, Systematics, Stratigraphic distribution.

Riassunto. In letteratura, per quanto riguarda il Terziario, sono descritte ventisette specie appartenenti al genere *Actinacis* (Scleractinia), uno dei più importanti Coralli costruttori dei complessi di scogliera eocenico-oligocenici dell'intera Tetide. È stata eseguita una dettagliata revisione sistematica delle specie descritte per l'Italia e per altre regioni europee. Lo studio si è basato su misure, in sezione sottile, dei vari caratteri morfologici di esemplari provenienti da diverse località italiane, sull'osservazione di olotipi e topotipi e sull'accurata verifica della letteratura esistente. Quale strumento operativo per identificare le diverse specie, viene proposta una combinazione di vari caratteri diagnostici e attributi morfometrici. I risultati dello studio dimostrano che, delle dodici specie descritte nelle località italiane, solo tre appartengono effettivamente al genere *Actinacis*. Vengono di conseguenza presentate una lista di sinonimi ed una tabella di distribuzione stratigrafica delle specie così identificate. Per quelle specie che non sono state oggetto della revisione sistematica, si propongono un'identificazione tassonomica ed una distribuzione stratigrafica soltanto generiche. L'esame preliminare della distribuzione stratigrafica e geografica delle varie specie di *Actinacis* indica che: 1) la distribuzione terziaria del genere va dal Paleocene superiore all'Oligocene superiore (dal Cuisiano superiore al Cattiano medio per quanto riguarda l'Italia); 2) la diversità specifica più elevata si è avuta durante l'Eocene medio, quando il genere comprendeva un numero relativamente elevato di specie geograficamente ristrette; 3) solo due specie, a larga distribuzione, hanno superato la crisi al passaggio Eocene-Oligocene, perdurando fino al tardo Oligocene, quando il genere si estinse a scala globale.

Abstract. Twenty-seven Tertiary species belonging to the cosmopolitan reef-building scleractinian genus *Actinacis*, have been described in the literature. A detailed systematic revision has been carried out for Italian and European species by thin section measurements of material mostly sampled from several Italian localities, by observation of some holotypes and topotypes and accurate examination of the available literature. A combination of several measured corallite morphologic characters and diagnostic features is proposed as a reliable tool for species recognition. Results indicate that only three species, of the twelve described for the Italian Tertiary sites, actually belong to the genus *Actinacis*. Moreover, a list of synonyms and a stratigraphic range chart of the established species are proposed. An approximate taxonomic identification and stratigraphic distribution are given for those species not included in the systematic revision. Preliminary examination of the stratigraphic and geographic distribution of *Actinacis* species suggests that: 1) the Tertiary distribution of the genus ranges from the Late Paleocene to the Late Oligocene (from Late Cuisian to Middle Chattian as concerns Italy); 2) the highest species diversity occurred during the Middle Eocene, when the genus consisted of a relatively large number of geographically restricted species; 3) only two widespread species survived the Eocene/Oligocene turnover and reached the Late Oligocene, when the genus became globally extinct.

Introduction.

The Scleractinian genus *Actinacis* d'Orbigny, 1849, is a well known and abundant, cosmopolitan reef-building coral ranging in age from the Cenomanian (Palestine; Felix, 1913; Great Britain; Duncan, 1879) to the Oligocene, a time of world-wide maximum growth and diversity of Tertiary reefs (Frost, 1977).

The palaeontologic importance of this genus is mostly related to its evolutionary history and palaeoecologic role as a major frame-builder, especially during Late Eocene-Early Oligocene time. *Actinacis* is considered to represent one of the eighteen genera which survived after the K/T extinction event (Drobne et al., 1988; Rosen & Turnsek, 1989). Extremely rare in the Danian, *Actinacis* became progressively abundant from the Middle Eocene until the Oligocene, when it formed monospecific communities in the Lower Rupelian of the Lessini Shelf (Vicenza, Northern Italy) (Bosellini F.R. & Russo, 1988; Bosellini F.R. & Trevisani, 1992) and in the Lower Chattian of Cairo Montenotte (Liguria, Northern Italy) (Pfister, 1985).

Recent studies carried out mostly in the classic Oligocene reef area of the Vicentin Southern Alps (Bosellini F.R. & Russo, 1988; Bosellini F.R. & Trevisani, 1992; Bosellini F.R. & Stemann, in press), revealed the high level of morphological variation shown by the genus *Actinacis*, especially *Actinacis rollei* Reuss. The high plasticity of this taxon has certainly contributed to the difficulty of finding accurate

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criteria for species recognition and has led many previous authors to establish new species for different morphotypes.

The purpose of this paper is to provide reliable criteria for species identification by a detailed taxonomic study of material sampled from several Italian localities and neighbouring countries (Spain), and to examine the regional distribution of *Actinacis* during the Tertiary, taking into account synonymies established both from the systematic revision proposed in this paper and from the literature.

Stratigraphic and geographic overview of the Tertiary species.

Twenty seven Tertiary species are reported in the literature, distributed within a vast area extending from the Caribbean to New Guinea (Tab. 1).

Four species are known in the Caribbean region: *Actinacis barretti* Wells, 1934, Middle Eocene of Jamaica; *A. caribiensis* Frost & Langenheim, 1974, Middle Eocene of Chiapas, Mexico (Frost & Langenheim, 1974); *A. sawkinsi* Wells, 1934, Middle Eocene of Jamaica; and finally *A. alabamiensis* (Vaughan, 1900), Middle Eocene of Jamaica, Late Eocene of Panama and Late Oligocene of Antigua, Alabama and Georgia (*fide* Budd et al., 1992).

Concerning Eastern Asia regions, *A. lata* Gregory, 1930, has been described in the Paleocene of the Samana Range, Pakistan; *A. digitata* Fritsch, 1878, in the Eocene of Borneo; *A. maitlandi* Gregory & Trench, 1916, in the Eocene (Lutetian) of Central New Guinea and in the Late Paleocene-Early Eocene of Java, Indonesia (Carbone et al., 1990) together with *A. cognata* Oppenheim, 1901 (Russo, unpublished data).

As regards Africa, three species have been described in Libya: *Actinacis cognata* Oppenheim, 1901, in the Eocene (Zuffardi Comerci, 1925) and *Actinacis paronai* Zuffardi Comerci, 1940, and *A.* cf. *rollei* Reuss, 1864, in the Oligocene (Zuffardi Comerci, 1925; Hladil et al., 1992). One species, *A.* cf. *delicata* Reuss, 1869, has been recorded from the Oligocene of Somalia (Zuffardi Comerci, 1937; Azzaroli, 1958). Moreover, Dalton (1908) created a new species, *Actinacis noetlingi*, from the Miocene of Burma.

In Europe, seventeen species have been established: one for the Paleocene, nine for the Eocene, five for the Oligocene, and two for the Miocene. Oc-

SPECIES	TYPE AREA	AGE
A. alabamiensis (Vaughan, 1900)	Alabama, U.S.A.	Late Oligocene
A. arborescens d'Achiardi, 1868	Veneto, Italy	Rupelian
A. barretti Wells, 1934	Jamaica	Middle Eocene
A. caribiensis Frost & Langenheim, 1974	Chiapas, Mexico	Middle Eocene
A. cognata Oppenheim, 1901	Friuli, Italy	Late Cuisian-Early Lutetian
A. conferta Reuss, 1868	Veneto, Italy	Rupelian
A. delicata Reuss, 1869	Veneto, Italy	Rupelian
A. deperdita Michelotti, 1871	Liguria, Italy	Early Chattian
A. digitata Fritsch, 1878	Borneo	Eocene
A. elongata de Angelis, 1894	Piedmont, Italy	Tortonian
A. gallemii Reig Oriol, 1990	Catalonia, Spain	Late Eocene
A. gomezalbai Reig Oriol, 1990	Catalonia, Spain	Late Eocene
A. lata Gregory, 1930	Pakistan	Paleocene
A. lobata de Angelis, 1894	Liguria, Italy	Early Chattian
A. maitlandi Gregory & Trench, 1916	New Guinea	Lutetian
A. michelottii de Angelis, 1894	Veneto, Italy	Rupelian
A. noetlingi Dalton, 1908	Burma	Miocene
A. oblita Michelotti, 1871	Piedmont, Italy	Tortonian
A. paronai Zuffardi Comerci, 1939	Libya	Oligocene
A. parvulina Eliasova, 1974	Moravia	Late Eocene
A. perelegans Oppenheim, 1901	Friuli, Italy	Late Cuisian-Early Lutetian
A. phineus Kolosvary, 1956	Hungary	Eocene
A. possagnensis Oppenheim, 1900	Possagno, Italy	Priabonian
A. rollei Reuss, 1864	Steiermark, Austria	Rupelian
A. sawkinsi Wells, 1934	Jamaica	Middle Eocene
A. subrollei Oppenheim, 1901	Friuli, Italy	Late Cuisian-Early Lutetian

Tab. 1 - List of *Actinacis* Tertiary species described in the literature. Area of type locality and relative age are indicated for each species.

currences of European species will be indicated in the systematic section of the present paper. *A. cognata* Oppenheim, 1901, is the only species described in the Paleocene, Slovenia (Turnsek in Drobne et al., 1988), ranging until the Eocene. In the Eocene the following species have been recognized in the literature: *A. possagnensis* Oppenheim, 1900, *A. perelegans* Oppenheim, 1901, *A. subrollei* Oppenheim, 1901, *A. phineus* Kolosvary, 1956, *A. parvulina* Eliasova, 1974, *A. gomezalbai* Reig Oriol, 1990, *A. gallemii*, Reig Oriol, 1990, together with *A. delicata* Reuss, 1869, and *A. rollei* Reuss, 1864, both described also in the Oligocene. The other Oligocene species are: *A. arborescens* d'Achiardi, 1868, *A. conferta* Reuss, 1868, *A. deperdita* Michelotti, 1871, *A. lobata* de Angelis, 1894, *A. Michelottii* de Angelis, 1894. Concerning the Miocene, Michelotti in Sismonda (1871) and de Angelis (1894) created two new species: respectively *A. oblita* and *A. elongata*, both from the Piedmont Basin, Italy.

After a detailed systematic revision of Italian and European species and an accurate examination of all the available literature, a list of synonymies will be proposed and the stratigraphic ranges of the established species will be traced.

Material and methods.

Although *Actinacis* occurs in Tertiary terrains from the Caribbean province to most Eastern Asia regions, it is from the Southern European countries, especially Italy, that the genus is mostly described and recorded.

A large part of the material examined in this paper actually comes from various Eocene-Oligocene Italian carbonate platforms. As regards the Eocene, *Actinacis* has been collected in both the following Upper Priabonian units: the Santa Giustina Limestone, Possagno, Treviso (Russo, 1979) and the Nago Limestone, Nago, Trento (Luciani, 1989); whereas Oligocene specimens of *Actinacis* have been collected in the Castelgomberto Limestone, Rupelian of the Eastern Lessini Mountains, Vicenza (Bosellini F.R., 1988; Bosellini F.R. & Trevisani, 1992); in the Lower Chattian coral deposits outcropping in the area of Cairo Montenotte, Liguria (Pfister, 1985; Fravega et al., 1987) and in the Castro Limestone, Castro, Salento Peninsula (Bosellini F.R. & Russo, 1992), recognized as Middle Chattian in age.

Additional Italian material has also been examined from several collections: the collection of Dainelli (Eocene corals of Friuli), housed in the Museum of Paleontology of the University of Florence, and the collections of De Angelis and Michelotti, both deposited in the Museum of Paleontology of the University of Rome. Other Eocene corals of Friuli have been studied from a private collection (Dr. Dalla Vecchia). The Eocene coral deposits of Friuli have been dated as Late Cuisian-Early Lutetian (Venturini & Tunis, 1992).

Finally, specimens of *Actinacis* have also been collected in the Eocene reefs outcropping in the "Conca d'Igualada", 70-80 km west of Barcelona (Spain). These reef deposits have been dated as Middle-Late Bartonian and Early Priabonian (Salas, 1979; Alvarez Pérez, 1993).

All the collected colonies of *Actinacis* have been measured and studied in thin section, while only the calicinal surface has been examined for type specimens.

In particular, the following corallite morphologic characters have been measured for species identification (Fig. 1): corallite diameter (CD); corallite spacing (CS); number of septa per corallite (NS); length of primary septa (L1); length of secondary septa (L2); length of tertiary septa (L3); palus thickness (PT); columella thickness (CT); thickness of coenosteum trabeculae (TT). In addition to these characters, also the septal pattern and the kind of coenosteal reticulum (trabecular, CRT; irregular, CRI; vermicular, CRV) have been qualitatively analyzed for species identification. In general, quantitative results are presented either as approximate ranges of values, or as means.

In the present paper, the data taken from corallite measurements has been qualitatively compared using plot diagrams. A statistical analysis has been considered necessary only for the extremely variable species *Actinacis rollei*, and has been performed and analyzed in a separate paper (Bosellini & Stemann, in press).

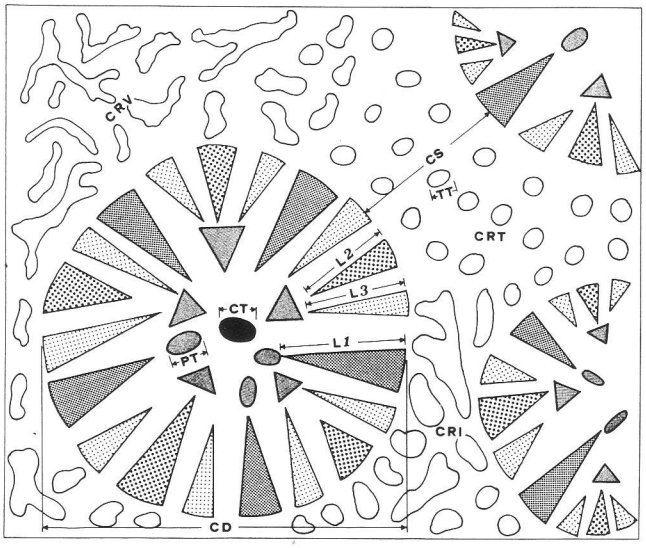


Fig. 1 - Schematic drawing of a calice of *Actinacis* showing characters considered for species identification. CD) corallite diameter; CS) corallite spacing; L1) length of primary septa; L2) length of secondary septa; L3) length of tertiary septa; PT) palus thickness; CT) columella thickness; TT) thickness of coenosteum trabeculae; CRT) trabecular coenosteal reticulum; CRI) irregular coenosteal reticulum; CRV) vermicular coenosteal reticulum.

Systematic palaeontology

The aim of the following section is the detailed systematic revision of all the *Actinacis* species described in the Tertiary of Italy and other European countries, by thin section measurements of collected material, observation of several holotypes and topotypes and careful examination of the available literature. In order to focus the main purpose of this study, the description of the species established as belonging to the genus *Actinacis* has been placed at the beginning of the present systematic revision. Consequently, the classification scheme followed in the Treatise on Invertebrate Paleontology, Part F, Coelenterata (Wells, 1956), has not been adopted as regards the suprageneric divisions.

Abbreviations of Repository Institutions. IPUM: Istituto di Paleontologia, Università di Modena, Italy; MPUR: Museo di Paleontologia, Università di Roma, Italy; IGF (for the former Istituto Geologico Fiorentino): Museo di Paleontologia, Università di Firenze, Italy; NMB: Naturhistorisches Museum Bern, Switzerland.

Phylum **Coelenterata**

Class Anthozoa Ehrenberg, 1834

Subclass Zoantharia de Blainville, 1830

Order Scleractinia Bourne, 1900

Suborder Fungiina Verrill, 1865

Superfamily *Poriticae* Gray, 1842

Family *Actinacididae* Vaughan & Wells, 1943

Genus *Actinacis* d'Orbigny, 1849

Type species: *Actinacis martiniana* d'Orbigny, 1849

Diagnosis. "Submassive to ramose; colony formation by extratentacular budding. Septa commonly in 3 cycles with one crown of 6 to 8 palar trabeculae. One columellar trabecula. M.Cret.-Oligocene" (Vaughan & Wells, 1943).

Discussion. D'Orbigny (1849) created the new genus *Actinacis* with the following diagnosis: "Ensemble dendroide; calices superficiels, espacés en dedans, intervalle poreux", and designated *Actinacis martiniana* d'Orbigny, from the Late Cretaceous of Figuières (Bouches-du-Rhône, France) as the type species of the genus.

The subsequent detailed diagnosis of the genus which appeared in Vaughan & Wells (1943) is considered by the present authors to be exhaustive.

Actinacis cognata Oppenheim, 1901

Pl. 1, fig. 1-4; Text-fig. 2, 3

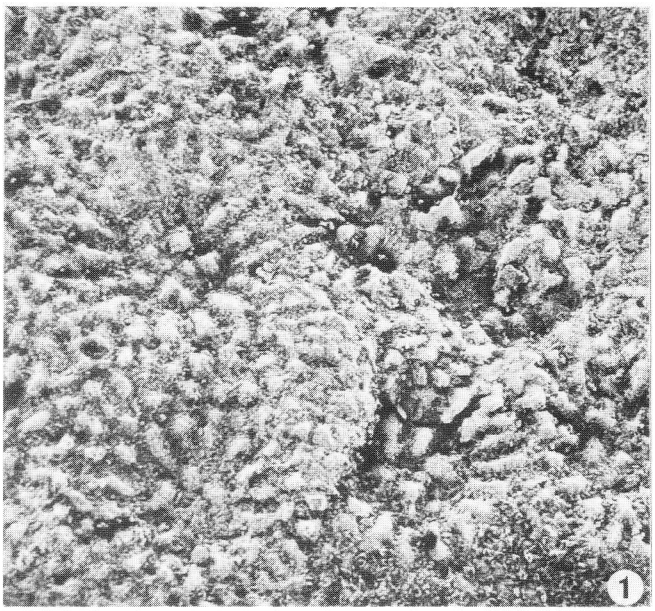
1875 *Actinacis delicata* - d'Achiardi, p. 82.
?1878 *Actinacis digitata* Fritsch, p. 129, pl. 17, fig. 7.
?1885 *Actinacis digitata* - van Cappelle, p. 119.
1899 *Actinacis delicatula* Oppenheim, p. 54.
1901 *Actinacis cognata* Oppenheim, p. 182, pl. 12, fig. 7; pl. 14, fig. 5.
1901 *Actinacis Sub-Rollei* Oppenheim, p. 200, pl. 14, fig. 4; text-fig. 13.
1906 *Actinacis* aff. *cognata* Oppenheim, p. 153.
1909 *Actinacis cognata* - Oppenheim, p. 315.
1909 *Actinacis delicata* - Felix, p. 118.
1912 *Actinacis cognata* - Oppenheim, p. 105, pl. 10, fig. 11-11b.
v. 1915 *Actinacis cognata* - Dainelli, p. 220, pl. 27, fig. 6, 10, 11; pl. 27, fig. 9.
1925 *Actinacis cognata* - Felix, pars 28, p. 261.
1925 *Actinacis cognata* - Zuffardi Comerci, p. 26 (pars).
1942 *Actinacis cognata* - Solé Sabaris, p. 164, pl. 7, fig. 49.
1949 *Actinacis cognata* - Kolosvary, p. 181, pl. 16, fig. 5, 5b.
1956 *Actinacis cognata* - Kolosvary, p. 78, pl. 19, fig. 4-8.
1956 *Actinacis phineus* Kolosvary, p. 78, pl. 19, fig. 9, 10.
1967a *Actinacis cognata* - Kolosvary, p. 200, text-fig. 20-23.
1974 *Actinacis cognata* - Eliasova, p. 137, text-fig. 14.
1988 *Actinacis cognata* - Turnsek in Drobne, Ogorelec, Plenicar, Zucchi Stolfa & Turnsek, p. 188, pl. 20, fig. 1; pl. 21, fig. 2; pl. 33, fig. 2-4.
1990 *Actinacis gallemii* Reig Oriol, p. 18, pl. 4, fig. 2-5.
1990 *Actinacis gomezalbai* Reig Oriol, p. 17, pl. 5, fig. 1, 2.
1993 *Actinacis cognata* - Alvarez Pérez, p. 237, pl. 22, fig. 2, 3.

Material. *A. cognata* of the collection of Dainelli (IGF 3538E, 3543E, 3544E). Several specimens from a private collection of Dr. F.M. Dalla Vecchia (IPUM 24913, 24914, 24915, 24916, 24917). Specimens collected in the "Conca d'Igualada", Spain (IPUM 24918, 24919, 24920, 24921, 24922). One specimen collected by A. Russo near Jati Bunkus, Java, Indonesia (IPUM 24923).

Description. Branched, ramose-dendroid, encrusting, fungiform or massive colonies, large from few cm to 20-30 cm. Colony plocoid, extratentacular budding. Corallites circular in outline, 0.7-1.1 mm in diameter. 16 to 24 septa are arranged in hexameral symmetry

PLATE 1

Fig. 1 - *Actinacis cognata* Oppenheim. Calical surface (Middle-Late Bartonian to Early Priabonian, Castelloli, Catalonia, Spain). SEM photograph; x 23 (IPUM 24918).
Fig. 2 - *Actinacis cognata* Oppenheim. Longitudinal section (Middle-Late Bartonian to Early Priabonian, Castelloli, Catalonia, Spain). SEM photograph; x 23 (IPUM 24919).
Fig. 3 - *Actinacis cognata* Oppenheim. Calical surface (Late Cuisian-Early Lutetian, Russiz, Friuli, Italy). Coll. Dalla Vecchia. SEM photograph; x 23 (IPUM 24913).
Fig. 4 - *Actinacis cognata* Oppenheim. Calical polished section (Late Cuisian-Early Lutetian, Noax and Rocca Bernarda, Friuli, Italy). Coll. Dainelli: IGF 3538E; x 22.
Fig. 5 - *Actinacis possagnensis* Oppenheim. Calical polished section (Late Priabonian, Possagno, Treviso, Italy). Coll. Russo: IPUM 19177; x 8.
Fig. 6 - *Actinacis possagnensis* Oppenheim. Calical polished section (Late Priabonian, Possagno, Treviso, Italy). Coll. Russo: IPUM 19177; x 10.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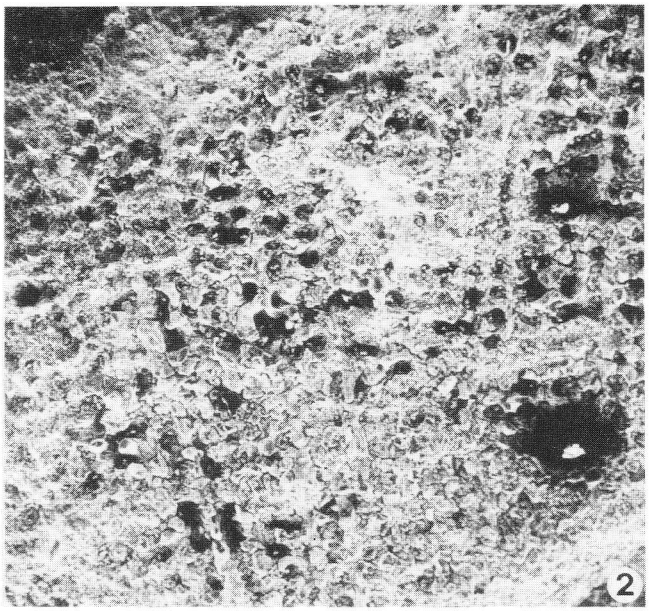
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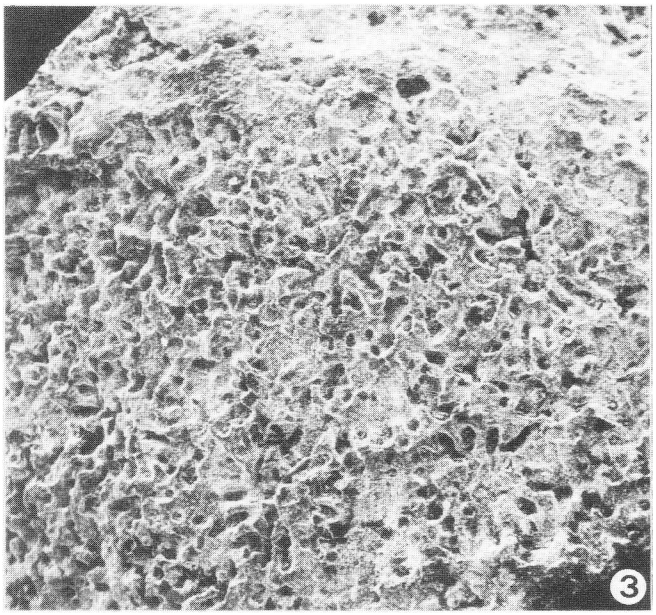
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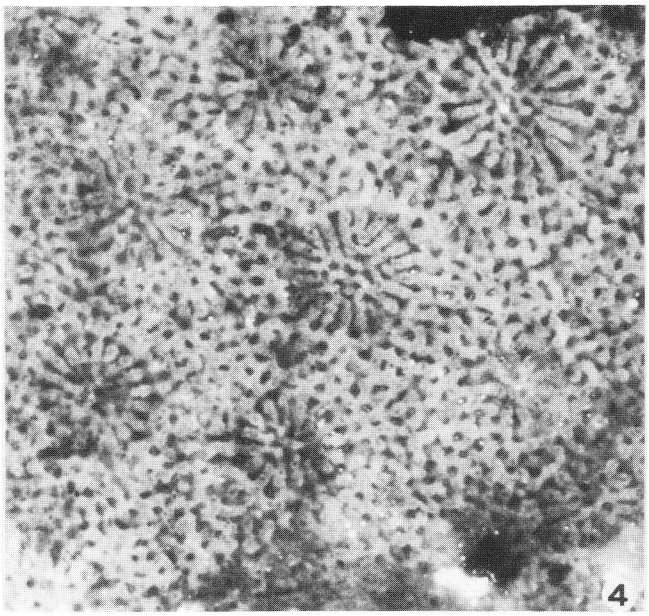
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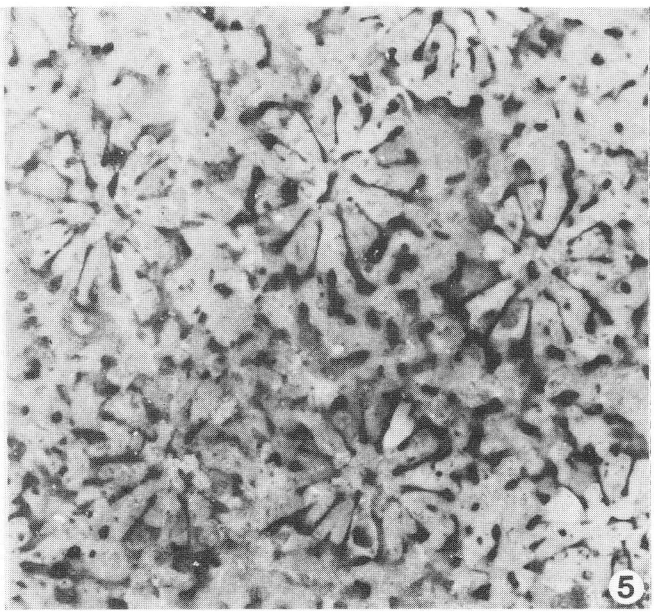
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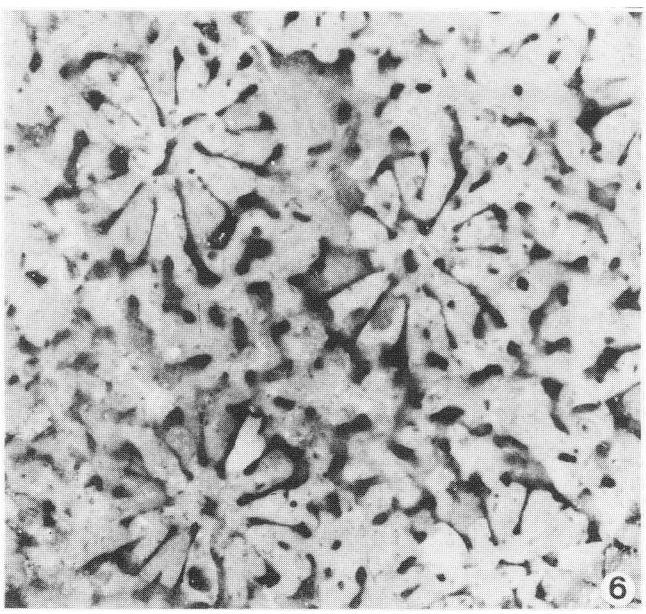
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(Fig. 3). Two tertiary septa (S3) and one secondary septum (S2) are organized to form a triplet while primary septa are free. Four triplets have been recognized in corallites with 20 septa and six triplets in the rare corallites with 24 septa. Pali, in general, are nine: five, oval-shaped or circular, placed in front of S1, and four, triangular in shape, disposed in front of the four triplets. Eleven pali have been observed in corallites with 24 septa, five oval and six triangular in front of the triplets. Generally, one palus in front of the cardinal septum is missing. The axial columella is constituted of one papilla. The coenosteum is composed by vertical trabeculae on the calicinal surface, while it appears irregularly vermiform according to deepness and orientation of the section. The trabeculae thickness is about 0.05 mm. Corallite wall discontinuous.

Size of main diagnostic characters is given in Fig. 3.

Occurrence. Paleocene (Late Danian). Dolenja vas, NW Dinarides, Slovenia (Turnsek in Drobne et al., 1988). Late Paleocene-Early Eocene of Java, Indonesia (Russo, unpublished data). Eocene. Late Cuisian-Early Lutetian. Cormons, Rosazzo, Russiz, Meduno, Noax and Rocca Bernarda, Friuli, Italy (d'Achiardi, 1875; Oppenheim, 1901, Dainelli, 1915). Middle Eocene. Rosici, Megjigja, Bosnia; Konjavac, Herzegovina (Oppenheim, 1901, 1909, 1912). Lutetian. Crni Kal, Slovenia (Kolosvary, 1967a). Bu-Meriam, Libya (Zuffardi Comerci, 1925). Middle-Late Eocene. Southern Moravia, Rep. Czechoslovakia (Kolosvary, 1949; Eliasova, 1974). Middle-Late Bartonian to Early Priabonian. Conca d' Igualada, Castelloli, Malvals, Catalonia, Spain (Solé Sabaris, 1942; Reig Oriol, 1990; Alvarez Pérez, 1993). Late Eocene. Precista, Rep. Macedonia (Oppenheim, 1906). Bükk Mountains, Hungary (Kolosvary, 1956). ? Eocene of Borneo (Fritsch, 1878; van Cappelle, 1885).

Actinacis possagnensis Oppenheim, 1900

Pl. 1 , fig. 5, 6; Text-fig. 2, 3

1900 *Actinacis possagnensis* Oppenheim, p. 53, pl. 9, fig. 5.
1925 *Actinacis possagnensis* - Felix, pars 28, p. 262.
v. 1979 *Actinacis possagnensis* - Russo, p. 42, pl. 2, fig. 1a,b.

Material. *A. possagnensis* (Coll. Russo, IPUM 19177, 19178).

Description. Colony generally massive, plocoid, extratentacular. Corallites, 2-2.8 mm in diameter, are mainly circular or sometime slightly oval. 22-24 septa are arranged in hexameral symmetry (Fig. 3), with the typical triplets not well defined. Pali, not always very well developed and simulating sometimes paliform lobes, are generally small, rounded or comma-like and disposed in front of primary and secondary septa. The corallite wall is discontinuous, formed of button-like structures, which may be connected to each other by thin bars. The columella consists of a single, circular trabecula, or of two small trabeculae connected together to form a pseudolamellar columella. A scarcely developed endotheca has been observed near the internal margins of septa. The coenosteum is trabecular on the surface and irregular in deeper sections. The irregularity is due to small horizontal bars which often link two or more vertical trabeculae. In longitudinal section the corallites are connected by irregular, arcuated, superposed and spaced tabulae.

Size of main diagnostic characters is given in Fig. 3.

Occurrence. Eocene. Late Priabonian. Valle Organa, Possagno, Treviso, Italy (Oppenheim, 1900; Russo, 1979).

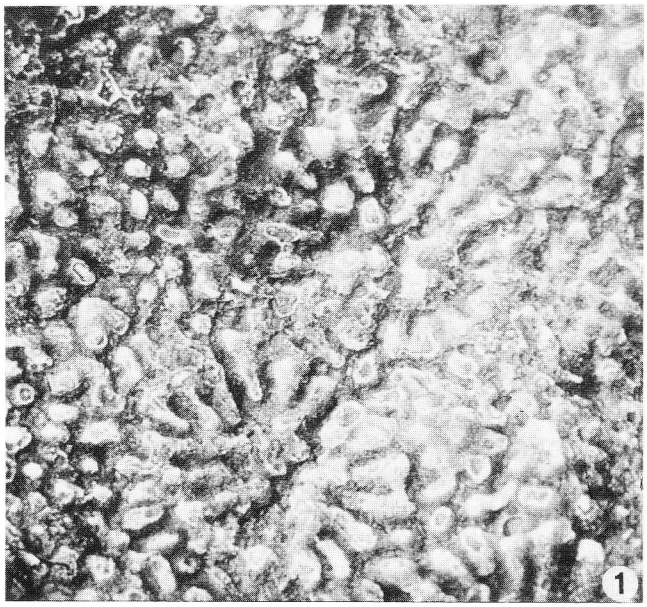
Actinacis rollei Reuss, 1864

Pl. 2 , fig. 1-6; Pl. 3, fig. 1; Text-fig. 2, 3

1864 *Actinacis rollei* Reuss, p. 27, pl. 8, fig. 6.
1868 *Actinacis rollei* - Reuss, pp. 160, 175.
1868 *Actinacis conferta* Reuss, p. 161, pl. 12, fig. 5.
1868 *Actinacis* sp. d'Achiardi, p. 93.
1868 *Actinacis arborescens* d'Achiardi, p. 108.
1868 *Actinacis conferta* - d'Achiardi, p. 144.
1868 *Actinacis rollei* - d'Achiardi, p. 144.
1869 *Actinacis delicata* Reuss, p. 249, pl. 25, fig. 5.
1871 *Actinacis deperdita* Michelotti in Sismonda, p. 28.
1874 *Porites polystyla* Reuss, p. 40, pl. 56, fig. 1-3.
1889 *Actinacis rollei* - Reis, p. 96.
1894 *Actinacis deperdita* - de Angelis, p. 23.
v. 1894 *Actinacis Michelottii* de Angelis, p. 24, pl. 1, fig. 5.
v. 1894 *Actinacis lobata* de Angelis, p. 24, pl. 1, fig. 21.
1913 *Actinacis rollei* - Oppenheim, p. 164, pl. 3, fig. 4.
1913 *Actinacis delicata* - Oppenheim, p. 166, pl. 3, fig. 1-3.

PLATE 2

Fig. 1 - *Actinacis rollei* Reuss. Calical surface (Rupelian, Castelgomberto, Vicentin Lessini Mountains, Italy). SEM photograph; x 23 (IPUM 24924).
Fig. 2 - *Actinacis rollei* Reuss. Longitudinal section (Middle Chattian, Castro, Salento Peninsula, Italy). SEM photograph; x 23 (IPUM 24925).
Fig. 3 - *Actinacis rollei* Reuss. Calical surface (Middle Chattian, Castro, Salento Peninsula, Italy). SEM photograph; x 23 (IPUM 24926).
Fig. 4 - *Actinacis rollei* Reuss. Longitudinal thin section (Rupelian, Castelgomberto, Vicentin Lessini Mountains, Italy). Sample AC 13; x 11 (IPUM 24927).
Fig. 5 - *Actinacis rollei* Reuss. Calical polished section (Rupelian, Castelgomberto, Vicentin Lessini Mountains, Italy). Sample AC 9; x 16 (IPUM 24928).
Fig. 6 - *Actinacis rollei* Reuss. Calical polished section (Rupelian, Castelgomberto, Vicentin Lessini Mountains, Italy). Sample AC 6; x 14 (IPUM 24929).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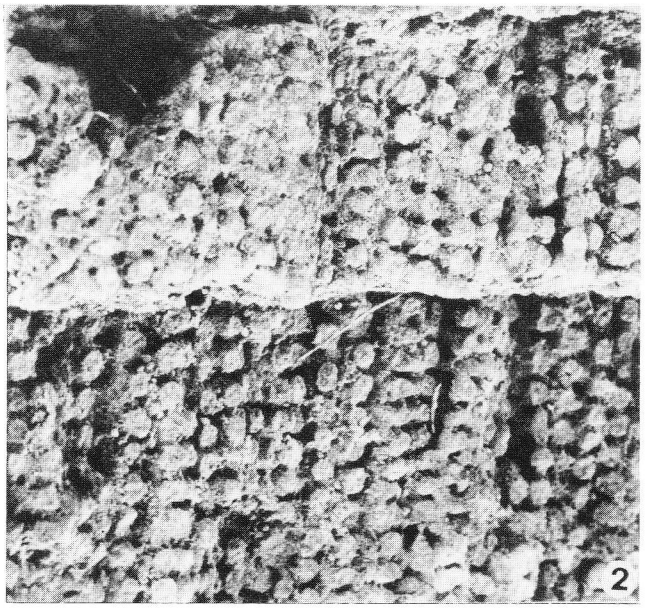
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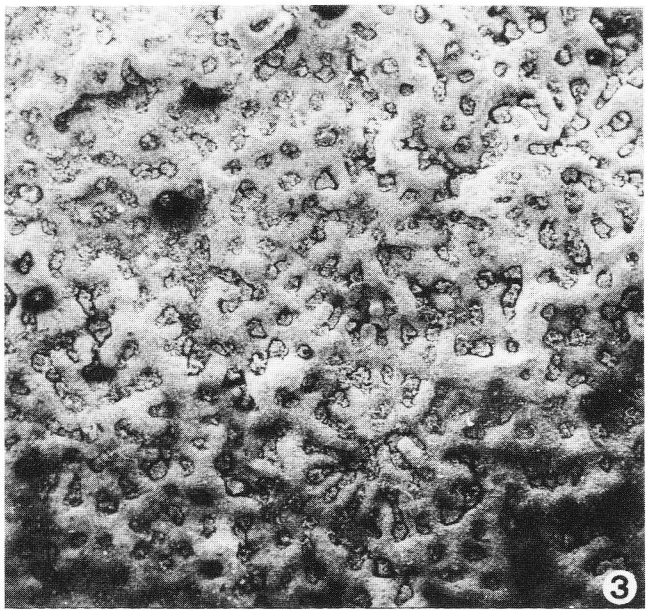
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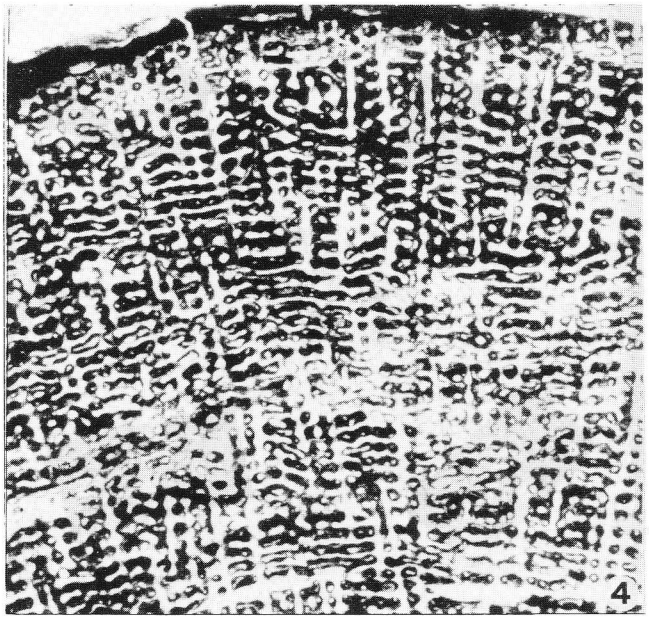
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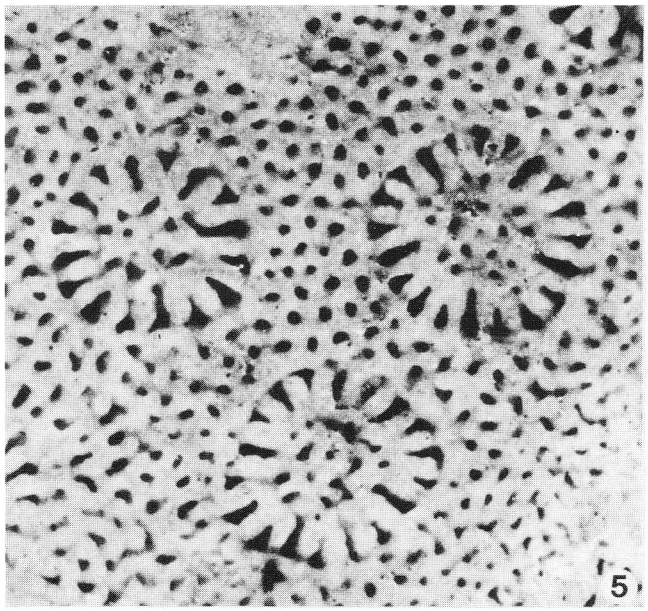
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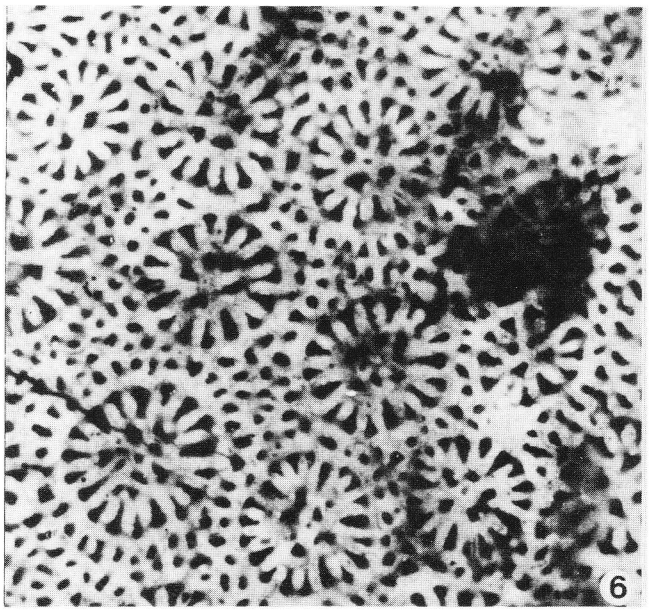
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1913 *Actinacis deperdita* - Oppenheim, p. 169.
1913 *Actinacis lobata* - Oppenheim, p. 170.
1913 *Actinacis Michelottii* - Oppenheim, p. 170.
1925 *Actinacis rollei* - Felix, pars 28, p. 262.
1937 *Actinacis* n. sp. cfr. *delicata* Zuffardi Comerci, p. 289, pl. 26, fig. 5.
1958 *Actinacis* n. sp. cfr. *delicata* - Azzaroli, p. 90.
1967b *Actinacis rollei* - Kolosvary, p. 211, fig. 7.
v. 1979 *Actinacis* sp. Russo, p. 43, pl. 2, fig. 2; text-fig. 5, 6.
v. 1980 *Actinacis rollei* - Pfister, p. 62, pl. 4, fig. 2-4.
1981 *Actinacis rollei* - Frost, p. 531.
v. 1985 *Actinacis rollei* - Pfister, p. 195.
1987 *Actinacis* cfr. *rollei* Fravega, Giammarino, Piazza, Russo & Vannucci, p. 33.
v. 1988 *Actinacis rollei* - Bosellini F.R., p. 124, pl. 1, fig. 5.
1988 *Actinacis rollei* - Bosellini F.R. & Russo, p. 387, text-fig. 3.
1988 *Actinacis rollei* - Bosellini F.R., Luciani, Russo & Sirotti, p. 362.
1989 *Actinacis rollei* - Luciani, p. 298.
1992 *Actinacis* cfr. *rollei* - Hladil, Otava & Galle, p. 1408, pl. 1, fig. 1, 2.
1992 *Actinacis rollei* - Darga, p. 76, pl. 15, fig. 4.

Material. *Actinacis lobata* (Coll. de Angelis, MPUR i. 2802). *Actinacis Michelottii* (Coll. de Angelis, MPUR i. 3274). *Actinacis rollei* (Coll. Pfister, NMB B1680). *Actinacis rollei* (Coll. Russo, IPUM 19179-19180). *Actinacis rollei* (Coll. Bosellini, IPUM 21756 a-h).

Colonies of *Actinacis rollei* have also been collected near Nago, Garda Lake, Trento (IPUM 24930), in the Vicentin Lessini Mountains, Castelgomberto (IPUM 24924, 24927, 24928, 24929), in the area of Cairo Montenotte, Liguria (IPUM 24931, 24932) and in the Salento Peninsula, Apulia region (IPUM 24925, 24926).

Description. Colony form branched, ramose-dendroid, encrusting, dome-shaped or massive (Bosellini F.R. & Russo, 1988, text-fig. 3), and large from few cm to 70-80 cm. Colony plocoid, extratentacular budding. Corallites are circular in outline and their diameter varies from 0.9 to 1.6 mm. Septa, 14-20 in number, are organized in a pentameral symmetry (Fig. 3), with one secondary septum and two tertiary septa arranged to form a triplet. Five triplets, in front of which are disposed five triangular pali, have been recognized in corallites with 20 septa. As regards primary septa, three S1 have ovaliform pali in front of them while the remaining two are free (Fig. 3). The columella is central and styliform. The wall is discontinuous with button-like structures in correspondence with septa.

The coenosteal reticulum appears to be trabecular on the calicinal surface, while it is irregular and/or vermiform if observed in deeper or tangential section.

Size of main diagnostic characters is given in Fig. 3.

Occurrence. Eocene. Early Priabonian. Eisenrichtersteins near Hallthurm, Bavaria, Germany (Darga, 1992). Late Priabonian. Italy: Possagno, Treviso (Russo, 1979); Monte Baldo (Bosellini F.R. et al., 1988); Nago (Luciani, 1989). Oligocene. Rupelian. Italy: Castelgomberto, Montecchio, Bastia, Vicentin Lessini Mountains (Reuss, 1868; de Angelis, 1894; Frost, 1981; Bosellini F.R., 1988; Bosellini F.R. & Russo, 1988); S. Luca, Crosara Laverda, Calvene, Marostican region, Vicenza (d'Achiardi, 1868; Reuss, 1869, 1874; Pfister, 1980). Reit im Winkel, Bavaria, Germany (Reis, 1889). Neustift, Steiermark, Austria (Reuss, 1864). Poljsica near Kranj, Slovenia (Kolosvary, 1967b). Early Chattian. Cairo Montenotte and Sassello, Liguria, Italy (d'Achiardi, 1868; Michelotti, 1871; de Angelis, 1894; Pfister, 1985; Fravega et al., 1987). Sirt Basin, Libya (Hladil et al., 1992). Middle Chattian. Castro, Salento Peninsula, Apulia region, Italy (Bosellini F.R. & Russo, 1992). Oligocene of Somalia (Zuffardi Comerci, 1937; Azzaroli, 1958).

Family *Poritidae* Gray, 1842

Genus *Goniopora* de Blainville, 1830

Type species: *Goniopora pedunculata* de Blainville, 1830

Goniopora oblita (Michelotti, 1871)

Pl. 3, fig. 6

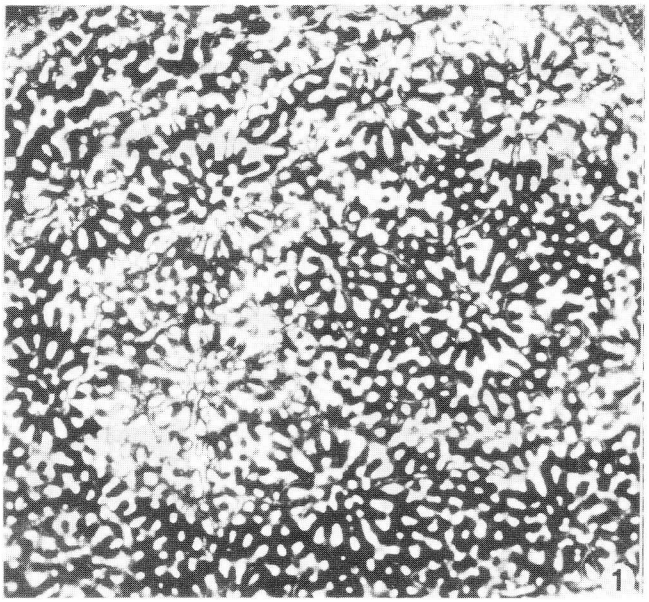
v. 1871 *Actinacis oblita* Michelotti in Sismonda, p. 28, pl. 9, fig. 9,10.
1894 *Actinacis oblita* - de Angelis, p. 184.
v. 1894 *Actinacis elongata* de Angelis, p. 184, pl. 1, fig. 6, 7.
1927 *Actinacis oblita* - Felix, p. 466.
1927 *Actinacis elongata* - Felix, p. 465.

Material. *Actinacis oblita* (Coll. Michelotti, MPUR 2985, 3 specimens, holotype). *Actinacis elongata* (Coll. de Angelis, MPUR 1647, 9 specimens, holotype).

Description. Branching to massive-digitated growth forms. Colony cerioid to subplocoid, extraten-

PLATE 3

Fig. 1 - *Actinacis rollei* Reuss. Calical thin section (Rupelian, Castelgomberto, Vicentin Lessini Mountains, Italy). Sample AC 13; x 10 (IPUM 24927).
Fig. 2 - *Astreopora perelegans* (Oppenheim). Specimen view (Late Cuisian-Early Lutetian, Noax and Rocca Bernarda, Friuli, Italy). Coll. Dainelli: IGF 3540E; x 3.
Fig. 3 - *Astreopora perelegans* (Oppenheim). Calical surface (Late Cuisian-Early Lutetian, Noax and Rocca Bernarda, Friuli, Italy). Coll. Dainelli: IGF 3540E; x 10.
Fig. 4 - *Astreopora perelegans* (Oppenheim). Calical surface (Late Cuisian-Early Lutetian, Noax and Rocca Bernarda, Friuli, Italy). Coll. Dainelli: IGF 3540E. SEM photograph; x 23.
Fig. 5 - *Astreopora perelegans* (Oppenheim). Calical thin section (Late Cuisian-Early Lutetian, Russiz, Friuli, Italy). Coll. Dalla Vecchia; x 16 (IPUM 24933).
Fig. 6 - *Goniopora oblita* (Michelotti). Calical surface (Tortonian, Stazzano, Alessandria, Italy). Coll. Michelotti: MPUR 2985, holotype; x 11.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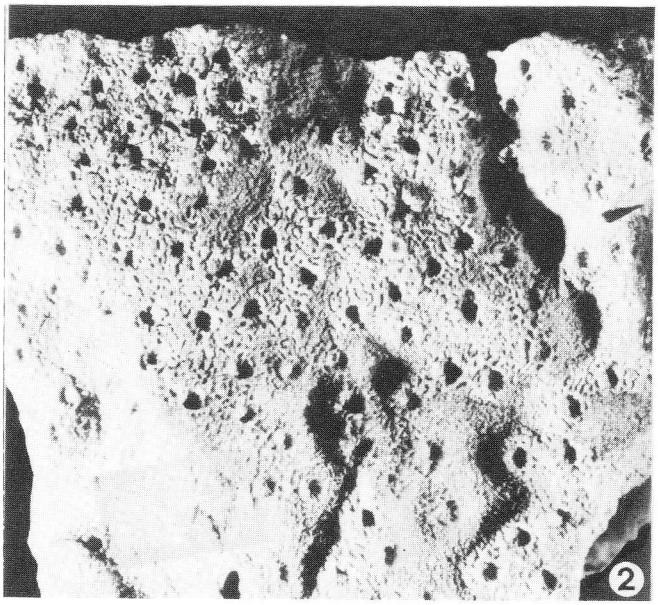
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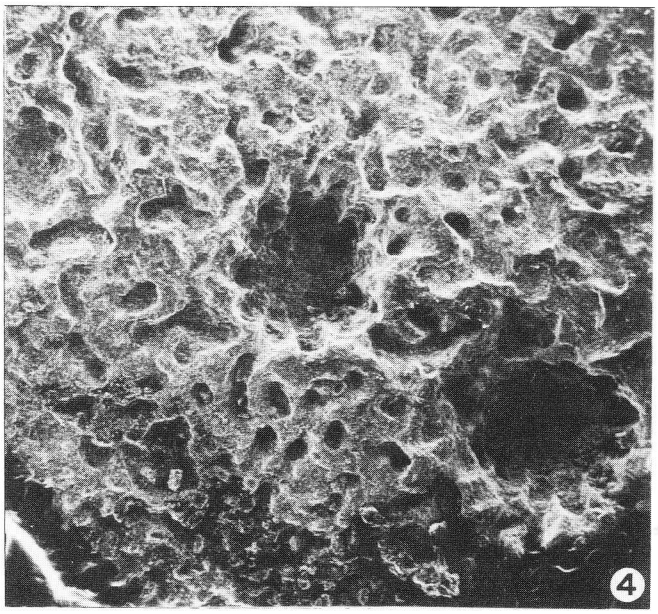
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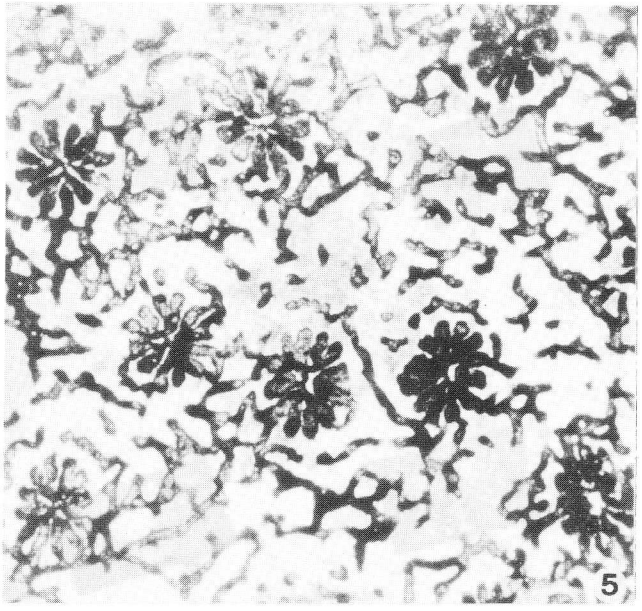
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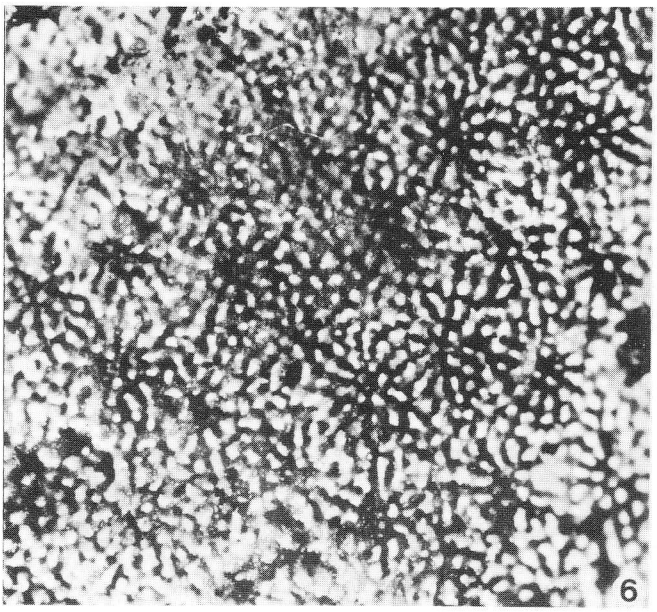
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tacular budding. Calices are round to polygonal in outline, diameter 1.5-1.8 mm. Septa, 16 to 24, are porous and arranged in three cycles. Primary septa reach the columella, which frequently consists of one papilla, and bear a crown of paliform lobes. Secondary septa are often fused with S 1, while tertiary septa are confined to the corallite margin. The coenosteum is scarcely and irregularly developed.

Remarks. The description of the holotype of Michelotti (*oblita*) and the holotype of de Angelis (*elongata*) clearly reveals that these species do not show the characters typical of the genus *Actinacis*. Both are cerioid and without the trabecular coenosteum well recognized in *Actinacis* species. The present revision indicates *A. elongata* as a synonym of *G. oblita*; however, a more detailed examination of the literature is necessary in order to establish whether the species created by Michelotti is synonymous with previous species.

Occurrence. Miocene. Tortonian. Stazzano and Sant'Agata, Tortona, Alessandria, Italy (Michelotti, 1871; de Angelis, 1894).

Suborder **Astrocoeniina** Vaughan & Wells, 1943

Family *Acroporidae* Verrill, 1902

Genus *Astreopora* de Blainville, 1830

Type species: *Astrea myriophthalma* Lamarck, 1816

Astreopora perelegans (Oppenheim, 1901)

Pl. 3, fig. 2-5

1901 *Actinacis perelegans* Oppenheim, p. 181, pl. 12, fig. 14, 14a.
v. 1915 *Actinacis perelegans* - Dainelli, p. 219, pl. 27, fig. 7-8; pl. 28, fig. 8.
1925 *Actinacis perelegans* - Felix, pars 28, p. 262.

Material. *Actinacis perelegans* (Coll. Dainelli, IGF 3539E-3541E). Several colonies from the private collection of Dr. F.M. Dalla Vecchia (IPUM 24933, 24934, 24935, 24936, 24937, 24938).

Description. Laminar, encrusting growth form. Colony plocoid, extratentacular budding. Calices are circular, widely spaced, and do not exceed 1 mm in diameter. Septa are 12, slightly crowded and arranged in hexameral symmetry. Paliform lobes have been recognized in front of primary septa. The columella is weak or absent. Meandroid-reticular coenosteum.

Remarks. The description of the holotype (Oppenheim, 1901) indicates the occurrence of twelve septa arranged in two cycles and the presence of six small pali surrounding a small button-like columella. The author also describes a vermiform coenosteum. However, a careful examination of the illustration of Oppenheim clearly reveals that the pali described by the author are actually paliform lobes and that the columella is extremely weak.

The study of the specimens of Dainelli and of some topotypes clearly indicates that the shape and structure of septa, the septal pattern, the type of coenosteum, the occurrence of paliform lobes and the weak or absent columella, do not belong to the genus *Actinacis* but are rather typical of the genus *Astreopora*.

Occurrence. Eocene. Late Cuisian-Early Lutetian. Cormons, Russiz, Noax, Rosazzo, Col dei Soldi, Buia, Meduno, Friuli, Italy (Oppenheim, 1901; Dainelli, 1915).

Identification of Italian species.

The detailed systematic revision of all the twelve Tertiary Italian species of *Actinacis* described in the literature reveals that only three of them actually belong to the genus and leads to the recognition of several diagnostic criteria for species identification (Fig. 3).

The distinction between the three different species of *Actinacis*, i.e. *A. cognata*, *A. possagnensis* and *A. rollei*, is based on three main distinctive characters: septal pattern, disposition of pali, and corallite diameter (Fig. 2a, 3). The three species clearly show a differ-

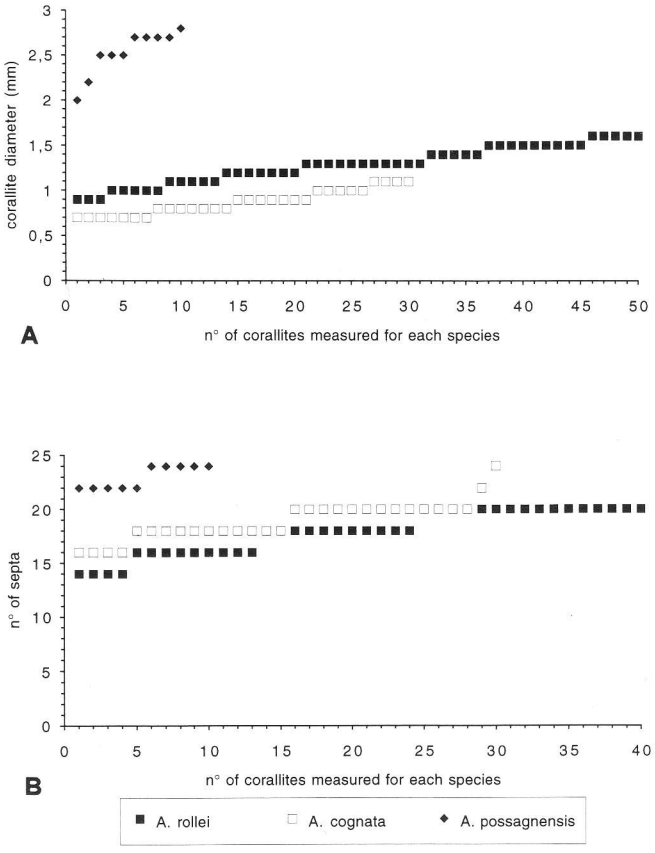


Fig. 2 - Comparison of the three established species of *Actinacis* by plot diagrams of measurements of corallite diameter (A) and number of septa per corallite (B).

KEY TO IDENTIFICATION

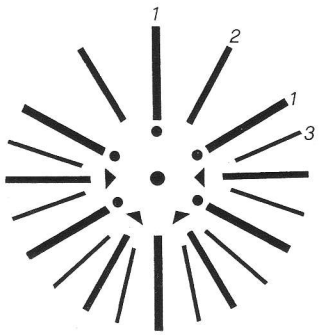
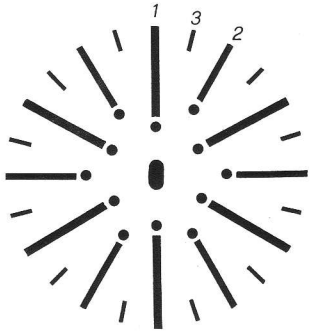
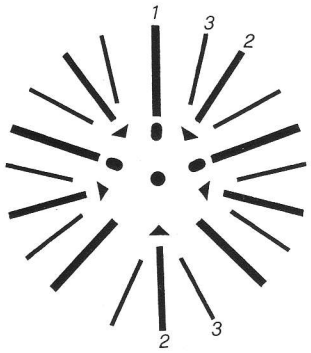
	Actinacis cognata	*Actinacis possagnensis*	*Actinacis rollei*
SIZE OF CHARACTERS	NS =16-24 CD = 0.7-1.1 mm CS = 0.3-0.7 mm max L1 = 0.3 mm max L2 = 0.2 mm max L3 = 0.1 mm PT = 0.07 mm CT = 0.05 mm TT = 0.05 mm	NS = 22-24 CD = 2-2.8 mm CS = 0.5-1.5 mm max L1 = 1.1mm max L2 = 0.8 mm max L3 = 0.3 mm PT = 0.1-0.2 mm CT = 0.3-0.5 mm TT = 0.2-0.3mm	NS = 14-20 CD = 0.9-1.6 mm CS = 0.4-0.9 mm max L1 = 0.4 mm max L2 = 0.3 mm max L3 = 0.1-0.2 mm PT = 0.1 mm CT = 0.05 mm TT = 0.07 mm
SEPTAL PATTERN			

Fig. 3 - Proposed scheme for identification of Tertiary Italian and European species of *Actinacis*. Range of values or average size of main diagnostic characters and schematic view of the septal arrangement are indicated for each species. Abbreviations are the same as those used in Fig. 1.

ent septal arrangement in particular as concerns the development and number of triplets and disposition and shape of pali. Moreover, *A. rollei* exhibits a visible pentameral symmetry, while *A. cognata* and *A. possagnensis* are characterized by an hexameral symmetry. As regards size of main characters, only the corallite diameter clearly distinguishes the three species, while measurements of the total number of septa indicate that only *A. possagnensis* is significantly different (Fig. 2).

The type of coenosteal reticulum (trabecular, irregular or vermicular), largely used by previous authors as one of the most distinctive characters, is very variably affected by conditions of preservation and therefore it should not be used as a main character for species identification.

Remarks on other species.

After careful review of the available literature, some remarks are given for those remaining species described as belonging to the genus *Actinacis* and not included in the synonymies of the previous systematic part. None of the following species has ever been described from the Tertiary of Italy.

- *Actinacis lata* Gregory, 1930 (p. 122, pl. 15, fig. 4a,b; pl. 16, fig. 6). Paleocene of Samana Range, Thal (Pakistan). The author describes two cycles of septa, which are well developed in length, slender and slightly undulating, and the occurrence of one crown of pali and epitheca. In our opinion, the presence of true pali is questionable as in the illustration of pl. 16, fig. 6, the pali look more like paliform lobes. Moreover, the genus *Actinacis* is always characterized by short and straight septa arranged in three cycles. Consequently, the characters described by Gregory are not typical of *Actinacis* and the species *A. lata* more probably belongs to the genus *Astreopora*.

- *Actinacis maitlandi* Gregory & Trench, 1916 (p. 529, pl. 21, fig. 1, 2). Lutetian of Fly River, Central New Guinea. According to the illustration of pl. 21, fig. 2a, this species certainly belongs to the genus *Actinacis* due to the presence of triangular pali in front of well defined triplets and ovaliform pali in front of S1, and of trabecular coenosteum. This species has been found also in the Late Paleocene-Early Eocene of Java, Indonesia (Russo, unpublished data).

- *Actinacis paronai* Zuffardi Comerci, 1940 (p. 208, text-fig. 34). Oligocene of Libya. The remarks on

SPECIES	SYNONYMIES
Actinacis alabamiensis (Vaughan, 1900)	= *A.sawkinsi* Wells, 1934 (*fide* Budd et al., 1992)
Actinacis barretti Wells, 1934	= *A.* cf. *barretti* Frost & Langenheim, 1974
Actinacis caribiensis Frost & Langenheim, 1974	
Actinacis cognata Oppenheim, 1901	= *A.delicata* d'Achiardi, 1875; Felix, 1909; nec Reuss, 1869 *A.delicatula* Oppenheim, 1899 ? *A.digitata* Fritsch, 1878; van Cappelle, 1855 *A. gallemii* Reig Oriol, 1990 *A. gomezalbai* Reig Oriol, 1990 *A. phineus* Kolosvary, 1956 *A. subrollei* Oppenheim, 1901
?*Astreopora lata* (Gregory, 1930)	= *Actinacis lata* Gregory, 1930
Actinacis maitlandi Gregory & Trench, 1916	
?*Turbinaria noetlingi* (Dalton, 1908)	= *Actinacis noetlingi* Dalton, 1908
Goniopora oblita (Michelotti, 1871)	= *Actinacis oblita* Michelotti, 1871; de Angelis, 1894; Felix, 1927 *Actinacis elongata* de Angelis, 1894; Felix, 1927
?*Porites paronai* (Zuffardi Comerci, 1940)	= *Actinacis paronai* Zuffardi Comerci, 1940
?*Astreopora parvulina* (Eliasova, 1974)	= *Actinacis parvulina* Eliasova, 1974
Astreopora perelegans (Oppenheim, 1901)	= *Actinacis perelegans* Oppenheim, 1901; Dainelli, 1915 Felix, 1925
Actinacis possagnensis Oppenheim, 1900	
Actinacis rollei Reuss, 1864	= *A.arborescens* d'Achiardi, 1868 *A.conferta* Reuss, 1868; d'Achiardi, 1868 *A.delicata* Reuss ,1869; Oppenheim, 1913 *A.deperdita* Michelotti in Sismonda, 1871; de Angelis, 1894; Oppenheim, 1913 *A.lobata* de Angelis, 1894; Oppenheim, 1913 *A.michelottii* de Angelis, 1894; Oppenheim, 1913 *Porites polystyla* Reuss, 1874

Tab. 2 - List of revised and established species. Their synonyms are also indicated.

this species are based on the original brief description and inadequate illustration. However, the author describes 12 septa while the presence of pali is not verifiable. Recently, Hladil et al. (1992, pl. 8, fig. 1, 2) illustrated this species for the Oligocene of the Sirt Basin, Libya, and the presence of two cycles of septa is confirmed. This character does not allow this species to be assigned to the genus *Actinacis*, and illustrations clearly show morphologic features more similar to the genus *Porites*.

- *Actinacis parvulina* Eliasova, 1974 (p. 137, pl. 3, fig. 6; text-fig. 15). Late Eocene of Kurdejov, Hustopece, Southern Moravia, Czech. Rep. The description and especially the illustration of text-fig. 15 clearly indicate that this species is characterized by two cycles of compact and slightly crowded septa, and by the absence of pali and columella. In our opinion, these characters are more typical of the genus *Astreopora*.

- *Actinacis noetlingi* Dalton, 1908 (p. 622, pl. 54, fig. 1). Miocene of Burma. This species is characterized by exsert corallites, 3.5 mm in diameter, wide corallite spacing and abundant coenosteum, crowded septa arranged in three cycles and absence of triplets. These characters, together with the illustration given by Dalton, indicate that this species could better belong to the genus *Turbinaria* rather than *Actinacis*.

- Concerning the Caribbean species, descriptions and figures illustrated in Wells (1934), in Frost and Langenheim (1974) and in Budd et al. (1992) respectively for *Actinacis barretti*, *Actinacis caribiensis* and *Actinacis alabamiensis*, clearly confirm that the three species show characters belonging to the genus *Actinacis*. As regards *A. sawkinsi*, it is considered synonymous with *A. alabamiensis* according to Budd et al. (1992).

Taking into account the systematic revision of Italian and European species of *Actinacis* and the above listed remarks, a scheme of synonymies is proposed (Tab. 2) together with a table of occurrences (Fig. 4).

OCCURRENCES	*A. alabamiensis*	*A. barretti*	*A. caribiensis*	*A. cognata*	*A. maitlandi*	*A. possagnensis*	*A. rollei*	AGE
Antigua, Caribbean	x							Late Oligocene
Salt Mountain, Alabama	x							Late Oligocene
Georgia, U.S.A.	x							Late Oligocene
Castro, Salento Peninsula, Italy							x	Middle Chattian
Sirt Basin, Libya							x	Early Chattian
Liguria, Italy							x	Early Chattian
Poljsica, Slovenia							x	Rupelian
Neustift, Steiermark, Austria							x	Rupelian
Reit im Winkel, Bavaria, Germany							x	Rupelian
Marostican region, Italy							x	Rupelian
Vicentin Lessini Mountains, Italy							x	Rupelian
Somalia							x	Oligocene
Nago and Monte Baldo, Veneto, Italy							x	Late Priabonian
Possagno, Treviso, Italy						x	x	Late Priabonian
Hallthurm, Bavaria, Germany							x	Early Priabonian
Bükk Mountains, Hungary				x				Late Eocene
Precista, Rep. Macedonia				x				Late Eocene
Lago Alahuela, Central Panama	x							Late Eocene
Southern Moravia, Rep. Czecho.				x				Middle-Late Eocene
Igualada, Catalonia, Spain				x				Middle-Late Bartonian-Early Priabonian
Konjavac, Herzegovina				x				Middle Eocene
Rosici and Megjigja, Bosnia				x				Middle Eocene
Chiapas, Mexico			x					Middle Eocene
St.Bartholomew, Jamaica	x	x						Middle Eocene
Bu-Meriam, Libya				x				Lutetian
Crni Kal, Slovenia				x				Lutetian
Fly River, Central New Guinea					x			Lutetian
Friuli, Italy				x				Late Cuisian-Early Lutetian
? Borneo				x				Eocene
Java, Indonesia				x	x			Late Paleocene-Early Eocene
Dolenja vas, Slovenia				x				Late Danian

Fig. 4 - Table of occurrences, with relative age, of Tertiary *Actinacis* species established both by a systematic revision and a careful review of the available literature.

Conclusions.

A detailed systematic study has been carried out for those twelve *Actinacis* species described in the literature from the most famous Tertiary reef sites of Italy. Our revision indicates that only three species, *A. cognata*, *A. possagnensis* and *A. rollei*, show morphologic characters typical of the genus *Actinacis*. Moreover, the combination of the established main diagnostic features (septal pattern, disposition of pali, corallite diameter and, to a lesser degree, total number of septa) provides a relatively easy and reliable method for identification of species.

A quite detailed stratigraphic distribution has been traced for *Actinacis* species established by the systematic revision, while ranges given for species whose

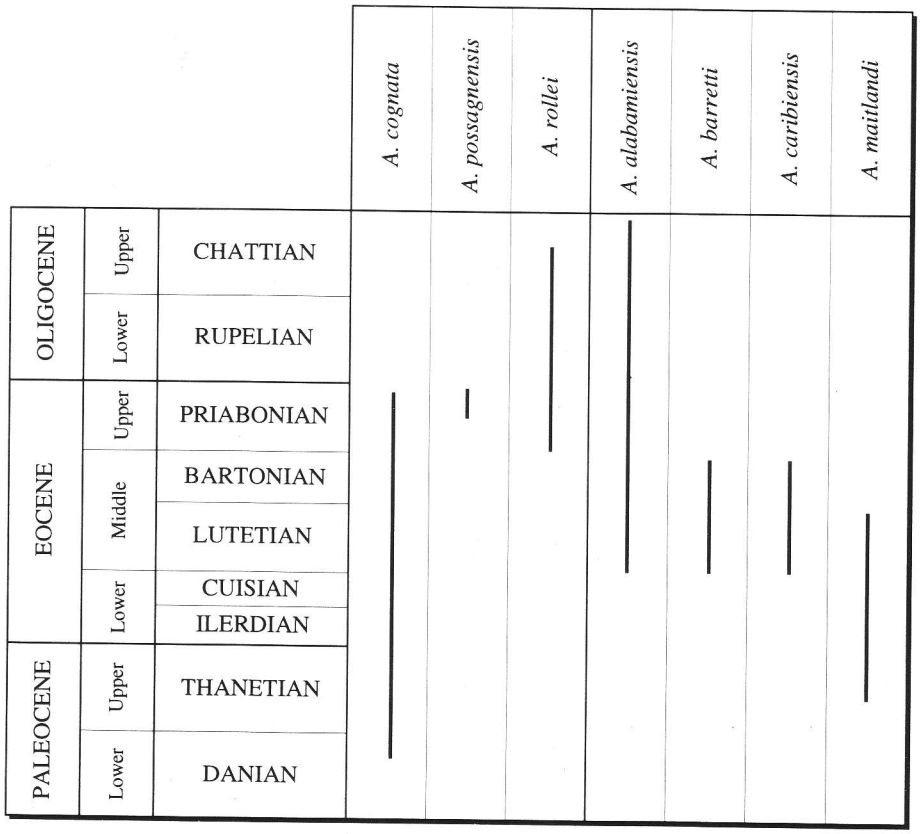


Fig. 5 - Stratigraphic distribution scheme of the established *Actinacis* species during Tertiary time. Ranges given for species whose taxonomic identification and stratigraphic distribution have been deduced from literature (*A. alabamiensis, A. barretti, A. caribiensis, A. maitlandi*) must be considered to be approximate.

taxonomic identification and stratigraphic distribution have been deduced from literature must be considered to be approximate (Fig. 5).

Preliminary examination of the stratigraphic and geographic distribution of *Actinacis* species suggests the following.

1) The Tertiary distribution of the genus ranges from Late Paleocene to Late Oligocene (from Late Cuisian to Middle Chattian as regards Italy).

2) The highest species diversity occurred during the Middle Eocene, when the genus consisted of a relatively large number of geographically restricted species.

3) Only two widespread species, *A. rollei* for the western Tethys and *A. alabamiensis* for the Caribbean, survived the Eocene/Oligocene turnover and extended until Late Oligocene.

4) The global Late Oligocene extinction of the genus is confirmed by our revision of *Actinacis* species previously ascribed to the Miocene and by the recent detailed compilation of Neogene Caribbean corals (Budd et al., 1994) which do not include *Actinacis* species.

5) As regards Italian and European coral reef communities, stratigraphic distribution together with palaeoecologic evidences show that *A. rollei* replaced *A. cognata* as a major frame-builder from the very Late Eocene.

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