APTIAN AND ALBIAN TETRAGONITIDAE (AMMONOIDEA) FROM NORTHERN CALIFORNIA

BY

MICHAEL A. MURPHY

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ABBREVIATIONS USED IN TEXT

CAS = California Academy of Sciences
ANSP = Academy of Natural Sciences of Philadelphia
UCB = University of California, Berkeley
UCLA = University of California, Los Angeles
UCR = University of California, Riverside
SOC = Shell Oil Company
USGS = United States Geological Survey
MC = Maurice Collignon Collection Moirans (Isère), France

Unless specified otherwise, all locality numbers given in the text refer to specimens in the University of California, Museum of Paleontology, Riverside.

APTIAN AND ALBIAN TETRAGONITIDAE (AMMONOIDEA) FROM NORTHERN CALIFORNIA

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ABSTRACT

The Family Tetragonitidae constitutes an important element of the Aptian and Albian ammonite faunas of northern California. The following genera are present: *Eogaudryceras, Anagaudryceras, Zelandites, Gabbioceras, Eotetragonites,* and *Tetragonites.* The *wintunius* zone (upper Aptian) and the *lecontei* and *hulenense* zones (lower Albian) are especially characterized by abundant and short-ranging species of the family.

The taxonomic position of the genera *Eogaudryceras, Anagaudryceras, Gabbioceras,* and *Eotetragonites* is reviewed. These taxa are all retained at the generic level.

One new species, *Eotetragonites shoupi,* is described from the middle *wintunius* zone, and occurrences of *Zelandites, Anagaudryceras,* and *Protetragonites* are reported from Albian strata.

INTRODUCTION

THE FAMILY TETRAGONITIDAE constitutes an important element of Cretaceous ammonite faunas from the Aptian through the Maestrichtian. Near Ono in northern California members of the family are especially abundant in strata of Aptian and Albian ages and are represented by the following genera: *Tetragonites, Eotetragonites, Gabbioceras, Eogaudryceras, Anagaudryceras, Zelandites, Gaudryceras,* and *Pseudophyllites. Kossmatella* has been reported, but both species referred to this genus are here assigned to *Anagaudryceras* and *Eotetragonites.*

Eotetragonites wintunius (Anderson), the stratigraphically lowest species of the family in the Ono district sequence occurs in the upper Aptian *E. wintunius* zone. *Gabbioceras, Eogaudryceras,* and *Tetragonites* also occur in upper Aptian strata just above *Eotetragonites. Eogaudryceras* ranges into the early Albian. *Anagaudryceras* with fold ribs first occur in the early Albian. This genus probably is derived from *Eogaudryceras* at about this time. A single occurrence of the genus *Gabbioceras* is recorded from lower Albian strata.

In Upper Cretaceous strata the family is represented by a few isolated specimens of *Pseudophyllites, Tetragonites, Zelandites, Gaudryceras,* and *Anagaudryceras.* These have been discussed by Matsumoto (1959*b*) in his recent comprehensive report on Upper Cretaceous ammonites from California.

This study was initiated to rectify the problem created by the citation of two holotypes for *Gabbioceras wintunium* Anderson (1938, pls. 15, 16). These two specimens obviously belong to different species, but their proper allocation necessitated a review of the entire family. This review included museum study of the type specimens as well as other collections and was supported by the University of California, Riverside, Intramural Research Fund. Field work was supported by a grant of the National Science Foundation and the Humble Oil & Refining Com-

pany. Kenneth Middleham, University of California, Riverside, did the photography. Acknowledgments are also due General Maurice Collignon; J.-P. Thieuloy, Faculté des Sciences, Grenoble; G. Thomel, Faculté des Sciences, Nice; R. Busnardo, Faculté des Sciences, Lyon; M. K. Howarth, British Museum (Natural History); Joseph Peck, University of California, Berkeley; Horace Richards, The Academy of Natural Sciences, Philadephia; L. G. Hertlein and G. D. Hanna, California Academy of Sciences; Mahlon Kirk, Shell Oil Company, for the loan of material and other courtesies. T. Matsumoto and C. W. Wright advised me on several problems.

Family TETRAGONITIDAE Hyatt, 1900

The members of the Family Tetragonitidae are characterized by the following: (1) a suture that has a bifid lateral lobe like *Lytoceras,* but with several auxiliary elements added; (2) a lirate ornamentation usually with constrictions; and (3) moderately involute coiling.

The major subdivisions of the family are based on the character of the suture line, especially the number of saddles in the internal suture, as well as the whorl shape (Gabbioceratinae) and ornamentation (Kossmatellinae). Genera are identified by whorl shape, special character of the ornamentation, and minor differences in the suture line.

Wright (1957, pp. L200–L203) recognized three subfamilies of the Tetragonitidae: Gaudryceratinae (including Hypogaudryceratinae); Kossmatellinae with the single genus *Kossmatella;* Tetragonitinae (including Gabbioceratinae).

Wiedmann (1962*a*, p. 150) subsequently erected the Subfamily Vertebritinae, based on the genus *Vertebrites.* He has also suppressed Kossmatellinae, placing *Kossmatella* in the Gaudryceratinae, and resurrected Gabbioceratinae. I have adopted Wiedmann's classification for reasons explained in the text.

Three subfamilies are present in the Aptian-Albian sequence of the Ono district: Gaudryceratinae Spath, 1927, generally regarded as the lineage from which the others were derived (Barremian-Maestrichtian); Tetragonitinae Hyatt, 1900 (Aptian-Maestrichtian); Gabbioceratinae Breistroffer, 1947 (Aptian-Cenomanian).

The classification adopted here is modified from previous ones in light of the information gained from the study of the California members of the family. It is summarized below.

Subfamily Gaudryceratinae Spath, 1927
- *Eogaudryceras* Spath, 1927
- *Anagaudryceras* Shimizu, 1934
- *Gaudryceras* de Grossouvre, 1894
- *Zelandites* Marshall, 1926
- *Kossmatella* Jacob, 1907
- *Parajaubertella* Matsumoto, 1943

Subfamily Tetragonitinae Hyatt, 1900
- *Eotetragonites* Breistroffer, 1947
- *Tetragonites* Kossmat, 1895
- (*Saghalinites*) Wright & Matsumoto, 1954
- *Pseudophyllites* Kossmat, 1895

Subfamily Gabbioceratinae Breistroffer, 1953
Gabbioceras Hyatt, 1900
Jauberticeras Jacob, 1907
Subfamily Vertebritinae Wiedmann, 1962
Vertebrites Marshall, 1926

Some of the genera in the foregoing list recently have been synonymized by Wiedmann. For example he regards *Gabbioceras* Hyatt, 1900 and *Parajaubertella* Matsumoto, 1943 as subjective synonyms (Wiedmann, 1962*b*, p. 9). He treats *Eotetragonites* Breistroffer, 1947 as a subgenus of *Eogaudryceras* Spath, 1927 (Wiedmann, 1962*c*, p. 44).

Where these generic names cover the same combination of morphologic characters, the classification should be revised. However when the intergradation is only postulated or is heterochronous, there is no real value in disturbing the present nomenclature. Thus I retain *Parajaubertella, Eotetragonites,* and *Anagaudryceras* while recognizing that transitional forms must and do occur between these and other genera.

Subfamily Gaudryceratinae Spath, 1927

Gaudryceratinae have a whorl shape that is characteristically rounded, reniform, or oval although departures are seen in the more compressed *Zelandites.* The shell is lirate or smooth with constrictions of various configurations, prominence and number forming the most prominent ornamentation patterns. Upper Cretaceous species have stronger ornamentation in the form of riblets and plication of the body chamber. The suture has more or less symmetrically bifid saddles and the internal suture usually has a single main saddle though some forms have additional small saddles in the internal suture.

These additional small saddles are actually part of the umbilical lobe. When the umbilical lobe is strongly retracted, they are not noticeably separate from the main internal saddle. If the umbilical lobe is not retracted the auxiliary saddles may develop into structures that are subequal in size to the principal internal saddle as in members of the Tetragonitinae and Gabbioceratinae. This phenomenon, however, does not manifest itself as early in the Gaudryceratinae as it does in the other subfamilies.

Three genera belonging to this subfamily occur in the Aptian and Albian strata of northern California. These are *Eogaudryceras, Anagaudryceras,* and *Zelandites.* The last is known only from a few poorly preserved fragments from the *Pseudouhligella dawsoni* zone and they are not discussed further in the text.

Figures 1, 2, and 3 illustrate the nomenclature used in this paper.

Genus *Eogaudryceras* Spath, 1927

Type species: *Eogaudryceras numidum* Coquand in Sayn, 1880.

Spath (1927), in designating the type of his genus, specified that it is the form from Blieux, Basses-Alpes, France, identified by Fallot (1920) as *Gaudryceras numidum,* which is to be the type of the Genus *Eogaudryceras.*

Several small specimens of *E. numidum* from Blieux in the Collection of M. Collignon show the species is quite variable with respect to the shape of the cross section (Fallot, 1920). G. Thomel has a large number of specimens of all sizes from

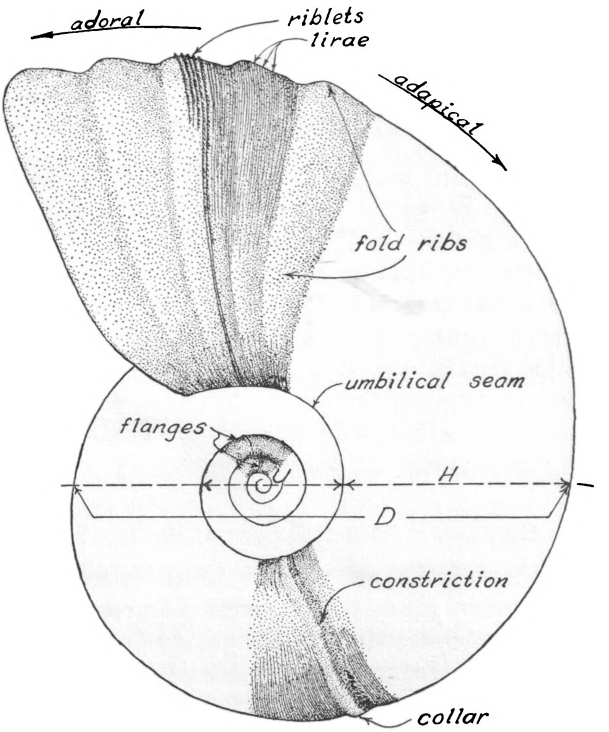


Fig. 1. Nomenclature of the tetragonitid shell, lateral view.

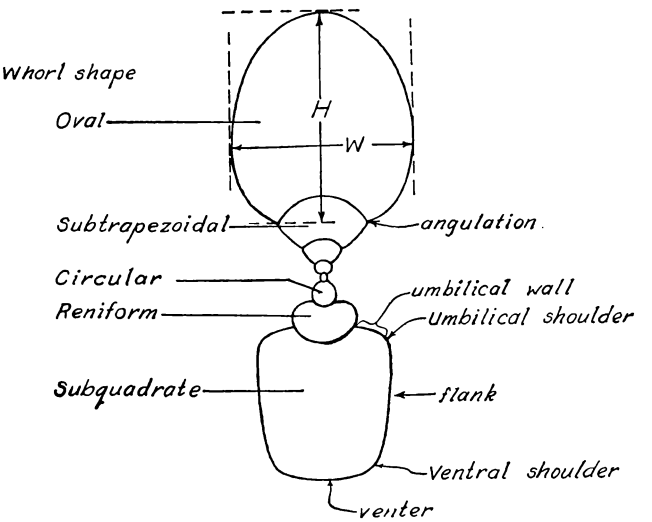


Fig. 2. Nomenclature of the tetragonitid shell in section.

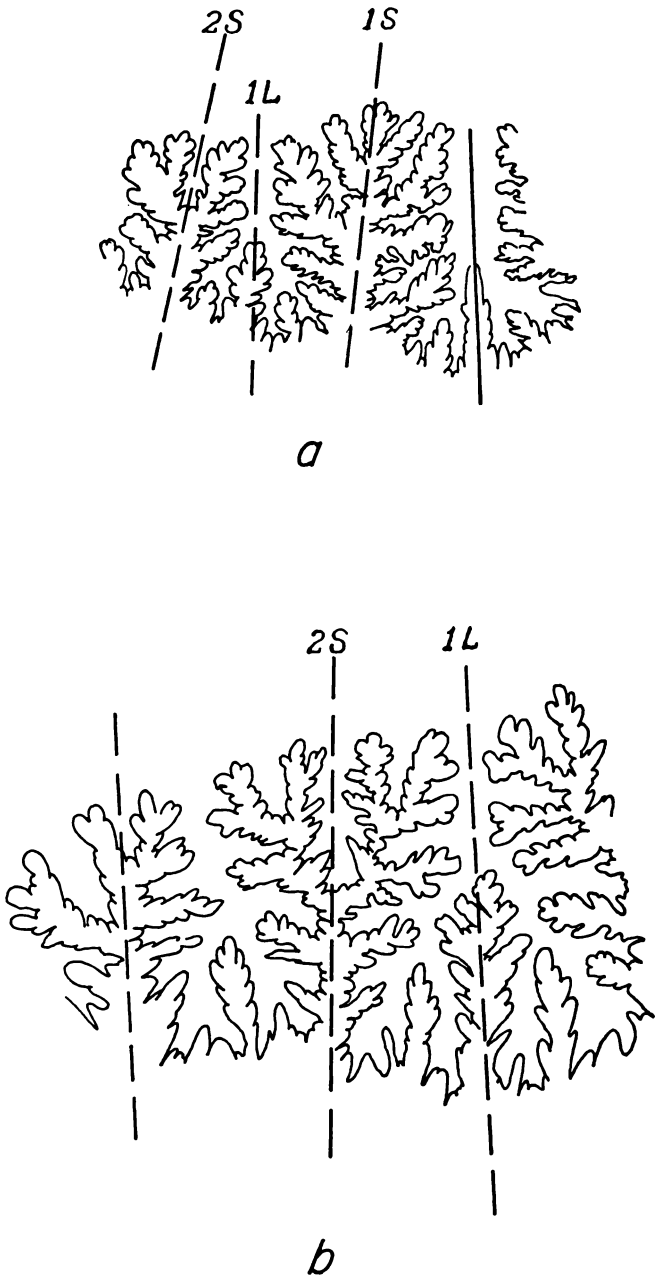


Fig. 3. Tetragonitid suture lines illustrating (*a*) a trifid first lateral saddle; a bifid second lateral saddle; an asymmetrically bifid first lateral lobe; and (*b*) a symmetrically bifid first lateral lobe and second lateral saddle. The third lateral saddle is termed irregularly bifid after Breistroffer.

neighboring localities which also show similar variability. In addition, Thomel's specimens show distinct constrictions on the larger shells. Constrictions, though very slight and irregularly developed, are present also on the younger whorls. This observation necessitates a change in the generic diagnosis given by Wright (1957, p. L200).

Eogaudryceras numidum has been cited as the central form from which almost all later members of the Tetragonitidae radiated. Thus it is the ancestor of *Eotetragonites, Jauberticeras, Gabbioceras, Gaudryceras,* and *Anagaudryceras.* Unfortunately the first two genera are its contemporaries, thus the stratigraphic record

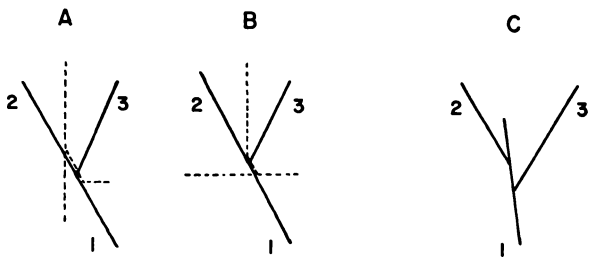


Fig. 4. Numbers refer to *Eogaudryceras* (1), *Gaudryceras* (2), and *Anagaudryceras* (3); letters refer to possible interpretations of their phylogeny; dashed lines separate the taxa. Interpretations A and B indicate *Eogaudryceras* becomes extinct by evolving into *Gaudryceras* before or after *Anagaudryceras* has split off; C, the interpretation adopted, shows *Eogaudryceras* living alongside its descendants.

does not yet support this interpretation even though morphology makes it the ideal ancestor and the extreme variation in the Gargasian of *Eogaudryceras numidum* is in keeping with this role.

Characteristics of Eogaudryceras numidum and the Gaudryceratinae.— See plate 5 for illustrations of the following discussion.

The shell of *E. numidum* has a rounded cross section that is oval to trigonal in the later whorls and reniform in earlier whorls. The apertural margin is slightly sinuous and the growth lines, lirae, constrictions, flanges, and collars are sigmoidal on the flanks and arch forward slightly on the venter. The shell is ornamented by very fine lirae on the umbilical wall, lower flank, and periphery. The midflank is generally smooth except for growth lines. Constrictions are variable in prominence, but on large shells they usually are more distinct than on small shells. Collars are only slightly developed or absent. The suture has a bifid 1S in the external suture and a single internal saddle, though some variants may show a second incipient internal saddle.

Albian members of *Eogaudryceras* develop collars such as are found in *E. aurarium* (Anderson).

The descendants that are most similar to *Eogaudryceras* are those classified as *Gaudryceras* and *Anagaudryceras.* Stronger collars develop in both genera and both also have strong ribs in adult whorls. The ornamentation of those forms leading to true *Gaudryceras* begins to show first in Albian forms such as *Gaudryceras* aff. *G. varagurense* Collignon (1963, p. 18) which shows a slight coarsening of the liration that is *continuous across the flank* and also a curvature of the ornamenta-

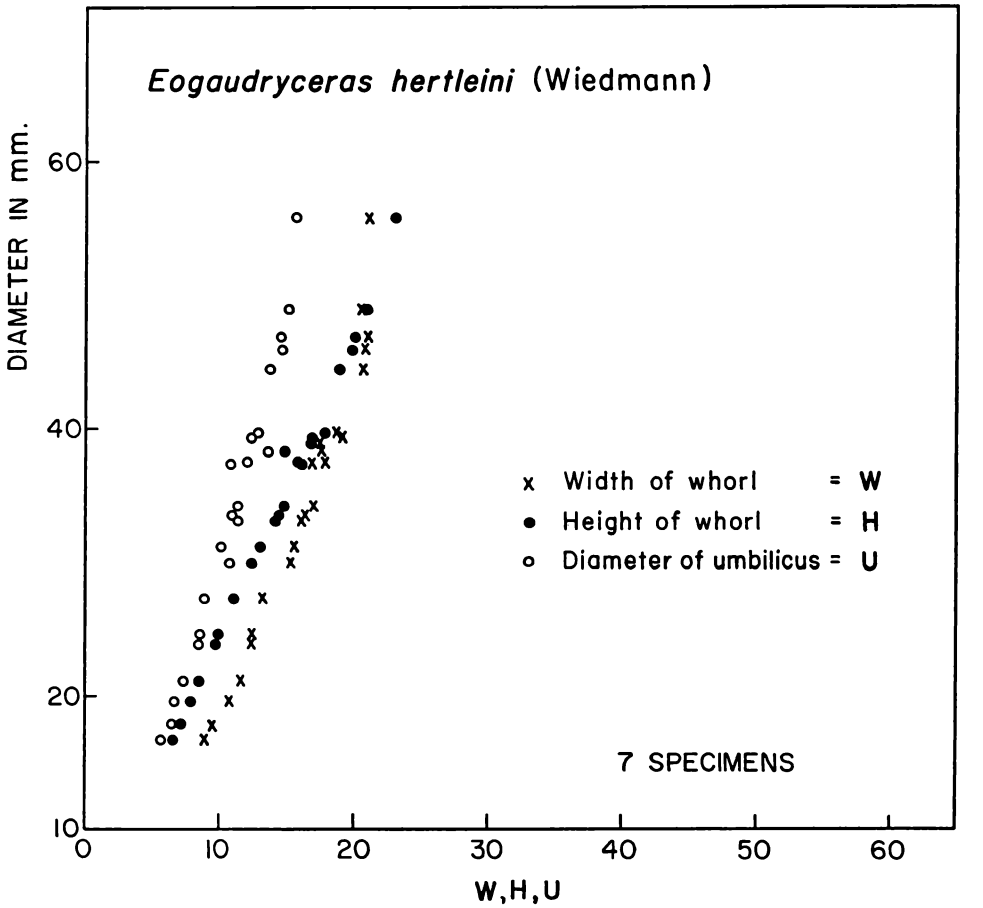


Fig. 5. *Eogaudryceras hertleini* (Wiedmann). Whorl width and height and diameter of the umbilicus are plotted against diameter of the shell. Each specimen was measured at all stages of growth permitted by the preservation.

tion intermediate between *E. numidum* and *G. mite,* the type species of *Gaudryceras.* This transition from one genus to the other is complete when the shell shows sharp strongly sigmoidal riblets. The configuration of the margin of the aperture is characterized by a strongly prorsiradiate direction on the lower flank which is strongly recurved to rectiradiate and even inclined adapically on the middle and upper flank.

In the forms leading to *Anagaudryceras* the ornamentation remains lirate and prorsiradiate; distinct collars precede the constrictions. In *Anagaudryceras* finely lirate fold ribs ornament the adult whorls.

The type of ribbing is not always exactly the same in all these forms, but at present not enough data are available to evaluate the significance of this variation.

The classification adopted here reflects the phylogenetic interpretation shown in figure 4C, where 1 represents *E. numidum* and other forms with fine lirae and weakly sigmoidal ornamentation (Eogaudryceras); 2 represents forms with riblets and strongly sigmoidal ornamentation (*Gaudryceras*); 3 represents forms with

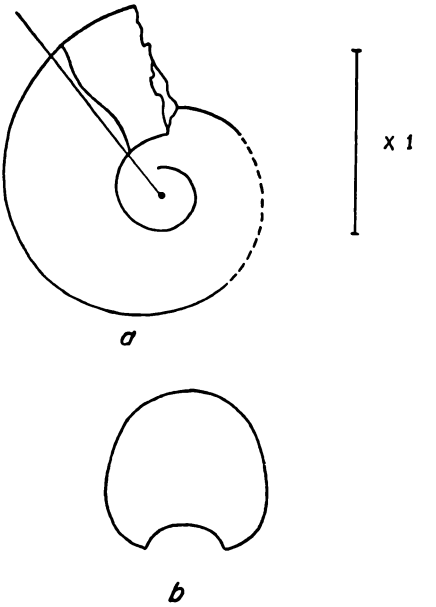


Fig. 6. (*a*) Lateral view of *E. hertleini* (Wiedmann) showing configuration of lirae with reference to a radial line originating at the protoconch. (*b*) Cross section of the whorl of *E. hertleini* (Wiedmann) at 53 mm diameter; UCLA specimen 25941.

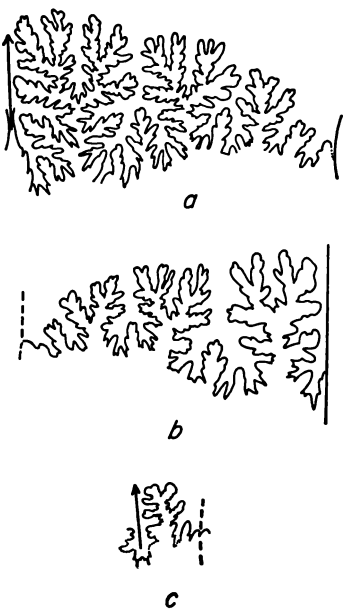


Fig. 7. (*a*) External suture line of *E. hertleini* (Wiedmann); UCLA specimen 25941 at 33 mm diameter. (*b*) External suture line of *E. hertleini* (Wiedmann); UCR specimen 29/1. (*c*) Internal suture line of *E. hertleini* (Wiedmann); UCR specimen 468/1 at 37 mm diameter.

fold ribs on the adult whorls (*Anagaudryceras*). Using these generic criteria, interpretation 4C is chosen because specimens of the other two taxa occur stratigraphically below some *Eogaudryceras*.

Eogaudryceras hertleini (Wiedmann)

(Pl. 1, figs. 2–5)

Lytoceras (*Gabbioceras*) *wintunium* Anderson, 1938 (in part), pl. 15, fig. 5 (not pl. 16, figs. 2–5).

Gabbioceras hertleini Wiedmann, 1962, v. 115, pp. 16, 18, 19, pl. 1, fig. 3.

Description.—The shell is of medium size with a maximum measured diameter of 88 mm (measurement taken on complete but crushed body whorl). The whorl cross section is wider than high in the younger stages of development, equant between 40 and 55 mm diameter, and slightly higher than wide in the later stages (growth pattern shown in fig. 5); whorls number 6 or 7. Ornamentation consists of very fine lirae more or less evenly spaced on the periphery and shoulders. The middle of the flank is smooth. The umbilical shoulder and umbilical wall show very fine unevenly spaced lirae. The ornamentation and growth lines are slightly sigmoidal between the umbilical seam and the venter (see fig. 6). Two or three thin sharp-crested ridges appear on the flanks of all specimens examined in the third or fourth whorl. Slight widely spaced constrictions of the internal mold parallel to the growth lines are present from as early as 10 mm diameter to the body whorl. Their position shows on the external shell of some young specimens as slight depressions or collars or both, but no consistent pattern is present in the young stages. Large shells show sigmoidal constrictions of the internal mold preceded by a low collar. Both are shown on the external shell. The external suture line (figs. 7*a, b*) has a deeper ventral lobe than lateral lobe and the first auxiliary is not so deeply incised as the lateral lobe. The suspensive lobe is retracted. The internal suture line (fig. 7*c*) has a single major saddle, and an incipiently developed second saddle.

Specimen number 8767 CAS Type Collection was chosen as the holotype because it was the only specimen known to Wiedmann. Unfortunately almost the entire outer shell surface is missing from this specimen.

The preceding description is based on the ten specimens listed below.

Specimen	*Locality*	*Zone*	*Remarks*	*Depository*
25940	UCLA 3015	*wintunius*	Coll. Murphy	UCLA
25941	UCLA 2848	*gardneri*	Coll. Murphy	UCLA
29–1	UCR 29	*wintunius*	Coll. Murphy	UCR
29–2	UCR 29	*wintunius*	Coll. Murphy	UCR
467–1	UCR 467	*wintunius*	Coll. Murphy	UCR
468–2	UCR 468	*wintunius*	Coll. Murphy	UCR
	CAS 1347*	?	Coll. Anderson	CAS
8767 (CAS)	ANSP 12884	?	Coll. Gabb	CAS
K140	SOC K140	*wintunius*	Coll. Kirk	SOC (Seattle)
M469	USGS M469	*wintunius*	Coll. Jones	USGS (Menlo Park)

* Nine separate locality descriptions from four separate zones are given for this locality in Anderson's paper (1938, pp. 100–327, 36 citations). This indicates that a locality was for him an area rather than a specific spot or horizon and therefore his locality numbers cannot be used to indicate stratigraphic position.

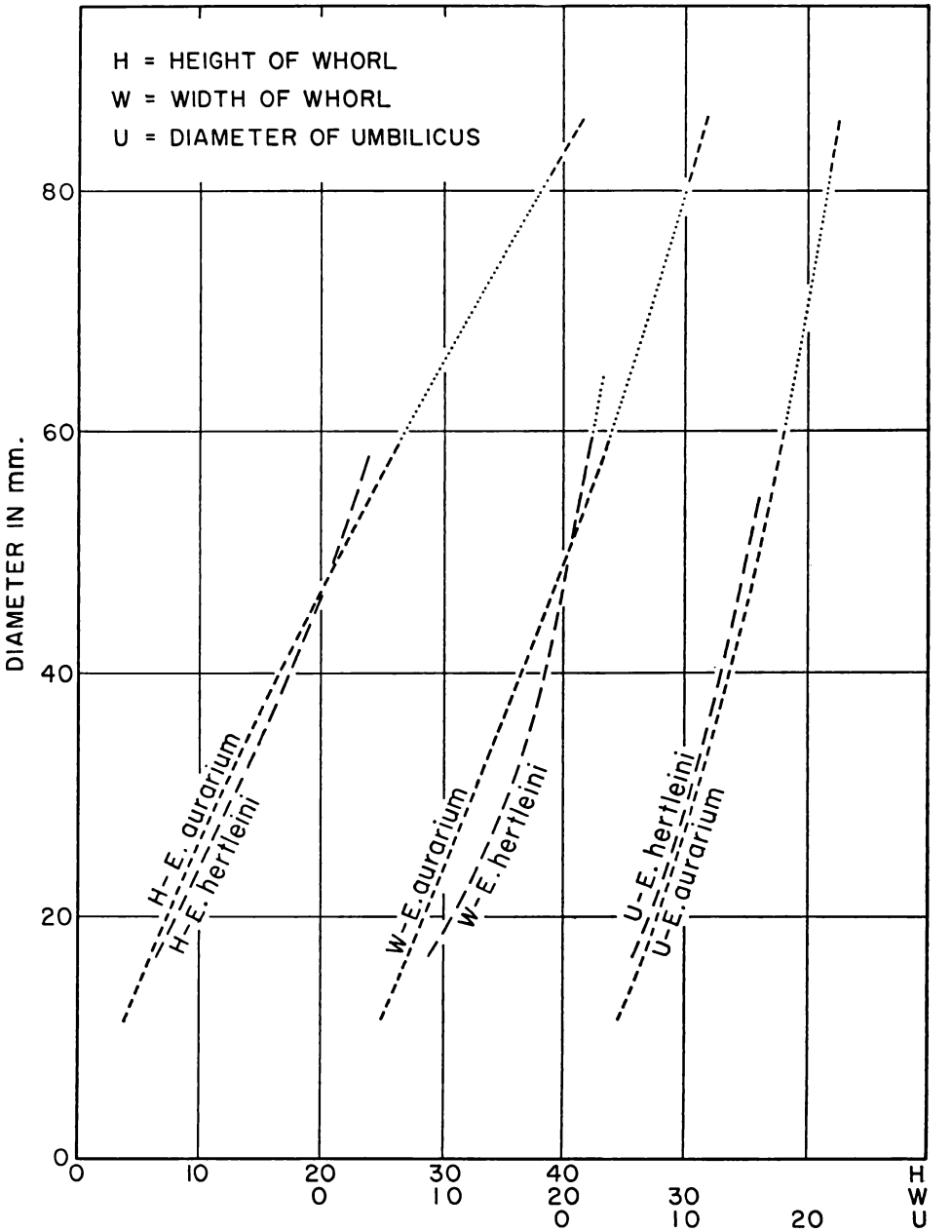


Fig. 8. A comparison of the rate of growth of the height and width of the whorl and the diameter of the umbilicus as a function of the shell diameter in *E. hertleini and E. aurarium.*

Comparison.—*Eogaudryceras hertleini* (Wiedmann) differs from *E. aurarium* (Anderson) in being slightly broader across the venter and in ratios of the height and width of the whorl and diameter of the umbilicus as compared to the diameter of the shell (fig. 8). This relationship gives *E. hertleini* a deeper umbilicus. Also *E. hertleini* has only 2 or 3 flanges on the third and fourth whorl whereas *E. aurarium* may have 8 to 13. This latter criterion should be used only when preservation is very good. The collars in *E. aurarium* are much more prominently developed. *E. hertleini* and *E. aurarium* are so similar morphologically that they can almost certainly be regarded as parts of the same lineage. The small differences noted above serve both to distinguish them and to indicate a close relationship that is verified by their sequential stratigraphic positions.

Eogaudryceras hertleini has a much higher cross section than E. *bourritanum* (Pictet) (pl. 5, fig .11) and a much narrower umbilicus than *E. shimizui* Breistroffer (pl. 5, fig. 3).

The relationship between the genotype *Eogaudryceras numidum* and *E. hertleini* is apparently very close. The two may be inseparable morphologically, but I do not have the material to document this conclusion at present.

Remarks.—Specimen number ANSP 12884 (the Academy of Natural Sciences of Philadelphia), the holotype of *Gabbioceras hertleini* Wiedmann, is the same specimen as CAS Type Collection No. 8767. This specimen deserves special discussion as it has been figured previously (Anderson, 1938, pl. 15, fig. 5) as the holotype of *Lytoceras* (*Gabbioceras*) *wintunium* Anderson (= *Eotetragonites wintunius*). Through some error two holotypes are figured in Anderson's paper for that species. It is clear from Anderson's description (1938, p. 150) that the specimen bearing CAS Type Collection No. 8767 is not the holotype of *Lytoceras* (*Gabbioceras*) *wintunium* and belongs neither to the species nor to the genera *Gabbioceras* or *Eotetragonites*. The stated locality, "locality 1347 (CAS), east of Mitchell Creek, 5 miles south of Ono, Shasta County" is also in error. The number 12884 is written on a small white rectangular label glued to the specimen. This number corresponds only to an Academy of Natural Sciences of Philadelphia locality and according to the original label written by W. M. Gabb, the specimens (No. 12884) came from "Cottonwood Creek, Shasta County, California." On this label in pencil are the words "10 specimens" indicating that the lot originally contained this many specimens. There are only nine specimens in the Academy's collections at the present time; all of these specimens bear the same type of locality label, with the same locality number, in the same written hand. It seems inescapable to conclude, therefore, that these specimens were collected by Gabb from Cottonwood Creek, and later Anderson borrowed the holotype of *E. hertleini* from the Academy of Natural Sciences of Philadelphia. The locality 1347 cited for the holotype unfortunately is given again by Wiedmann (1962*b*, p. 19), who was unaware of this correction of the Academy's records.

H. G. Richards, associate curator of the collections of the Academy of Natural Sciences of Philadelphia, has agreed that the specimen should remain at the present depository, the California Academy of Sciences.

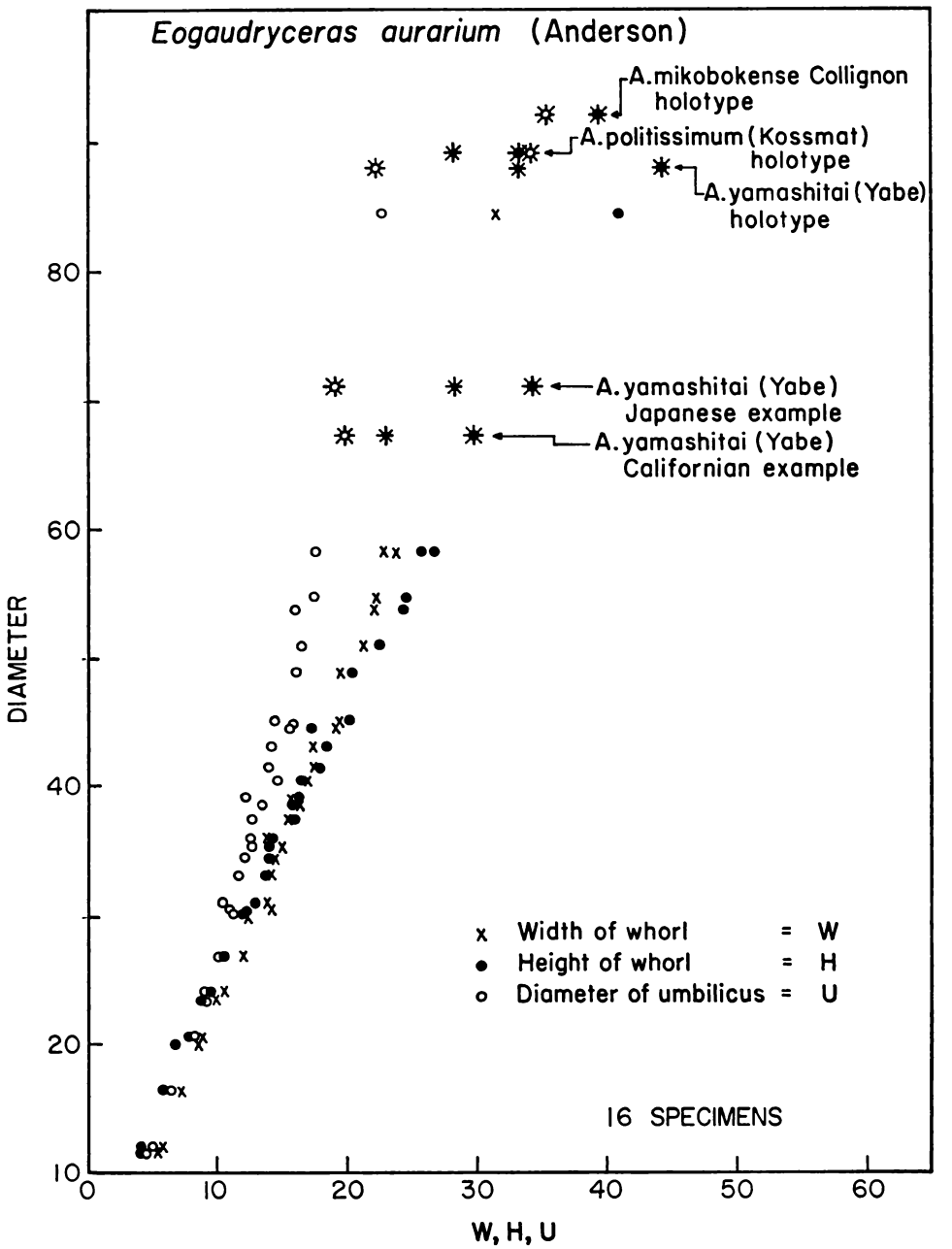


Fig. 9. Whorl width and height and diameter of the umbilicus are plotted against the diameter of the shell. Each specimen was measured at all stages of growth permitted by the preservation. Stars indicate specimens discussed by other workers.

Stratigraphic position.—Unfortunately all localities at which this species has been collected are isolated outcrops whose stratigraphic position is only approximately known. They lie in the upper *E. wintunius* zone, except for one specimen which was found in the *Acanthohoplites gardneri* zone.

The stratigraphic position of the holotype is also in the upper *E. wintunius* zone judging from those associated with it in Gabb's collection and from the localities at which most of the other members of the species have been recovered.

Eogaudryceras aurarium (Anderson)

(Pl. 1, figs. 6–8)

Lytoceras (Kossmatella?) aurarium Anderson, 1938, p. 151, pl. 20, figs. 1, 2.
Gaudryceras aurarium (Anderson), Murphy, 1956, p. 2118, fig. 6.
Anagaudryceras aurarium (Anderson), Popenoe, *et al.*, 1960, p. 1509.
Anagaudryceras aurarium (Anderson), Imlay, 1960, p. 99, pl. 11, figs. 18, 19 (not pl. 11, fig. 24).

The holotype is CAS type specimen number 8750.

Description.—Shell is of medium size with a maximum measured diameter of 86 mm, but fragments of somewhat larger shells are known. The whorl section is wider than high in the younger stages, equant between 35 and 45 mm diameter, and higher than wide at larger diameters (see fig. 9). The number of whorls is about seven and a half in a full-grown specimen. Ornamentation consists of more or less evenly spaced lirae that are more pronounced on the periphery and umbilical edge than on the flanks of the whorl. At approximately the second whorl, thin sharp-crested flanges appear on the flanks and periphery. They are not present after the fifth whorl. These flanges vary from 8 to 13 per whorl and are inclined adorally on the flanks. The ornamentation, in general, is inclined adorally but shows very little sinosity. Prominent constrictions of the internal mold preceded by narrow, rounded collars are present on the body whorl of all mature specimens. Both show on the outer shell. The external suture line (fig. 10) is virtually identical with that of *E. hertleini.* The internal suture line has a single saddle.

Comparison.—*E. aurarium* differs from *E. hertleini* in being more acutely rounded across the venter, and in the ratios of height and width of the whorl and diameter of the umbilicus as compared to the diameter of the shell (see fig. 8). Also in the early whorls *E. aurarium* has 8 to 13 flanges on the flank and periphery as compared to 2 or 3 in *E. hertleini,* and it has more prominent collars.

Imlay (1960, p. 99, pl. 11, figs. 18, 19, 24) assigned a species from Chitina Valley, Alaska, to this taxon, but the cross section of his larger specimen (Imlay, 1960, fig. 24) is more inflated with a broader venter. The strong constrictions of the body whorl lack the collar of *E. aurarium.* I would guess that a larger specimen would have fold ribs clearly developed. The young specimen (Imlay, 1960, figs. 18, 19) is very similar to *E. aurarium.*

Eogaudryceras aurarium has a much higher cross section than *E. bourritanum* (Pictet) (pl. 5, fig. 11) and a much narrower umbilicus than *E. shimizui* (pl. 5, fig. 5) Breistroffer. It differs from the above and also from the genotype, *E. numidum,* in possessing strong sigmoidal collars in the larger shells.

Anagaudryceras yamashitai (Yabe) although similar in dimensions to *E. aurarium* apparently has a much flatter flank. Both *A. mikobokense* and *A. politissimum*

have a much wider umbilicus. *A. politissimum* Collignon (MC Collection #1938–1941 from Madagascar) has three lobes on flank at a whorl height of 17 mm. The suture is then strongly retracted and has 4 or 5 auxiliaries on umbilical wall. This gives the suture a much larger number of elements than *E. aurarium*. The septum shows only one major saddle in internal suture, but the preservation is poor. Matsumoto also figures a specimen of *A. yamashitai* with 3 distinct lobes on the flank at 67 mm diameter.

A. madraspatanum (Blanford) has well-developed lirae on the flanks whereas *E. aurarium* and *E. hertleini* do not. *A. limatum* (Yabe) has heavy fold ribs on the body whorl. *A. yokoyamai* has two prominent saddles in the internal suture (Yabe, 1903, fig. 6).

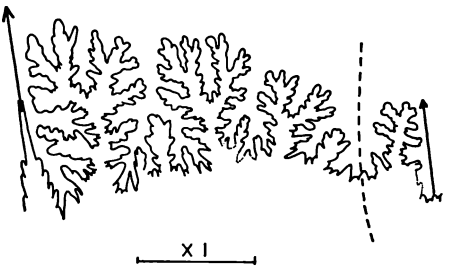


Fig. 10. Suture line of *E. aurarium*, specimen UCR 1000–4.

According to the definitions of genera that I have adopted above, many of the species referred to here as *Anagaudryceras* would be placed in *Eogaudryceras* or in *Gaudryceras*. I have not personally inspected most of these Upper Cretaceous specimens and, therefore, have not attempted to reclassify them.

Stratigraphic position.—*E. aurarium* ranges from the middle *Leconteites leontei* zone through the *Brewericeras hulenense* zone, lower Albian. It has been collected from the following UCR collecting localities: 12, 16, 30, 31, 32, 33, 89, 98, 135, 351, 358, 364, 402, 422, 424, 431, 998, 1000.

Remarks.—Anderson placed this species in *Lytoceras* (*Kossmatella?*) apparently on the basis of the "transverse undulations not unlike those of *Gaudryceras sacya* (Forbes)" (1938, p. 152). The reason for this statement is not clear, but it is possible that he regarded specimens of *E. aurarium* and *Anagaudryceras* sp. as members of the same species and thus attributed plicate ribs to *E. aurarium*.

Eogaudryceras aurarium is relatively abundant in the Ono district being represented in the UCR and UCLA collections by 33 specimens and by numerous specimens in the collections of other institutions in California.

Genus *Anagaudryceras* Shimizu, 1934

Type species: *Ammonites sacya* Forbes, 1846.

Anagaudryceras as characterized by Wright and Matsumoto (1954, p. 113) seems to be transitional with *Eogaudryceras*. I can see no morphological gap between the two or characters that will distinguish one genus from the other except

the presence of fold ribs. The presence or absence of collars seems quite variable as a taxonomic feature at the generic level and therefore not useful. It is present in the Upper Cretaceous *Gaudryceras,* in Albian forms like *E. shimizui* without fold ribs, and in *Anagaudryceras whitneyi* with fold ribs. The number of elements in the suture may be useful in differentiating some species and perhaps even genera of the later Cretaceous, but the relative depth (or retraction) of the suspensive lobe of the suture line seems too variable in *Eogaudryceras numidum* to be a criterion of generic importance (see also Casey, 1960, p. 8).

I characterize the genus as does Wright (1957, p. L200) with slight modification: oval cross section, ornamentation of fine prorsiradiate or sinuous lirae, with periodic constrictions and collars that have the configuration of the lirae, outer volutions with fold ribs.

This definition of the genus requires the addition of collars and fold ribs to the basic ornamentation of *Eogaudryceras.* Wright and Matsumoto (1954, p. 113), however, concluded that "This ribbing (fold ribs) however is variable within and between species both as regards its form and stage of growth at which it appears; it forms no reliable basis for generic classification." They did not cite examples. It is clear that a similar development of the ornamentation of the adult volutions is present in *Eotetragonites* and somewhat in *Gabbioceras,* but these genera are morphologically distinct on other grounds. It appears to me from observations of California material and the Alaskian-Canadian collections of David L. Jones of the United States Geological Survey that *Anagaudryceras* is a distinct branch of the Gaudryceratinae. In any case, the fold ribs in this combination make a useful stratigraphic indicator as they are not known below the Albian.

Anagaudryceras sp.

(Pl. 2, figs. 1, 2, 4)

Six specimens tentatively grouped together were collected from the Huling Creek and North Fork of Cottonwood Creek drainages. All specimens are incompletely preserved or crushed so that more positive discrimination is, at present, impossible.

Three of these specimens show a configuration and inclination of the growth lines and constrictions on the flanks of the whorl that are similar to *Anagaudryceras sacya* (Forbes), but the ornamentation is somewhat less inclined and sinuous than the specimen figured by Whiteaves from Queen Charlotte Islands (1884, pl. 25) or by Matsumoto from Alaska (1959, pl. 22, fig. 4). Matsumoto's specimen is more like *Anagaudryceras whitneyi* (Gabb), a species thus far recorded only from California. The inclination of the constrictions (fig. 11) seems to be consistent in the few California specimens in hand suggesting that *Anagaudryceras* sp. and *A. whitneyi* are distinct. Also the cross section of the whorl seems larger at equal diameters, but this is difficult to evaluate.

Three specimens were found from 70 to 110 feet below the base of the *Brewericeras hulenense* zone in the middle *Leconteites lecontei* zone and below the lowest occurrence of *Douvilleiceras.* They are important as they are the earliest specimens referable to *Anagaudryceras* that have been found in California.

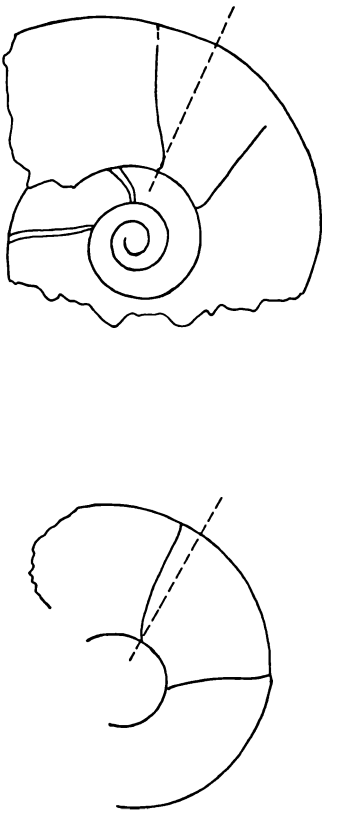


Fig. 11. A comparison of the constriction inclination in *A. whitneyi* and *Anagaudryceras* sp. The dashed line in each figure is normal to the tangent to the whorl at the intersection of the constrictions with the umbilical seam.

Anagaudryceras whitneyi (Gabb)

(Pl. 2, figs. 3, 5, 6)

Ammonites whitneyi Gabb, 1869, p. 134, pl. 22, figs. 14, 14*a*, 14*b*.
Lytoceras (*Kossmatella*) *whitneyi* (Gabb), Anderson, 1938, p. 152, pl. 31, figs. 1, 2.
?Anagaudryceras sacya (Forbes), Matsumoto, 1959, pl. 22, fig. 4.

The holotype is ANSP 4799.

Description.—The shell is of medium size with a maximum measured diameter of 140 mm (measurement taken on specimen without complete body whorl). The cross section is subquadrate in the last two whorls of the only large specimen sectioned (fig. 12), and equant between 30 and 60 mm.

The fold ribs appear on the holotype at a smaller diameter than on the other specimens, but the taxon exhibits considerable variation in this respect. The shell is generally poorly preserved but a few small patches indicate very fine closely spaced lirae were present on the fold ribs. Ornamentation of the inner whorls con-

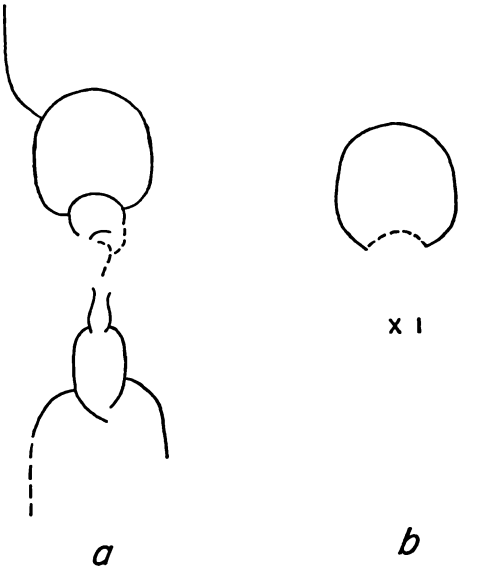
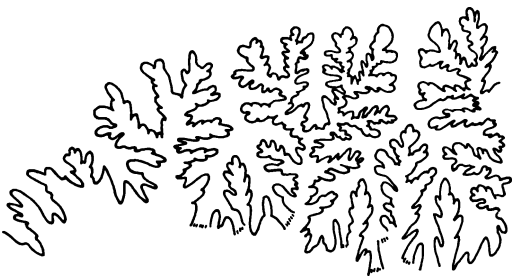


Fig. 12. (*a*) Cross section of *A. whitneyi*, specimen UCR 186–2. Parts of specimen have been deformed, but tendency toward a subquadrate cross section is distinguishable. (*b*) Cross section of *A. whitneyi*, specimen SOC K173 at 50 mm diameter.



x 2

Fig. 13. External suture line of *A. whitneyi*, specimen UCR 186–1.

sists of lirae over the entire shell. Prominent strongly adorally inclined constrictions are present on the early volutions from the youngest part of the shell observed (9 mm diameter). They number 4 or 5 per whorl, are preceded by a collar, and appear on the outer shell as grooves. The external suture line is minutely incised, strongly retracted, and in general resembles other members of the family except that the auxiliaries of the suspensive lobe are more numerous (fig. 13). The internal suture line was not studied because of the preservation of the specimen, but the septum of one specimen shows only a single internal saddle.

Comparison.—Anagaudryceras whitneyi (Gabb) differs from *Anagaudryceras sacya* Forbes and *Anagaudryceras* sp. of this paper in the possession of deep and more strongly adorally inclined constrictions.

Five specimens have been collected from the Ono Quadrangle: two from the Bald Hills Member of the Budden Canyon Formation (UCR 186); one from 20 to 30 feet lower in the upper Chickabally Member (UCLA 2824); one collected by Mahlon Kirk from the upper Chickabally Member (SOC 173); the holotype collected by Gabb from Cottonwood Creek. Gabb's locality is probably near the UCR and UCLA localities.

Stratigraphic position.—Judging from its preservation, the locality of the holotype is probably the lowest conglomerate bed in the Bald Hills Member or the upper beds of the Chickabally Member of the Budden Canyon Formation. The lower conglomerate bed was discussed by Murphy and Rodda (1960, p. 836).

Specimens of known locality are restricted to this bed or the upper Chickabally Member and are Albian in age. The specimen collected by Kirk is the oldest, but its exact position in the sequence is not known. Anderson (1938, p. 152) reported a specimen from the Dry Creek section in Tehama County "associated with species of upper Albian age." Anderson's specimen was not examined.

Remarks.—Gabb's original drawing (1869, fig. 14) of the holotype with fold ribs on the outer three whorls is incorrect, as the fold ribs are present only on the last one and a half whorls. Constrictions are the only coarse ornament on the earlier whorls. His drawing of the suture is accurate.

David L. Jones, of the U.S. Geological Survey, has recently collected a number of specimens from the Queen Charlotte Islands which appear to belong to *Anagaudryceras whitneyi* (personal communication). Similar forms collected by G. M. Dawson from Skidgate Inlet were referred by Whiteaves (1884, pl. 25) to *Lytoceras sacya* Forbes.

Subfamily Tetragonitinae Hyatt, 1900

The Subfamily Tetragonitinae is comprised of forms in which the principal lateral lobes of the suture are bifid, the major saddles trifid or irregularly trifid, and several auxiliary lobes and saddles are present. The internal suture normally has two or more saddles and the dorsal lobe is typically prolonged forming a septal lobe on the preceding septum. The growth rugae, lirae, and constrictions, and thus the margin of the aperture, are strongly inclined adorally on the lower flanks and generally recurved on the upper flank. In some taxa they are concave adorally on the venter. The surface of the shell may be smooth, lirate, with riblets or constrictions. Many taxa also show a flattening of the flanks and venter that results in the quadrate or trapezoidal cross section from which the name of the group is derived.

Genus *Eotetragonites* Breistroffer, 1947

Type species: *Eotetragonites raspaili* Breistroffer, 1947 (= *Ammonites depressus* Raspail, 1866)

Breistroffer (1947, p. 72) specified two morphologic features that characterized the genus *Eotetragonites:* constrictions of a special type and sutures with irregularly bifid saddles. Since he does not clarify "d'un type special," I interpret these words to mean a deeply impressed constriction that is convex on the flank and venter with a kneelike bend at the peripheral shoulder that is convex adapically. He chose as type species *Lytoceras* (*Tetragonites*) *depressus* Raspail, as figured

in Kilian (1913, pl. 11, fig. 3), which he renamed *Eotetragonites raspaili* Breistroffer (1947, p. 99).

The type is from Hyèges (Basses-Alpes), France, where a large number of specimens assigned to several species of this genus have been collected. Examination of these specimens suggests that some of the described species from this locality are connected by completely gradational series and belong to one species. The names that have been used for them in these and nearby strata are *Eotetragonites duvali, E. raspaili, E. jacobi,* and *E. kossmatelliformis* (Thomel, 1964). With this background in mind I hesitate to assign d'Orbigny's species, *Ammonites duvalianus,* to the genus *Tetragonites* as has been done recently by Basse (1952, p. 604) and Drushchits (1960, p. 261), neither of whom uses Breistroffer's genus. Neither would I go so far as Wiedmann (1962*a*, p. 150) who has used *Eotetragonites* as a subgenus of *Eogaudryceras.*

Wiedmann remarks that *Eotetragonites duvalianum* has been erroneously associated with *Tetragonites* by the writers above and by Collignon (1956, p. 98). It is clear from the history of the classification that the members of the genus show strong relationship to both *Eogaudryceras* and *Tetragonites* and further that there is demonstrable continuous morphological variation between the three taxa, suggesting a gradual evolutionary progression from *Eogaudryceras* through *Eotetrogonites* to *Tetragonites.*

I therefore place Eotetragonites in the Subfamily Tetragonitinae to reflect the bifurcation of the family tree. This occurs in the Gargasian where *Eotetragonites* can be differentiated first from *Eogaudryceras.* These genera each lead to separate and major branches of this general group of Lytoceratina (see also discussion in Murphy, 1967*a*).

Breistroffer originally included the following species in *Eotetragonites: raspaili* Breistroffer, type species (= *A. depressus* Raspail); *jacobi* (Kilian) var. *ambiguua* Breistroffer; *blieuxiensis* Breistroffer; *plurisulcatus* Briestroffer; *wintunius* (Anderson); *kossmatelliformis* (Fallot); and *jacobi* (Kilian). This gives a clear idea of his concept. To this list must be added *jallaberti* (Pictet), *duvalianus cheniourensis* Breistroffer, *duvalianus* (d'Orbigny), *umbilicostriatus* Collignon, *gainesi* (Anderson), and *shoupi* n. sp., described in the following pages. I have also suggested that the Albian species *balmensis* be classified as *Eotetragonites* (Murphy, 1967*a*) rather than *Tetragonites.*

The lower Albian species *gainesi* Anderson and *umbilicostriatus* Collignon are very closely related to the Aptian forms as is shown in the difficulty of identification of any but complete and well-preserved specimens.

The middle and upper Albian species *plurisulcatus* Breistroffer and *jallaberti* (Pictet) have a more rounded depressed section and more anteriorly inclined constrictions with a prominent anterior arch on the venter.

The California species are of special interest because their body chamber is frequently preserved, in contrast to European specimens that rarely retain their body chamber. California specimens show that the body chamber habitually developed prominent, closely spaced constrictions so that the shell resembles the adult *Anagaudryceras.*

Wiedmann (1962*a*, p. 150) has made *Eotetragonites* a subgenus of *Eogaudryceras*, but they have become separately evolving groups by the Gargasian and I prefer to retain *Eotetragonites* at the generic level.

Eotetragonites gives rise to *Tetragonites*, which is first recorded in the Clansayesian (Murphy, 1967*a*).

Forms classified above as *Anagaudryceras* have a number of traits in common with the *Eotetragonites*, but the rounded whorl shape and collars preceding the constrictions in the young relates *Anagaudryceras* more closely to *Eogaudryceras*. The plication of the dwelling chamber in *Anagaudryceras* is probably an example of parallel evolution in a genus closely related to *Eotetragonites*.

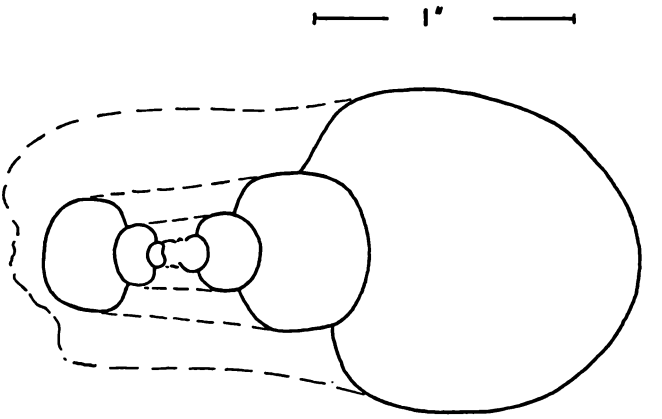


Fig. 14. Cross section of *Eotetragonites wintunius*, specimen UCR 391–1 at about 60 mm diameter.

Eotetragonites wintunius (Anderson)

(Pl. 3, figs. 4, 5, 6)

Lytoceras (*Gabbioceras*) *wintunium* Anderson, 1938, pl. 16, figs. 2–5 (not pl. 15, fig. 5).

Description.—The shell attains a moderate size, the largest specimen observed being about 90 mm in diameter. The whorl cross section (fig. 14) is depressed reniform to diameter of about 8 mm. Between that stage and the body whorl the cross section is subquadrate. The body whorl is more oval in shape and almost equal in height and width. The shell surface is smooth and polished in the young acquiring lirae in the fourth whorl that are distinct on the umbilical wall, umbilical shoulder, and the ventral shoulder but faint or absent on the flank and venter. The growth lines are slightly convex on both the flank and the venter and parallel the constrictions, which show on the outer shell as narrow grooves. The same pattern of ornamentation continues on the body whorl except that the lirae are more or less restricted to the periphery, and the constrictions are deeper and have a tendency to be placed close together so that they resemble the fold ribs in *Anagaudryceras*. The external suture (fig. 15*a*) is similar to that of other *Eotetragonites*. The internal suture line has a single principal saddle (fig. 15*b*) and an incipient development of a second saddle.

Comparison.—Eotetragonites wintunius is distinguished from *E. duvalianus, E. kossmatelliformis,* and *E. raspaili* by its less prominent constrictions which are less curved on both flanks and venter and by its less rounded venter. *E. jacobi* has much weaker and irregularly spaced constrictions that are less inclined on the upper flank. The cross section of *E. jallabertianus* is much more rounded and the constrictions much more prominent.

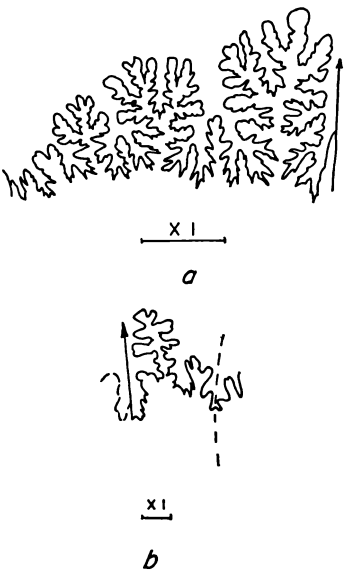


Fig. 15. (*a*) External suture line of *E. wintunius,* specimen UCR 43–1, at 37 mm diameter. (*b*) Internal suture line of *E. wintunius,* specimen UCR 496–1, at about 40 mm diameter.

The California forms likely to be confused with this species are *Eotetragonites shoupi* n. sp. with which it occurs and species of the genus *Tetragonites. E. shoupi* is distinguished by its rounded cross section and the nature of the umbilical wall. *Tetragonites* species in California are all virtually smooth and have a much more strongly inclined constriction on the flank and adapical inflection of the ornamentation on the venter.

Remarks.—Two holotypes for this species were designated by Anderson (1938, pl. 15, fig. 5; pl. 16, fig. 2) (see p. 11 for discussion). From his description, it is obvious that the intended holotype was plate 16, figure 2, and this specimen (CAS Type Collection No. 8758) was subsequently designated (Wiedmann, 1962*b*, p. 20) as the type specimen of *Lytoceras* (*Gabbioceras*) *wintunium* Anderson (1938, p. 150). The trivial name is misspelled *"wyntunium"* on page 65 and in table 2 in Anderson, 1938.

Stratigraphic distribution.—Eotetragonites wintunius is found in the middle and upper parts of the *E. wintunius* zone as defined by Popenoe *et al.* (1960, p. 1508). It has been recorded only from northern California.

Eotetragonites wintunius has been found at UCR localities 43, 92, 101, 366, 367, 368, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 385, 386, 387, 390, 391, 412, 415, 416, 425, 469, 470, 471, 472, 473, 478, 479, 480, 482, 485.

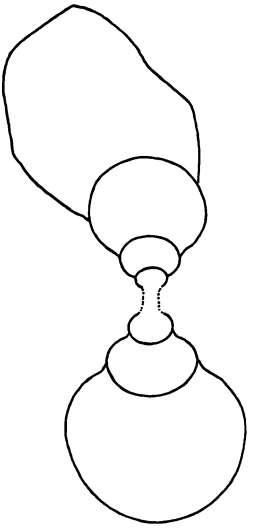


Fig. 16. Cross section of *E. shoupi* n. sp., specimen UCR 417–1, showing the way the shell of the shell of the later whorls overlaps the preceding whorls at the umbilical suture. This tendency to mantle the previous whorl with a thin extension of the shell wall toward the axis of coiling is characteristic of this species.

Eotetragonites shoupi n. sp.

(Pl. 3, figs. 7, 8, 9)

Lytoceras (*Gabbioceras*) *angulatum* Anderson, 1938 (in part), pl. 35, fig. 2 (not pl. 15, figs. 3, 4); *Gabbioceras* sp. Murphy, 1956, p. 2116.

Description.—The shell is of medium size, the largest measured diameter being 90 mm. The whorl cross section varies from reniform in the younger whorls to almost circular in the penultimate whorl (fig. 16). The body whorl is crushed and distorted on all specimens, but appears to be somewhat more compressed laterally than the penultimate whorl. The penultimate whorl tends to have an angulation at the peripheral shoulder as in *E. wintunius*, but not so distinct as in that species. The number of whorls is about 7. The shell is smooth to a diameter of about 6 mm. Lirae then develop at the umbilical shoulder, on the ventral shoulder, and across the venter. The growth lines, lirae, and constrictions all have a characteristic slight adorally convex configuration on the flank and across the venter. Constrictions appear as early as 15 mm diameter and are from 9 to 11 in number on the penultimate whorl. They show on the external shell as narrow grooves often preceded by a slight collar except on the adult body whorl where they are more closely spaced and form fold ribs similar to those of *Anagaudryceras*, but with a coarse liration of the ventral area. However, considerable individual variation of the ornamentation exists on the body whorl of this species.

The external suture (fig. 17*a*) is virtually identical with that of *E. wintunius*. The internal suture (fig. 17*b*) has a single saddle.

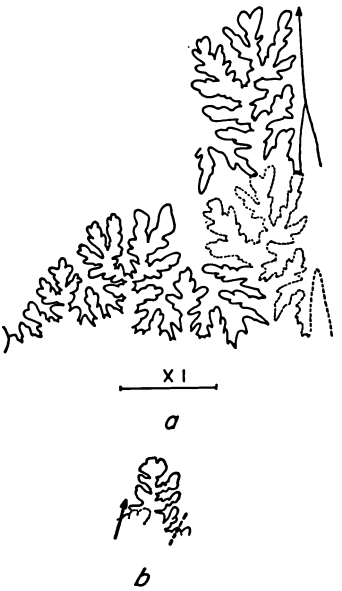


Fig. 17. (*a*) External suture of *E. shoupi* n. sp., specimen UCR 497–1, at 44 mm diameter. (*b*) Internal suture of *E. shoupi* n. sp., specimen UCR 43–2, at approximately 25 mm diameter.

Comparison.—*E. shoupi* n. sp. is distinguished from the other similar California forms by the rounded cross section of the early whorls as opposed to the angulate whorl of *G. angulatum* and the subquadrate whorl of *E. wintunius*. Also a characteristic feature that can be used in identification is the way previously formed whorls are overlapped along the umbilical seam by the subsequently formed ones. (fig. 16).

The other *Eotetragonites* species with markedly rounded venters are *E. jallabertianus* and *E. plurisulcatus*, both of which have a much less height/width ratio than *E. shoupi* and thus a depressed rather than circular cross section.

Stratigraphic distribution.—*E. shoupi* has been found in the middle part of the *wintunius* zone in northern California only. It has been found at UCR localities 43, 329, 390, 392, 413, 414, 417, 471, 473.

Remarks.—*E. shoupi* n. sp. was included by F. M. Anderson in the species *Gabbioceras angulatum* (e.g., plesiotype of *G. angulatum*, CAS Type Collection No. 8754). The species is described on the basis of twelve specimens in the collections of UCLA and UCR.

Eotetragonites gainesi (Anderson)

(Pl. 4, figs. 1–5)

Lytoceras rel. *duvalianum* (d'Orbigny) Anderson, 1902 (in part), p. 81, pl. 6, figs. 140, 143.
Lytoceras (*Kossmatella*) *gainesi* Anderson, 1938, pl. 20, figs. 3, 4, 5, p. 153.

The holotype is specimen number 12101 in the Museum of Paleontology, UCB.

Description.—The shell is of medium size, with a maximum diameter of about 85 mm (based on an incomplete specimen). The whorl cross section (fig. 18) of

part of the body whorl with fold ribs is subquadrate but with a rounded venter, reniform in the early growth stages and subquadrate in the intermediate stages. The number of whorls of the adult specimen averages 7. Ornamentation consists of growth lines and close evenly spaced constrictions that develop into fold ribs on the last whorl. Constrictions are usually pronounced and deep (pl. 4, figs. 3, 5), but some specimens have smooth venters (pl. 4, fig. 4) and much subdued con-

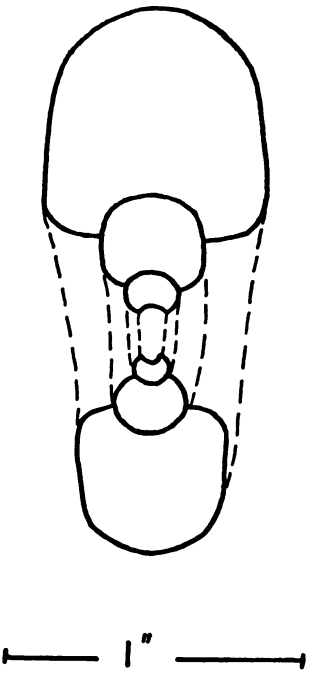


Fig. 18. *Eotetragonites gainesi* (Anderson) showing the cross section of UCR specimen 402–11.

strictions of the shell across the flank (pl. 4, fig. 2). This ornamentation originates early in the ontogeny, but the number of constrictions per whorl is less in the younger whorls than in the later ones. The suture (fig. 19) is similar to that of other members of the genus.

Comparison.—This species is probably most similar to *Eotetragonites kossmatelliformis* (Fallot). It differs from that form, as well as other Aptian species with strong constrictions, in its tendency to develop a smooth venter, by the very close spacing of the constrictions, and from the type of *kossmatelliformis* in having a greater height/width ratio of the cross section.

Anderson (1938, p. 153) did not specifically state the difference between this species and *A. whitneyi*. It seems that the smaller size and weakening of the constrictions across the venter in *gainesi* were his prime considerations in differentiating the two species, but the latter characteristic is variable. He also compares the subquadrate whorl of *gainesi* to the nearly circular whorl of the small *whitneyi*. This characteristic and the relative sizes of the two species seem to be the easiest way of distinguishing them in the field. The specimens of *A. whitneyi* are all much larger than the largest *gainesi*.

Remarks.—The species was placed in *Kossmatella* by Anderson and by Wiedmann (1962*a*, p. 164)

Kossmatella is probably derived from *Eotetragonites*, possibly via the type species, *E. raspaili*, or *E. kossmatelliformis*. Species of *Kossmatella* show marked constriction of the whorl, ribs that are reduced or that disappear on the venter, absence of liration on the venter, a prominent liration on the flanks.

Though some specimens assigned to this taxon exhibit much reduced ribbing on the venter (pl. 4, figs. 1, 2, 4), others show no reduction of the ventral orna-

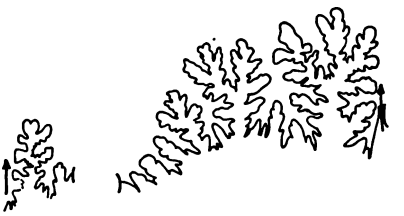


Fig. 19. *Eotetragonites gainesi* (Anderson) showing the internal and external parts of the suture of UCR specimen 402/10 and UCR specimen 1000/12, respectively.

mentation (pl. 4, figs. 3, 5), and none of the specimens shows any liration of the flanks. The ornamentation is generally more sigmoidal and the whorl less constricted than in the species of *Kossmatella*. For these reasons I prefer to classify this species as a member of the genus *Eotetragonites*.

It seems to be descended from the *E. duvalianus-wintunius* plexus, as it has the incipient internal saddle and the weakening of the ventral ornamentation faintly present in *E. wintunius*. *E. gainesi* is very closely related to several other members of this genus in widely separated parts of the world and shows a range of variation comparable to the Gargasian forms found abundantly in the French Alps.

Anderson first called the species *Lytoceras* rel. *duvalianum* d'Orbigny (1902, p. 81). Later he decided it was a separate species and apparently originally intended to call it *duvaliforme* as indicated by penciled notations in his personal copy of his 1902 paper. This probably explains the *nomen nudum Lytoceras duvaliforme* nov. (1938, p. 116) and *Gaudryceras duvaliforme* (1938, p. 68, and table 2), which apparently remained unnoticed in the manuscript after the name *gainesi* was finally applied to the species.

Stratigraphic position.—*Anagaudryceras gainesi* (Anderson) has been collected from UCR localities 31, 70, 89, 98, 104, 348, 401, 402, and 1000, and UCLA locality 3900.

The species ranges from the middle *Leconteites lecontei* zone through the *Brewericeras hulenense* zone.

Genus *Tetragonites* Kossmat, 1894

The four species of *Tetragonites* described from the Aptian and Albian strata of the Pacific Coast, *T. rectangularis alaskaensis*, *T. lecontei* Murphy, *T. jonesi* Murphy, and *T. hulenensis* Murphy, are discussed in a companion paper to this one on the genus *Tetragonites* (Murphy, 1967*a*).

Subfamily Gabbioceratinae Breistroffer, 1953

The subfamily is composed of Tetragonitidae with a strongly angulate cross section at some stage in the ontogeny; fine ornamentation composed of lirae, growth lines, constrictions, and collars that is prorsiradiate on the flanks and generally forms an adorally convex arch on the venter; the external suture is gaudrycerid or in later forms with additional elements added in the internal suture and modification of the second lateral lobe, which is divided by the angulation. The members of the subfamily have been recognized in strata ranging in age from Aptian (Gargasian) through lower Cenomanian.

Genus *Gabbioceras* Hyatt, 1900

Gabbioceras Hyatt, 1900, p. 132.
Gabbioceras Hyatt, Anderson, 1938, p. 149 (not pl. 15, fig. 5; pl. 16, figs. 2–5; pl. 35, fig. 2).
Gabbioceras (*Jauberticeras?*) *lamberti* Breistroffer, Breistroffer, 1947, p. 73.
Gabbioceras Hyatt, Wright, 1957, p. L203 (not figs. 4*a*, 4*b* = *Jauberticeras*).
Gabbioceras Hyatt, Wiedmann, 1962 (in part), p. 11 (not p. 16, group of *G. hertleini*).

Type species: *Gabbioceras angulatum* Anderson, 1902.

The genus is characterized by a strong angulation present on the flank of the two whorls preceding the body whorl, a rounded venter, the oval shape of the adult body whorl, and the more closely spaced constrictions of the body whorl than of the preceding whorls.

Wiedmann (1962*a*, pp. 19, 20) considers *Parajaubertella* to be a subjective synonym of *Gabbioceras* and places Matsumoto's species in *Gabbioceras*.

The figured suture of *Parajaubertella kawakitanum* Matsumoto is very similar to that of *Gabbioceras angulatum*. It differs in having the ventral lobe undercut the first lateral saddle and in having the lateral lobe displaced toward the umbilicus as a result. The second lateral saddle (fig. 21*a*) of *G. angulatum* is unusual, most specimens having bifid saddles as does *kawakitanum*. The whorl shapes of the specimen of *kawakitanum*, figured by Matsumoto, from Alaska (1959*a*, pl. 23, fig. 1*b*, 1*d*), and also of the holoytpe (Matsumoto, 1943, fig. 2), have an almost vertical umbilical wall and are dissimilar to the whorl shape of *G. angulatum*. The ornamentation of the two species is similar, that is, laevigate, weak constrictions and collars in the early stages, and body whorl with distinct, closely spaced constrictions. The species *Parajaubertella imlayi*, although similar in suture, has a vertical-walled umbilicus and an inflated, a more or less flat-sided whorl, and widely spaced constrictions and collars on the adult body whorl. Thus both lack the distinctive morphological character of *Gabbioceras*, the carinate cross section.

David L. Jones is studying the Alaskan forms of *Parajaubertella* and reports that the two species of Matsumoto may be variants of the same species. I believe it would reflect the phylogeny more accurately to classify the *Parajaubertella* as an offshoot of *Eogaudryceras*, which is recognized by its depressed cross section, vertical umbilical wall, and sharply rounded umbilical edge.

Eotetragonites wintunius (Anderson) was assigned to the genus *Gabbioceras* by Anderson (1938), but it has a distinctly different pattern of ornamentation, and the cross section of the whorl is subquadrate. Others have followed his example (Murphy, 1956; Wiedmann, 1962*a*) in spite of the fact that Breistroffer (1947, p. 73) included *Gabbioceras wintunium* Anderson in his genus *Eotetragonites*.

Gabbioceras angulatum Anderson

(Pl. 3, figs. 1, 2, 3)

Ammonites batesi Trask, Gabb, 1869 (in part), p. 132, pl. 20, figs. 9, 9*a*; pl. 21, figs. 10, 10*a*, only (not *Ammonites batesi* Trask, 1855, p. 40; not Gabb, 1864, p. 67, pl. 13, figs. 16, 16*a*, 16*b*).

Gabbioceras batesi Hyatt, 1900, p. 570.

Lytoceras (*Gabbioceras*) *angulatum* Anderson, 1902, p. 87, pl. 6, fig. 139; Anderson, 1938, p. 150, pl. 15, figs. 3, 4 (not pl. 35, fig. 2).

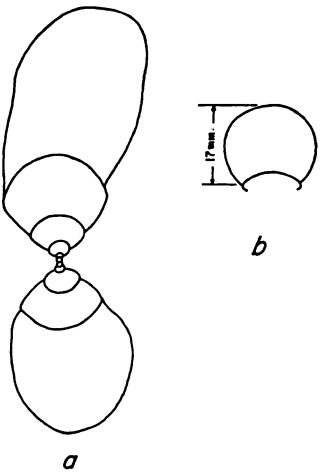


Fig. 20. (*a*) Cross section of *G. angulatum*, specimen 415–1, at a diameter of about 55 mm (shell body whorl deformed). (*b*) Cross section of whorl immediately preceding body chamber of adult specimen, specimen 223–1.

Description.—The shell is of medium size, approximately 70 mm in diameter with the complete body whorl. The whorl cross section (fig. 20) is depressed reniform to approximately 7 mm diameter. At this stage an angulation develops at the midflank of the whorl and persists to about 30 to 35 mm diameter. The whorl flank again becomes rounded and the cross section more or less equant. The body whorl is crushed on all available specimens, but apparently is somewhat higher than wide. Whorls number 7 when the adult body whorl is present. Ornamentation consists of growth lines, fine spiral striae, and constrictions. The configuration of the growth lines and their prominence changes during the ontogeny as follows: adorally inclined on the umbilical wall throughout growth; cross the venter convex adapically to a diameter of 15 mm and thereafter slightly convex adorally; constrictions develop as early as 35 mm diameter, approximately the stage at which the angulation disappears, and are spaced from 10 to 35 mm apart on the venter; a collar usually precedes the constriction, but on some specimens it is lacking on the body whorl; very faint spiral striae occur on the ventral area of the phragmacone, but do not show on the adult body whorl; in the early stages of growth the growth lines are visible only under magnification. The suture line (fig. 21*a*, *b*) is

gaudrycerid with a single internal lateral saddle, but with the incipient development of a second internal saddle.

Comparison.—This species differs from other similarly appearing California species in the possession of a pronounced angulation of the two whorls preceding the body whorl. This configuration of the whorl gives the umbilicus a conical shape. In the field the species most easily confused with *G. angulatum is Eotetragonites shoupi* n. sp. *E. shoupi* may be distinguished from *G. angulatum* by its nearly

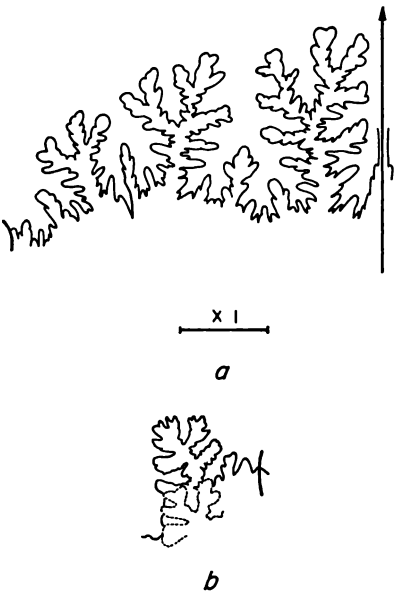


Fig. 21. (*a*) External suture line of *G. angulatum*, specimen 223–1. (*b*) Internal suture line of *G. angulatum*, specimen 393–1, at about 33 mm diameter.

circular whorl shape between 10 and 35 mm diameter, by the ornamentation of the shell on the ventral shoulder (especially near the umbilical seam, which is coarser and strongly inclined adapically), and generally by more closely spaced constrictions of the last two whorls.

Remarks.—Gabb's figure (1869, pl. 21, fig. 10*b*) of the suture line is misleading because he shows the suture of *Lytoceras batesi* (Trask) in which the saddles of the auxiliary lobe are not retracted and are as large as the second lateral saddle. Since Gabb originally included *G. angulatum* in *Ammonites batesi,* he doubtless used a specimen for his suture line other than the one portrayed in his plate 21, figure 10. Anderson (1938, p. 150) accepted Gabb's figure even after describing the species. Anderson's work has misled authors who had no access to the original material to accept Gabb's figure also (e.g., Wiedmann, 1962*b*, fig. 3, p. 13).

Stratigraphic position.—*Gabbioceras angulatum* has been collected from the following localities: 92, 223, 328, 365, 393, 394, 395, 397, 398, 399, 400, 403, 404, 408, 415, 425, 468, 501, 635.

The species ranges from the middle part of the *Eotetragonites wintunius* zone into the lower part of the *Acanthohoplites gardneri* zone.

Family LYTOCERATIDAE Neumayr, 1875

Subfamily Lytoceratinae Neumayr, 1875

Schindewolf (1961) and Wiedmann (1962*a*) disagree with the classification put forward in the Treatise of Invertebrate Paleontology (Wright, 1957), and they have suppressed Spath's family Protetragonitidae. They refer the taxa in the group to the Lytoceratinae. In addition, Wiedmann (1962*c*, p. 17) has synonymized *Leptotetragonites* Spath and *Hemitetragonites* Spath with *Protetragonites* Hyatt. I agree with these simplifications of the classification.

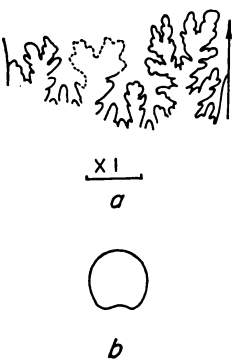


Fig. 22. (*a*) External suture line of *Protetragonites* of *P. crebrisulcatus* (Uhlig), specimen UCR 89/1, at 36 mm diameter, approximately double normal size. (*b*) Cross section at approximately 25 mm diameter, specimen UCR 89/1.

Previously *Protetragonites* and *Leptotetragonites* have been separated because their whorl sections were different and the number of constrictions was different. At the Institut Dolomieu, Faculté des Sciences, Grenoble, is a group of specimens from La Faurie (Hautes-Alpes) identified as *Leptotetragonites honnoratianus.* Small specimens in this group show few constrictions, whereas larger specimens show more depending on their size. Most specimens from this locality are deformed and flattened between the bedding planes, but I have collected large specimens there that show a round cross section and others that show only a slightly oval cross section. In other respects the small shells are not different from the small pyritic specimens preserved in the marls in other areas and identified as *Protetragonites quadrisulcatus.* It seems, therefore, that the number of constrictions is a characteristic of size, and the shape of the whorl is not reliable as a taxonomic criterion where the specimens are preserved in limestone. These observations support Schindewolf's and Wiedmann's action.

I regard *Hemitetragonites* as a subjective synonym of *Protetragonites,* as I do not believe the relative amount of incision of the suture is a diagnostic taxonomic feature at the generic level.

Genus *Protetragonites* Hyatt, 1900

Type species: *Ammonites quadrisulcatus* d'Orbigny.

Members of this genus are characterized by smooth or lirate, evolute shells, the succeeding volutions just barely touching. The cross section is round or ovate. The suture line is like that in *Lytoceras* ss., but generally much less frilled. Constrictions of the shell are straight or curved.

Protetragonites cf. *P. crebrisulcatus* (Uhlig)
(Pl. 1, fig. 1)

Description.—The test is small, with a maximum measured diameter of 39 mm with most of the living chamber missing. The cross section is nearly circular. Growth lines, lirae with irregular spacing, and constrictions ornament the outer volutions, but without magnification the shell appears almost smooth. Well-defined constrictions number about 4 per volution and show on the outer shell as slight grooves bordered adapically by lirae and adorally by more pronounced, sharp-crested lirae. The external suture is shown in figure 22 and is characteristic of the genus.

A single specimen was found in the middle *Leconteites lecontei* zone at UCR locality 89.

BIOSTRATIGRAPHY

The Aptian and Albian strata of California may be characterized and subdivided on the basis of members of the Family Tetragonitidae. The upper Aptian (probable Gargasian equivalent) *Eotetragonites wintunius* zone (Murphy, 1956, p. 2112) contains *Eotetragonites wintunius* (Anderson), *E. shoupi* n. sp., *Eogaudryceras hertleini* (Wiedmann), and *Gabbioceras angulatum* (Anderson). The first two are restricted to this zone, whereas *G. angulatum* and *E. hertleini* are found in the next overlying *Acanthohoplites gardneri* zone with *Eotetragonites gardneri* Murphy and *Tetragonites lecontei* Murphy. The *Acanthohoplites reesidei* zone, intervening between the *A. gardneri* and *Leconteites lecontei* zones, has yielded no tetragonitids. The *L. lecontei* zone contains *Tetragonites lecontei, T. hulenensis* Murphy, *Eogaudryceras aurarium* (Anderson), *Eotetragonites gainesi* (Anderson), and *Anagaudryceras* sp. The *Brewericeras hulenense* zone bears essentially the same tetragonitid fauna as the *L. lecontei* zone. The *Oxytropidoceras packardi* zone contains poorly preserved *Anagaudryceras,* but they are not diagnostic of it. *Zelandites* appear in the lower *Pseudouhligella dawsoni* zone (approximately = *Mortoniceras hulenana* of Murphy, 1956) and *Anagaudryceras whitneyi* is apparently restricted to the upper part of this zone. Though reworked specimens have been found in the immediately overlying conglomerates, this would not alter the age significance of the taxon.

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PLATES

PLATE 1

Fig. 1. *Protetragonites* cf. *P. crebrisulcatus* (Uhlig). Specimen 89/1, UCR Collection, East Fork of Huling Creek, California, middle *Leconteites lecontei* zone, lower Albian.

Figs. 2–5. *Eogaudryceras hertleini* (Wiedmann). Figs. 2, 3, and 5, specimen 467/1, UCR Collection, Bald Hills, California, upper *Eotetragonites wintunius* zone, upper Aptian. Fig. 4, specimen from CAS locality 1347.

Figs. 6–8. *Eogaudryceras aurarium* (Anderson). Fig. 6, specimen 402/2, UCR Collection, East Fork of Huling Creek, California, *Brewericeras hulcnense* zone, lower Albian. Fig. 7, locality unknown. Fig. 8, specimen 31/2, UCR Collection, near Huling Creek, California, upper *Leconteites lecontei* zone, lower Albian, showing the flanges characteristic of the early whorls.

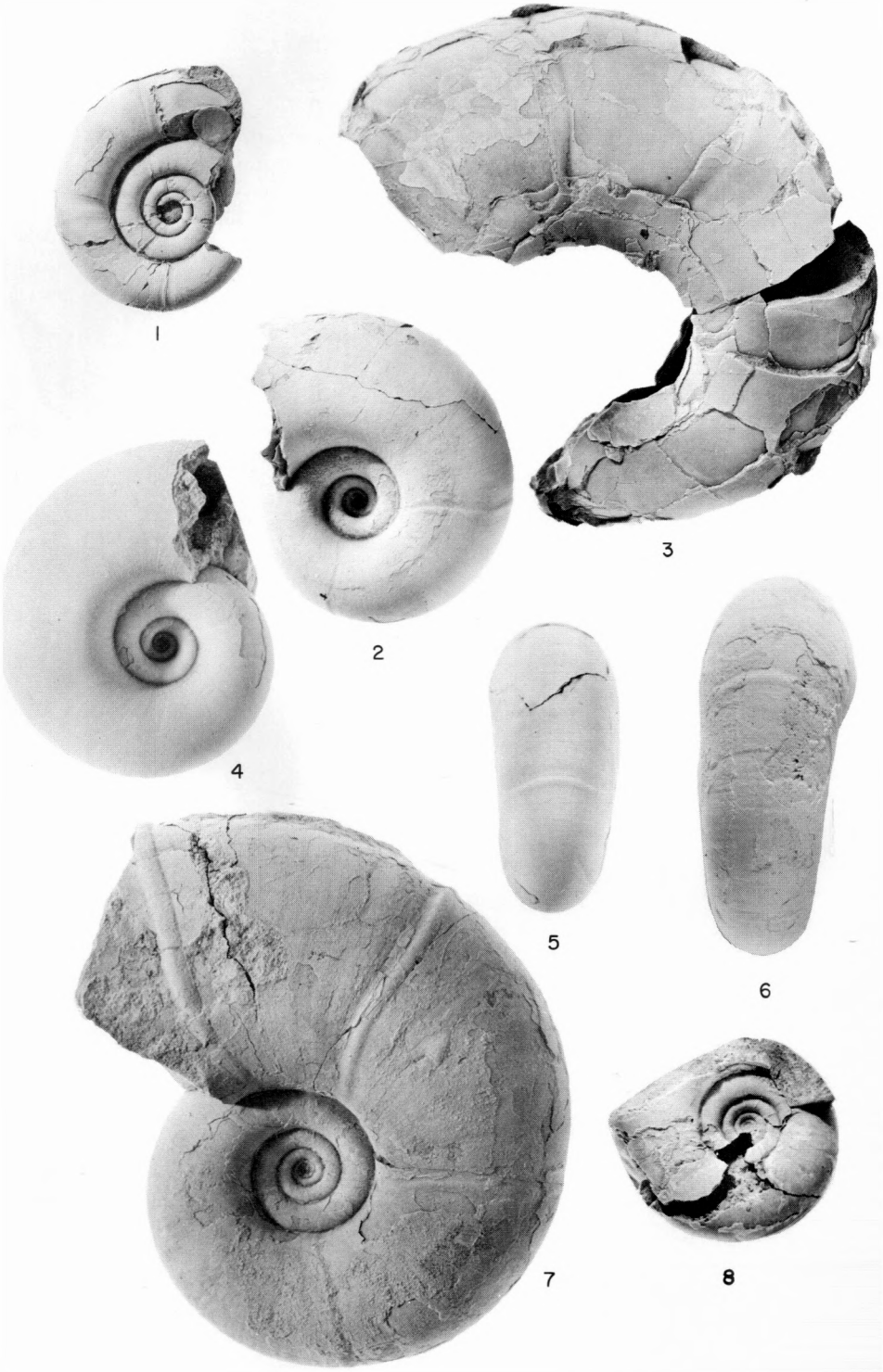

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PLATE 2

Figs. 1, 2, 4. *Anagaudryceras* sp. Figs. 1, 2, outer and inner whorls of specimen 89/10, UCR Collection, middle *Leconteites lecontei* zone, lower Albian. Note the almost rectiradiate constrictions in fig. 2.

Fig. 3. *Anagaudryceras whitneyi* (Gabb). Holotype ANSP Collection number 4799, Cottonwood Creek, Shasta County, California.

Figs. 5, 6. *Anagaudryceras whitneyi* (Gabb). SOC Collection K173/1, near Bee Creek, Ono Quadrangle, California.

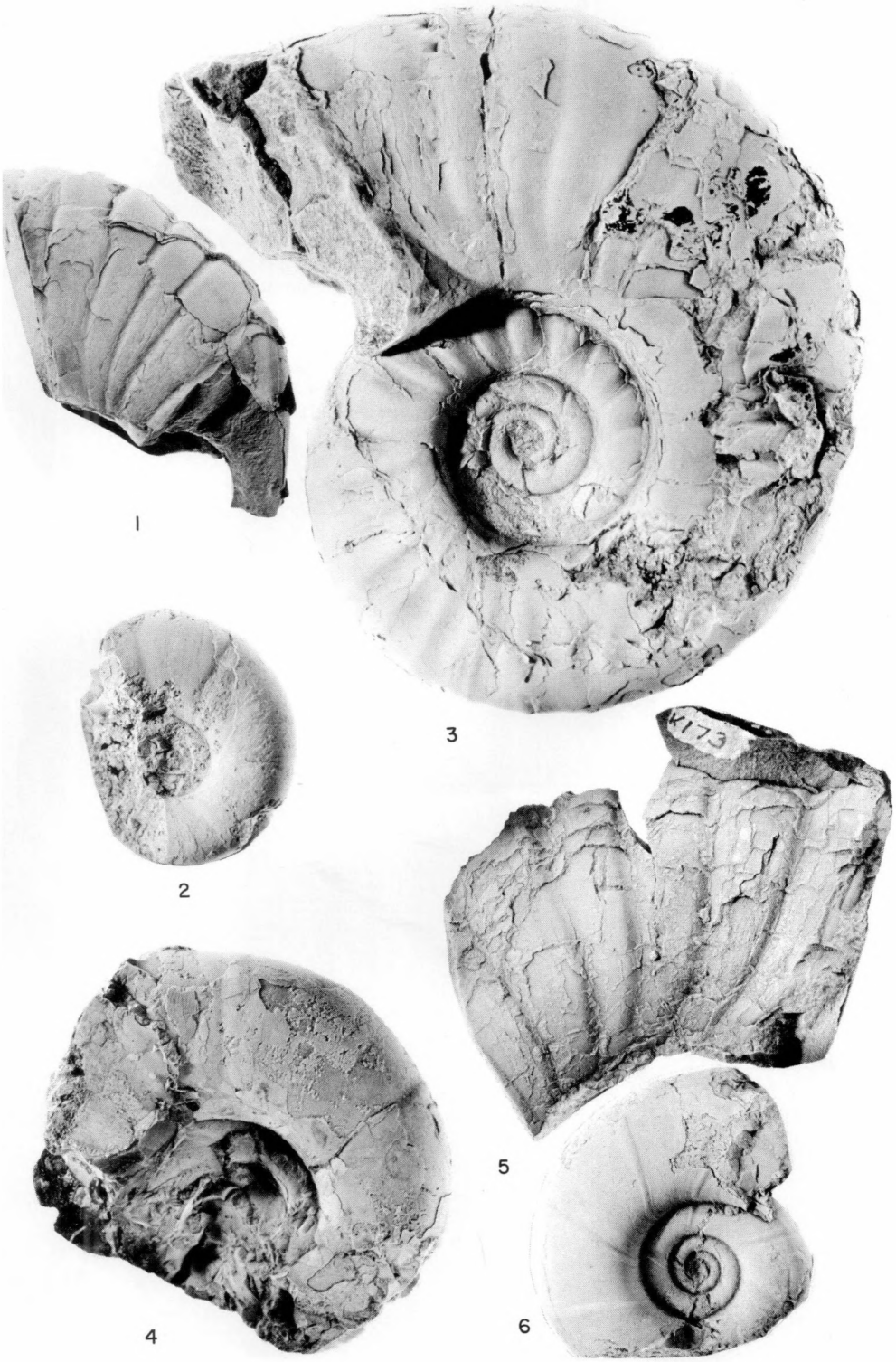

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PLATE 3

Figs. 1, 2, 3. *Gabbioccras angulatum* Anderson. Fig. 1, specimen UCR 393/1, near Mitchell Creek, Bald Hills, California. Fig. 2, specimen UCR 403/1, near Bee Creek, California. Fig. 3, specimen UCR 501/1, North Fork of Cottonwood Creek, Ono Quadrangle, California. *E. wintunius* zone, upper Aptian.

Figs. 4, 5, 6. *Eotetragonites wintunius* (Anderson). Specimen UCR 472/1, note the lirae developed on the peripheral shoulder, but not present on flanks or venter, *E. wintunius* zone.

Figs. 7, 8, 9. *Eotetragonites shoupi* n. sp. Fig. 7, specimen UCR 497/1, float near Mitchell Creek, Ono Quadrangle, California. Fig. 8, holotype, specimen UCR 413/2, *E. wintunius* zone, near Mitchell Creek, Bald Hills, Ono Quadrangle, California. Fig. 9, specimen UCR 392/1, note liration all the way across the venter as opposed to *E. wintunius*.

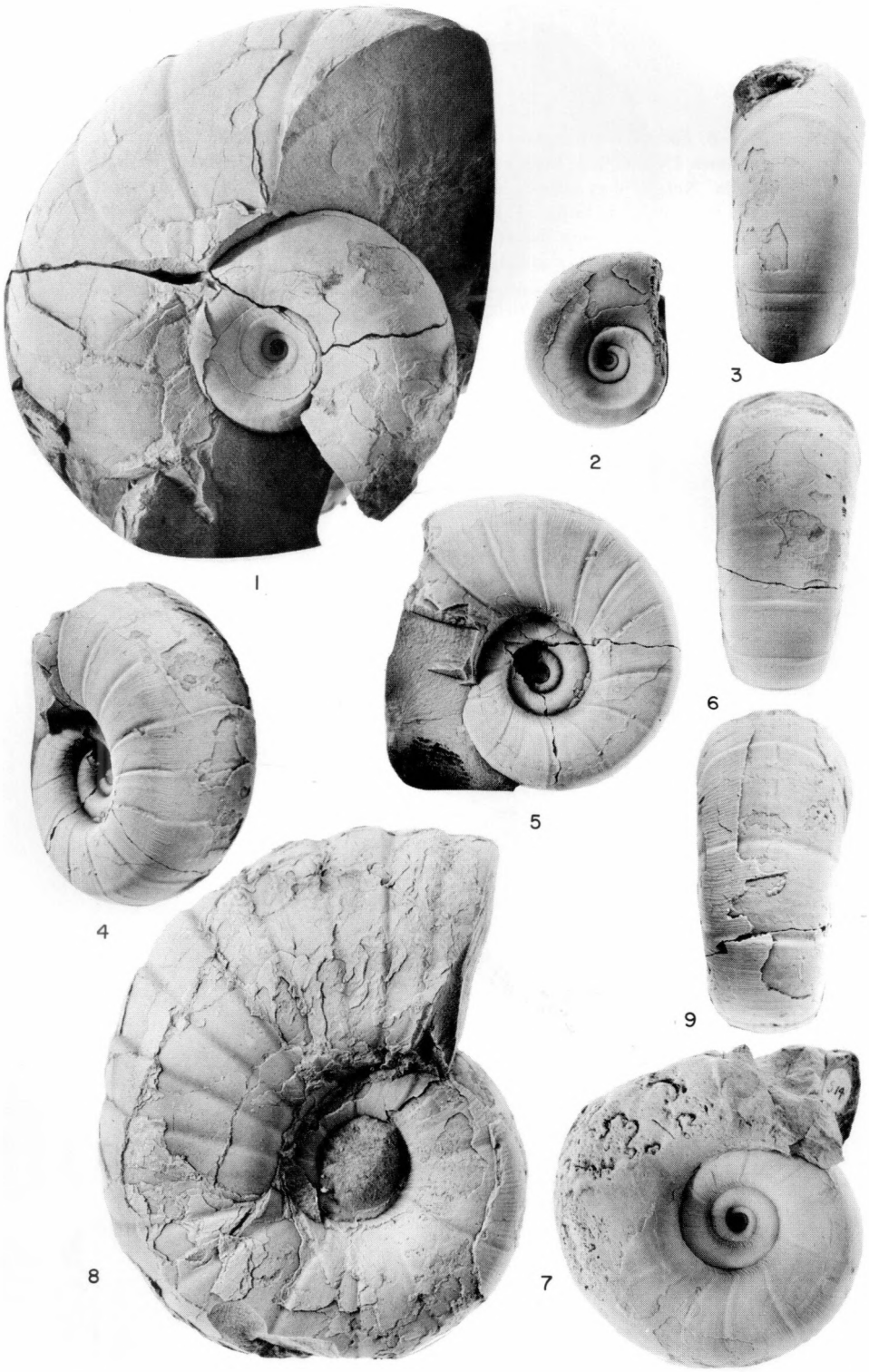
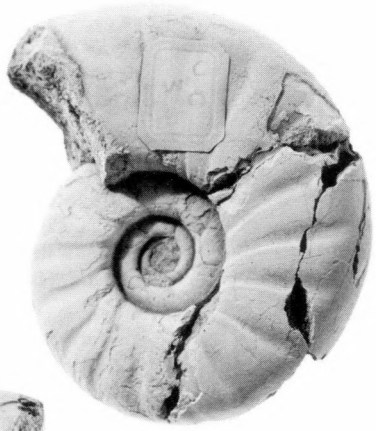

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PLATE 4

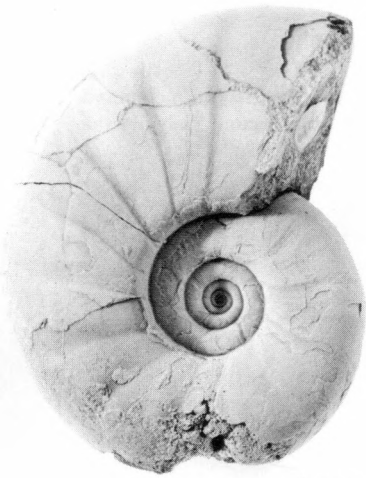
Figs. 1–5. *Eotetragonites gainesi* (Anderson). Fig. 1, UCB 12101. Figs. 2, 3, specimen UCR 402/7, East Fork of Huling Creek, Ono Quadrangle, California. Note almost smooth venter and weaker constriction of the whorl than the specimens in figs. 1, 3, 5. Figs. 3, 5, specimen UCR 1000/9, *Brewericeras hulenense* zone, lower Albian.

Figs. 6, 7. *Gabbioceras* aff. *G. michelianus* (d'Orbigny). Specimen UCR 422/3, near the East Fork of Huling Creek, Ono Quadrangle, California in the *B. hulenense* zone.

Figs. 8, 9. *Tetragonites hulenensis* Murphy. Specimen UCR 98/4, holotype, from *B. hulenense* zone, Huling Creek, Ono Quadrangle, California.



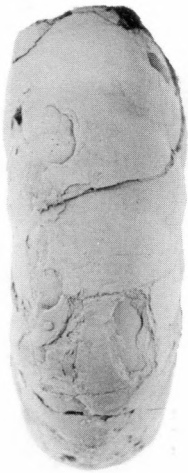
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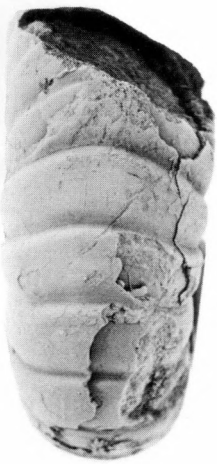
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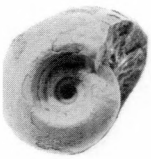
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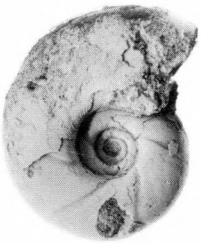
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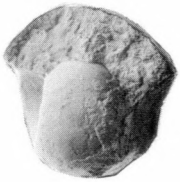
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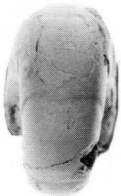
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PLATE 5

Figs. 1, 2, 4–6. *Eogaudryceras numidum* (Coquand). Figs. 1, 2, Gerard Thomel Collection, Hyèges (Basses-Alpes), France. Large specimen illustrating a trigonal cross section, single saddle of the internal suture as shown on the septal face, and well-developed constrictions. Figs. 4, 5, M. Collignon Collection, Blieux (Basses-Alpes). Two specimens illustrating variation in the cross section. Fig. 6, FG Collection, Blieux (Basses-Alpes), showing the ornamentation of the early volutions.

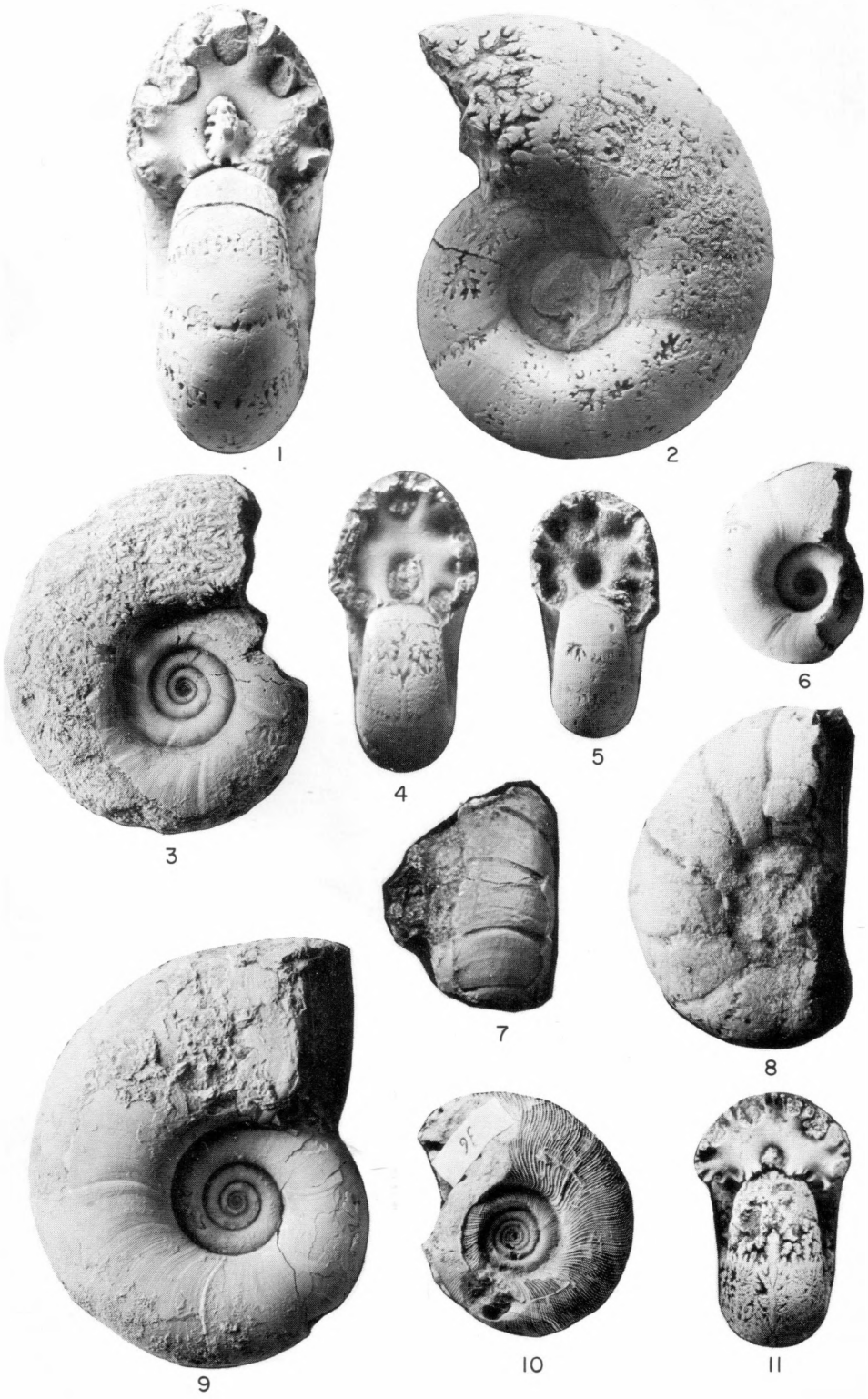
Fig. 3. *Eogaudryceras shimizui* Breistroffer. Specimen figured by Jacob (1908, pl. 1, fig. 16), MHNG Pictet Collection, Escragnolles (Alpes Maritimes), France. Note the similarity of the ornamentation between this specimen and the early volutions of *A. whitneyi* (pl. 2, fig. 6).

Figs. 7, 8. *Eotetragonites jallabertianus* (Pictet). MHNG Pictet Collection from Mt. Saxonet near Geneva. These specimens show the character and configuration of the constrictions of this poorly studied taxon. They are the best specimens of *E. jallabertianus* preserved in Pictet's Collection.

Fig. 9. *Gaudryceras* sp. ind. aff. *G. varagurense* Kossm., Collignon. M. Collignon Collection, specimen 1062 in Atlas des Fossiles caracteristiques de Madagascar (Albien). This form is interpreted as an intermediate one between *Eogaudryceras* as characterized by *E. numidum* and *Gaudryceras* ss. as shown in fig. 10 of this plate. Compare the configuration of the ornamentation in the three figures. Note this specimen has lirae developed all across the flank.

Fig. 10. *Gaudryceras* sp. British Museum (Natural History), Maestrichtian of Angola. Note the strongly sigmoidal pattern of the riblets and collars characteristic of *Gaudryceras*.

Fig. 11. *Eogaudryceras bourritianum* (Pictet). Neotype, MHNG Pictet Collection. Note the incipient second saddle of the internal suture developing from the U in this Albian species of *Eogaudryceras*.


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