With Regards of the Authors

JOURNAL OF PALEONTOLOGY, V. 61, NO. 1, P. 70–100, 7 FIGS., JANUARY 1987

GYRODIFORM GASTROPODS FROM THE PACIFIC COAST CRETACEOUS AND PALEOCENE

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ABSTRACT—Seven previously described and seven new taxa of gyrodiform naticoids from West Coast Late Cretaceous–Paleocene age strata are discussed. *Gyrodes* (*Gyrodes*) *dowelli* White of Turonian age is a typical *Gyrodes*; *G. robustus* Waring from the Paleocene has the shape of *Gyrodes* s.s. but lacks the crenulations. *G. greeni* Murphy and Rodda, *G. yolensis* n. sp., *G. quercus* n. sp., *G. banites* n. sp., *G. canadensis* Whiteaves, *G. pacificus* n. sp., and *G. expansus* Gabb comprise the new subgenus *Sohlella,* which thus ranges from Cenomanian through Maastrichtian. *Gyrodes robsauli* n. sp. resembles "*Polinices*" (*Hypterita*) *helicoides* (Gray), and *Hypterita* is reassigned to the Gyrodinae as a subgenus of *Gyrodes. Gyrodes onensis* n. sp. of Albian age is similar to the *G. americanus* group of Sohl (1960). Three taxa—*Natica allisoni* (Murphy and Rodda) of Cenomanian age and *N. conradiana* Gabb and *N. conradiana vacculae* n. subsp. of Turonian age—which have all been previously considered to be *Gyrodes* are placed in *Natica.* Well marked relict color patterns on *N. conradiana* and *N. conradiana vacculae* suggest that these naticids from northern California and southern British Columbia were tropical forms.

Diversity of taxa and size of specimens are reduced at the end of the Turonian, suggesting a change in West Coast marine conditions at that time.

INTRODUCTION

W. P. POPENOE had written a first draft for the gyrodiform gastropods of the Pacific Coast, and T. Susuki had taken many of the photographs, but the manuscript remained incomplete at the time of Popenoe's death. L. R. Saul and T. Susuki have, therefore, completed the paper.

Geographic and stratigraphic distribution of fourteen species of gyrodiform naticid gastropods are found to assist in paleogeographic and paleoclimatic reconstructions of West Coast terranes from Baja California, Mexico, to Vancouver Island, British Columbia. These species are useful in correlating shallow-water sediments that lack ammonites and planktic foraminifers. All of the West Coast Cretaceous species previously assigned to *Gyrodes* are discussed. They range in age from Albian to Selandian (Figure 1). Only *Gyrodes dowelli* White, 1889, is considered to belong to the typical subgenus. *Gyrodes robustus* Waring resembles a typical *Gyrodes* in shape but lacks the crenulations near the suture and along the umbilical margin. *Sohlella* n. subgen. is erected to include *G. quercus* n. sp., *G. canadensis* Whiteaves, *G. pacificus* n. sp., and *G. expansus* Gabb. *Gyrodes greeni* Murphy and Rodda, *G. yolensis* n. sp., and *G. banites* n. sp. are questionably included in *Sohlella.* The subgenus *Hypterita* (Woodring, 1957) has a gyrodiform growth line and is moved from the Polinicinae to the Gyrodinae, which increases the geologic range of *Gyrodes* to the present. The inclusion of *G. robsauli* n. sp. in *Hypterita* extends the geologic range of this subgenus back to Late Cretaceous. *Gyrodes onensis* n. sp. resembles Sohl's (1960) group of *G. americanus* (Wade, 1926), but *G. allisoni* Murphy and Rodda, *G. conradianus* (Gabb), and *G. conradianus vacculae* n. subsp. are probably not *Gyrodes* and are reassigned to *Natica.* This reassignment is supported by a funicle in the umbilicus of *G. conradianus* and *G. conradianus vacculae,* and relict color patterns retained on some specimens. Such markings are otherwise unknown in *Gyrodes,* an absence perhaps preservational rather than original. Color pattern is not usually recognized as being a generic characteristic, but the markings retained on *Natica conradiana* and *N. conradiana vacculae* are strikingly similar to those of such tropical naticas as *N. chemnitzii* Pfeiffer, 1840, *N. marochinensis* Gmelin, 1791, and *N. gaultieriana* Recluz, 1844.

PATTERNS OF OCCURRENCE

Sohl (1960, p. 117) found that Gulf Coast *Gyrodes* were present in all lithologic types from sandstone through limestone and were unaffected by facies changes, but West Coast

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gyrodiform gastropods occur most commonly in coarse to medium grained sandstone. They are represented by few specimens from fine grained sandstone to mudstone lithologies. Although naticids are confined to soft substrates (Taylor et al., 1980, p. 380), these West Coast gyrodiform species are most abundant at localities where *Turritella* spp. are rare or lacking, and they may have inhabited shallower depths and higher energy bottoms than did the turritellas. But, as Recent European naticids confine their predation almost entirely to bivalves (Fretter and Graham, 1962, p. 242), the absence of gyrodiform naticids from overwhelmingly turritellid or anchurid faunas may reflect food preference rather than water depth. Naticid predation on turritellas is, however, documented as early as Albian (Taylor et al., 1983). The pattern of occurrences of these genera in the Chico Formation of Butte County, California, supports a shallow depth habitat for these naticids—probably subtidal but shallower than 30 m.

Despite the abundance of naticids from many Pacific Coast Cretaceous localities naticid drill holes are either not recognized or are rare in associated shells. Naticid drill holes of Albian age from the Blackdown Greensand of England (Taylor et al., 1983) are not ascribed to ampullines or gyrodines, and Sohl (1969) connects the appearance of naticid drill holes to the rise of the Polinicinae. In West Coast faunas the gyrodiform naticids are relatively more common than polinicines until the Campanian. Probable naticid drill holes are found in *Meekia sella* Gabb of mid to late Maastrichtian age from near Martinez, Contra Costa County, California, and gastropod drill holes have been recognized in West Coast turritellas of latest Cretaceous and Paleocene age (Saul, 1983), but such holes are uncommon before the Eocene. West Coast naticids appear to lag behind Atlantic basin naticids in shell drilling.

Recent naticas from temperate and cooler waters are not marked with strong color patterns. The presence of these relict color markings on specimens of *Natica conradiana* and *N. conradiana vacculae* from the Redding area suggests warmer water than is presently found at that latitude. In the Panamic fauna *Natica chemnitzii, N. brunneolinea* McLean, 1970,

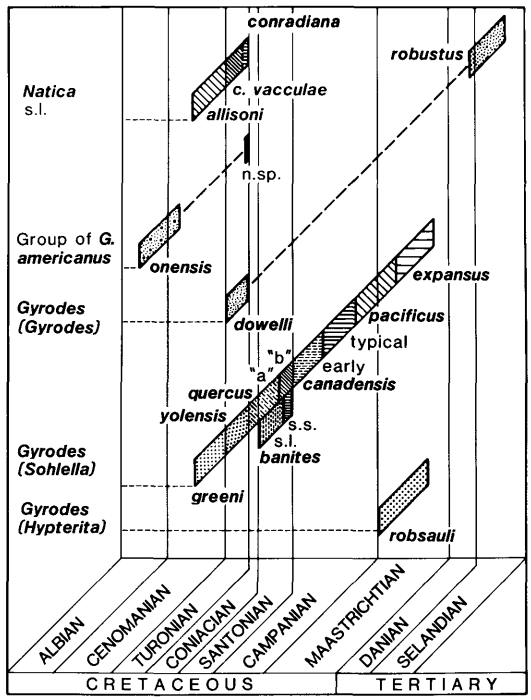

FIGURE *1*—Stratigraphic ranges of West Coast gyrodiform gastropods discussed in this paper.

and *N. inexpectans* Olsson, 1971, have color patterns somewhat similar to *N. conradiana vacculae*. Of these, *N. chemnitzii* ranges farthest north, being found in the Gulf of California and as far north as Magdalena Bay (approximately 25°N) on the Pacific Coast of Baja California, Mexico (Keen, 1971, p. 475). These Cretaceous naticas are abundant in pre-Senonian deposits, and *N. conradiana vacculae* occurs as far north as Sydney Island, British Columbia.

Size of specimens of gyrodiform gastropods studied for this paper is not randomly distributed through the time period. Both large and small specimens of Albian through Turonian age were available. Only small specimens of Coniacian and Santonian age are present in the collections. Some early Campanian specimens are of moderate size as are most mid and late Campanian age specimens. Many specimens of Maastrichtian age are as large as specimens of Albian through Turonian age. The largest available are those of Paleocene age; they are also larger than specimens of *Gyrodes* measured by Sohl (1960, p. 117–118) from the Maastrichtian of Tennessee and Mississippi. Unlike the col-

or markings, size is not indicative of a climate zone, but abrupt changes in size distribution, such as that between late Turonian and early Coniacian specimens, suggest altered marine conditions.

The greatest diversity of these gyrodiform gastropods is in Albian through Turonian stages despite smaller and fewer collections from Albian and Cenomanian age strata. Mid Cretaceous species of gyrodiform gastropods discussed in this paper are placed in *Natica* and three *Gyrodes* subdivisions: *Gyrodes* s.s., group of *G. americanus,* and *Sohlella.* At the end of the Turonian, three out of four supraspecific taxa disappear from the West Coast Cretaceous record. Species of Late Cretaceous age are all *Gyrodes* and except for *G.* (*Hypterita*) *robsauli* n. sp. are *Sohlella* (Figure 1). The presence of *Gyrodes* (?*Sohlella*) *banites* n. sp. in the Santonian, a possible elaboration of the *Sohlella* lineage, temporarily increases post-Turonian diversity. A succession of species of *Sohlella* is represented by abundant specimens through the mid Maastrichtian. The only Paleocene species is doubtfully assigned to *Gyrodes* s.s.

Color markings, size distribution, and taxonomic diversity combine to indicate a marine event near or at the end of the mid Cretaceous. Whereas eastern North Pacific mid Cretaceous faunas contain species such as *Gyrodes* (*Gyrodes*) *dowelli* White related to those of the Western Interior and Gulf Coast in addition to the apparent tropical or Tethyan element, early Senonian faunas of this area are largely made up of genera with a long North Pacific history. In addition to a more temperate climate, the Senonian had decreased interchange with the Gulf Coast and Western Interior. This faunal change seems abrupt, occurring between late Turonian and early Coniacian. A gradual warming trend may be indicated by the increase in specimen size and diversity of taxa in the late Campanian–Maastrichtian, but tropical naticas do not reappear in California deposits until the Eocene (Marincovich, 1977).

TERMS

Terms used in describing the gyrodiform gastropods are diagrammed in Figure 2. A species is described as small if no specimen exceeds 20 mm in width, as medium if "adult" specimens are between 20 and 39 mm in width, and large if some specimens exceed 40 mm in width. The umbilicus is the cavity left at the axis in shells whose adaxial whorl walls do not coalesce to form a solid columella. In the naticids discussed herein the umbilicus is at the adapical end of a semicircular depressed area, the umbilical depression. The umbilical depression is usually bounded by spiral biangulations on the base of the whorl and by the inner lip of the aperture. The funicle is a spirally wound ridge which extends adapically into the umbilicus from the inner lip. Its outer end at the inner lip is a usually semicircular umbilical callus. Adapical to the funicle is the sulcus. Its outer end at the inner lip is between the umbilical callus and the parietal callus. Abapical to the funicle is the channel. Its outer end at the inner lip is between the umbilical callus and the anterior end of the inner lip. On gyrodine naticids the growth line forms an antispiral sinus within the umbilical area. This broadly arching sinus is terminated abaxially by a strongly prosocline flexure of the growth line. In gyrodines having an angulate or subangulate margin to the umbilical area, this flexure coincides with the angulation. All of the naticids discussed in this paper have prosocline growth lines—that is, growth lines across the flank which lean adapically in the spiral direction.

The West Coast gyrodiform gastropods studied here are usually retrieved from well-cemented sandstone matrix which adheres to the often recrystallized shell. Some shells are coated with a thin skin of calcite that obscures sculpture, causes the shell to appear thicker, increases the apparent width, and may be difficult to distinguish from the shell itself. Many specimens are post-depositionally deformed. Recovery of complete specimens is unusual; the outer lip is thin and seldom found complete. Five measurements were made: height (h) of shell parallel to the axis of coiling; width (w) or diameter of shell normal to the axis of coiling (=MD, maximum diameter of Sohl, 1960); height of spire (s); height of penultimate whorl (p) measured at the aperture parallel to the axis of coiling; portion of penultimate whorl exposed adapical to the suture (e) measured near the aperture. To facilitate comparison the measurements were com-

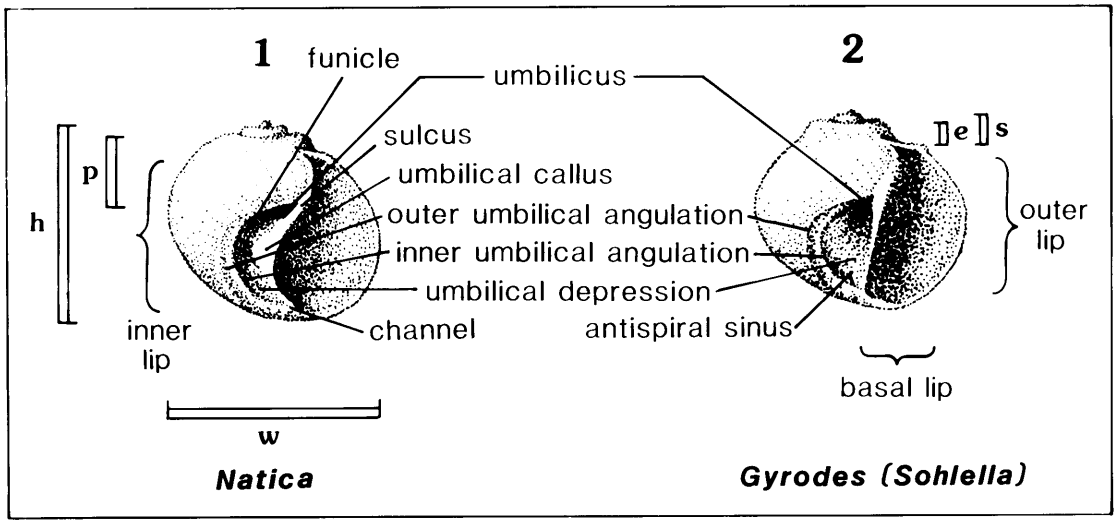

FIGURE 2—Diagrams of *1, Natica* s.l., and *2, Gyrodes* (*Sohlella*) to illustrate the morphologic terms used in the description of these gastropods. The following dimensions have been measured: height (h) of shell parallel to axis of coiling; width (w) of diameter of shell normal to the axis of coiling (=MD, maximum diameter of Sohl, 1960); height of spire (s); height of penultimate whorl (p) measured at the aperture parallel to the axis of coiling; portion of penultimate whorl exposed adapical to the suture (e) measured near the aperture.

bined into ratios of diameter to height (w/h), spire height to total height (s/h), height of penultimate whorl to total height (p/h), and portion of penultimate whorl exposed to height of penultimate whorl (e/p). These ratios and their means (where more than two specimens were measured) are plotted on Figure 3. As all of these gastropods are of gyrodiform shape—resembling slightly squashed marbles—the differences in their various ratios are not dramatic. The forms of *Gyrodes* (*Sohlella*) *quercus, G.* (?*S.*) *banites,* and *G.* (*S.*) *canadensis* discussed in the descriptions are plotted individually. Ratios of *G.* (*S.*) *quercus* "a" and *G.* (?*S.*) *banites* s.l. are similar, those of *G.* (*S.*) *quercus* "b" and *G.* (?*S.*) *banites* s.s. more distinct, especially for w/h and p/h, indicating a more expanded whorl. The dimensional changes between *G.* (*S.*) *quercus* "a" and "b" reverse the trend of those between *G.* (*S.*) *quercus* s.s. and "a", but both w/h and p/h trends between *G.* (?*S.*) *banites* s.l. and s.s. continue in the direction of those between *G.* (*S.*) *quercus* s.s. and "a". *Gyrodes* (?*S.*) *banites* and *G.* (*S.*) *pacificus* are relatively wider than the other species and ?*N. allisoni* is the most equant. Species cannot be discriminated on measurements alone.

Institutional abbreviations used are: ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences; CGS, Canadian Geological Survey; CIT, California Institute of Technology; LACMIP, Los Angeles County Natural History Museum Invertebrate Paleontology; LSJU, Stanford University; UCB, University of California, Berkeley; UCBMP, University of California, Berkeley, Museum of Paleontology; UCLA, University of California, Los Angeles; UCR, University of California, Riverside; USGS, U.S. Geological Survey; USNM, U.S. National Museum.

ACKNOWLEDGMENTS

Study of later Cretaceous formations and faunas of the Pacific Coast, of which this report is a small part, has been supported by grants-in-aid from the Penrose Fund of the Geological Society of America, from the National Science Foundation, and from research funds of the Academic Senate, University of California, Los Angeles. Essential comparative material was loaned by H. G. Richards of the Academy of Natural Sciences of Philadelphia, P. U. Rodda of the California Academy of Sciences, T. Bolton and J. A. Jeletzky

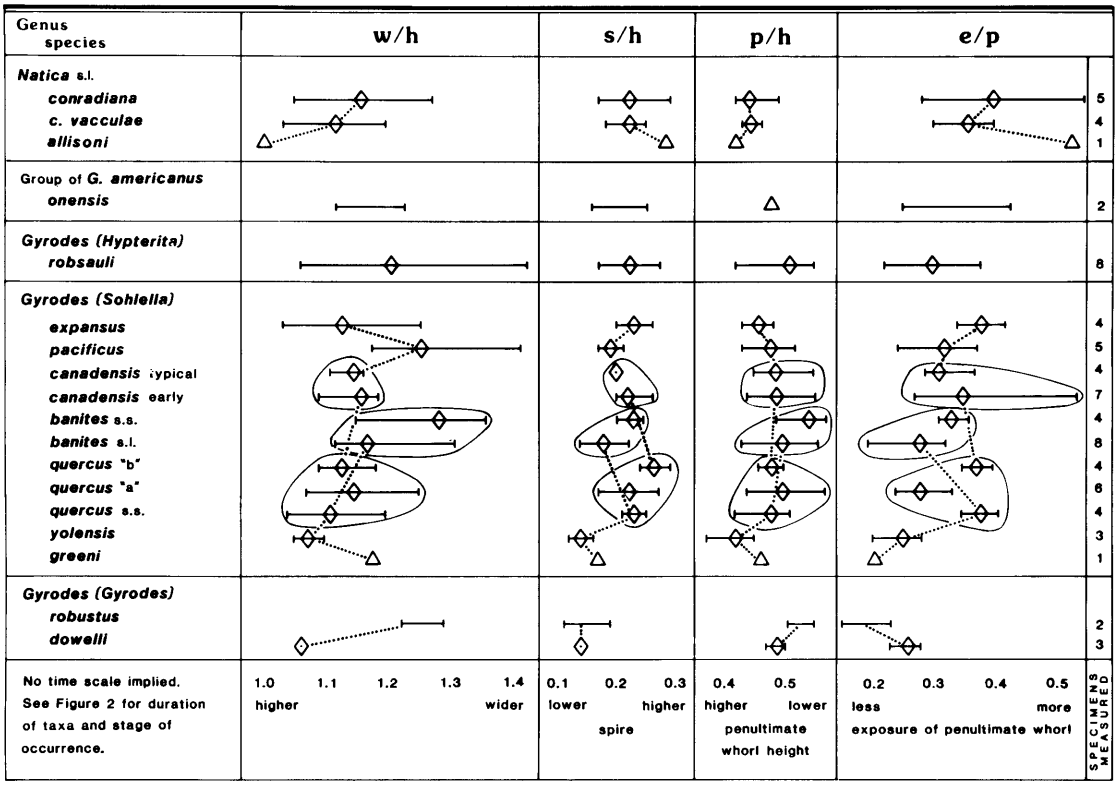

FIGURE 3—Ratios derived from five measurements h, w, s, p, and e of gyrodiform gastropods. See Figure 2 for explanation of measurements. Bar is total range of ratio and mean is indicated by diamond. Single specimen measurements (and 2 specimen measurements in which the ratios are the same) are plotted by triangle. Forms of a species discussed in the descriptions are encircled. Taxa inferred to be closely related are connected by dashed lines. Length of w/h bar is probably increased by slight post-depositional crushing of some specimens. Except for *Natica allisoni* all taxa are wider than high. *Gyrodes dowelli* is the least variable taxon. *G.* (*S.*) *banites* s.l. is contemporaneous with *G.* (*S.*) *quercus* "a"; *G.* (*S.*) *banites* s.s. is contemporaneous with *G.* (*S.*) *quercus* "b"; and the graph suggests increasing distinction of *G.* (*S.*) *banites* from *G.* (*S.*) *quercus.*

of the Geological Survey of Canada, and J. W. Durham of the Department of Paleontology, University of California, Berkeley. R. L. Cleevely provided a cast of a naticid from the Upper Greensand which helped resolve a taxonomic quandry. H. Tappan and A. R. Loeblich assisted in the resolution of nomenclatorial problems and with manuscript revisions. Figures were expertly drafted by V. D. Jones. This paper has greatly benefited from the critical reading of M. A. Murphy and J. T. Smith, and R. B. Saul has improved its readability.

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA Linnaeus, 1758

Class GASTROPODA Cuvier, 1797

Order MESOGASTROPODA Thiele, 1927

Family NATICIDAE Forbes, 1838

Subfamily GYRODINAE Wenz, 1941

Discussion.—Marincovich (1977, p. 213) included Gyrodinae of Wenz in Ampullospirinae Cox, 1930, but ampullospirins are usually higher spired with a shell that is higher than wide and have a closed or very narrowly open umbilicus with a cord or ridge extending from the anterior inner lip into the umbilicus. Gyrodinae are low spired, and the shell is usually wider than high. Most have an open, usually wide open, umbilicus without a funicle (Wenz, 1941, p. 1017). Shell surface is textured by growth lines and is not polished. The growth line is strongly prosocline across the flank and within the umbilical depression

forms a characteristic, broadly U-shaped, antispiral sinus. Naticinae differ from Gyrodinae, which are predominantly fossil, in having a less prosocline growth line that lacks a broadly U-shaped, umbilical, antispiral sinus.

Genus GYRODES Conrad, 1860

Type species.—*Natica* (*Gyrodes*) *crenata* Conrad, 1860. =*Rapa supraplicata* Conrad, 1858, by subsequent designation Gardner, 1916, p. 496.

Discussion.—*Gyrodes* comprises a distinctive group of naticid gastropods predominantly of later Cretaceous age. Some species of Aptian age are ascribed to it but do not belong to the typical subgenus. Of the few described Paleocene *Gyrodes,* only *G. robustus* resembles the typical subgenus.

Conrad (1860, p. 289) characterized *Gyrodes* as "Globose, thin in substance; whorl channelled above; umbilicus profound without a callus on the columella or base." He followed this diagnosis with the description of two new species, *Natica* (*Gyrodes*) *crenata* and *N.* (*Gyrodes*) *alveata,* and referred *Natica petrosa* Morton, 1834, to *Gyrodes.*

Gyrodes has been discussed subsequently by a number of workers, among whom may be mentioned Stoliczka (1868, p. 297), Meek (1876, p. 309), Fischer (1887, p. 768), Gardner (1916, p. 496), Cossmann (1925, p. 102), and Sohl (1960, p. 116). Sohl's diagnosis, which well represents the modern concept of the genus, defines it as comprised of "Medium- to large-sized subglobose low-spired shells with wide deep umbilicus free of callus; ornament restricted to growth lines and commonly nodes or crenulations near suture and at umbilical margins; aperture subovate, inclined; inner-lip callus very thin." The absence of umbilical callus in the genus is stressed by practically all workers. Cossmann (1925, p. 103) emphasized that this genus has a "columelle non calleuse, non réfléchie sur l'ombilic, dont la paroi interne ne comporte aucun épaisissement ni aucune arête." Despite this universal exclusion from *Gyrodes* of forms having callosities in the umbilicus, three Pacific Coast taxa, *G.* (*Sohlella*) *quercus* n. sp., *G.* (*?Sohlella*) *banites* n. sp., and *G.* (*Hypterita*) *robsauli* n. sp., that possess callosities are included in *Gyrodes* s.l. because of their probable phylogenetic relationship to forms that lack such structures and otherwise possess characteristics of *Gyrodes.*

Sohl (1960) suggested subdivision of *Gyrodes* into three main types, based upon characters of the umbilical margin and the suture: 1) species of the typical form—exemplified by *G. supraplicatus* [type-species]—have a crenulate and sharp umbilical margin and crenulations near the suture; 2) species resembling *G. americanus* (Wade, 1926) bear a smooth whorl-surface and rounded umbilical margin; 3) species similar to *G. spillmani* Gabb, 1861, have a rounded umbilical margin and a noncrenulate but distinctly channeled suture. The first group, *Gyrodes* s.s., is represented in the Pacific Coast Cretaceous only by *Gyrodes dowelli* White, 1889, a Turonian species. The Pacific Coast Paleocene species, *Gyrodes robustus* Waring, 1917, similar in shape to *Gyrodes* s.s. but lacking crenulations, is questionably assigned to *Gyrodes* s.s. One West Coast species, *G. onensis* n. sp., resembles *G. americanus* (Wade). With one exception the remaining Pacific Coast *Gyrodes* appear most similar to the group of *G. spillmani* Gabb—forms with a "distinctly channeled suture." In the multitude of specimens in Pacific Coast collections, this character is somewhat variable; specimens from separate collections of essentially the same age, and other lots from the same locality and horizon, have subsutural bands which vary from flattened to tabulate to more-or-less channeled. Additionally, these Pacific Coast forms have a distinctly biangulate umbilical margin rather than the rounded margin of the *G. spillmani* group. Consequently, these West Coast forms are assigned to a new subgenus, *Sohlella.* The final group is that of the subgenus *Hypterita,* which is represented by the new species *G.* (*H.*) *robsauli.*

Subgenus GYRODES Conrad, 1860

Diagnosis.—Species of *Gyrodes* with a crenulate and sharp umbilical margin, and crenulations near the suture, with growth lines adjacent to the suture commonly notched.

GYRODES (GYRODES) DOWELLI White, 1889
Figure 4.1, 4.5, 4.7

Gyrodes dowelli WHITE, 1889, p. 19, Pl. 3, figs. 8, 9; ANDERSON, 1958, p. 149, Pl. 21, figs. 8, 9; JONES, SLITER, AND POPENOE, 1978, p. XXII. 10, Pl. 1, figs. 13, 14.

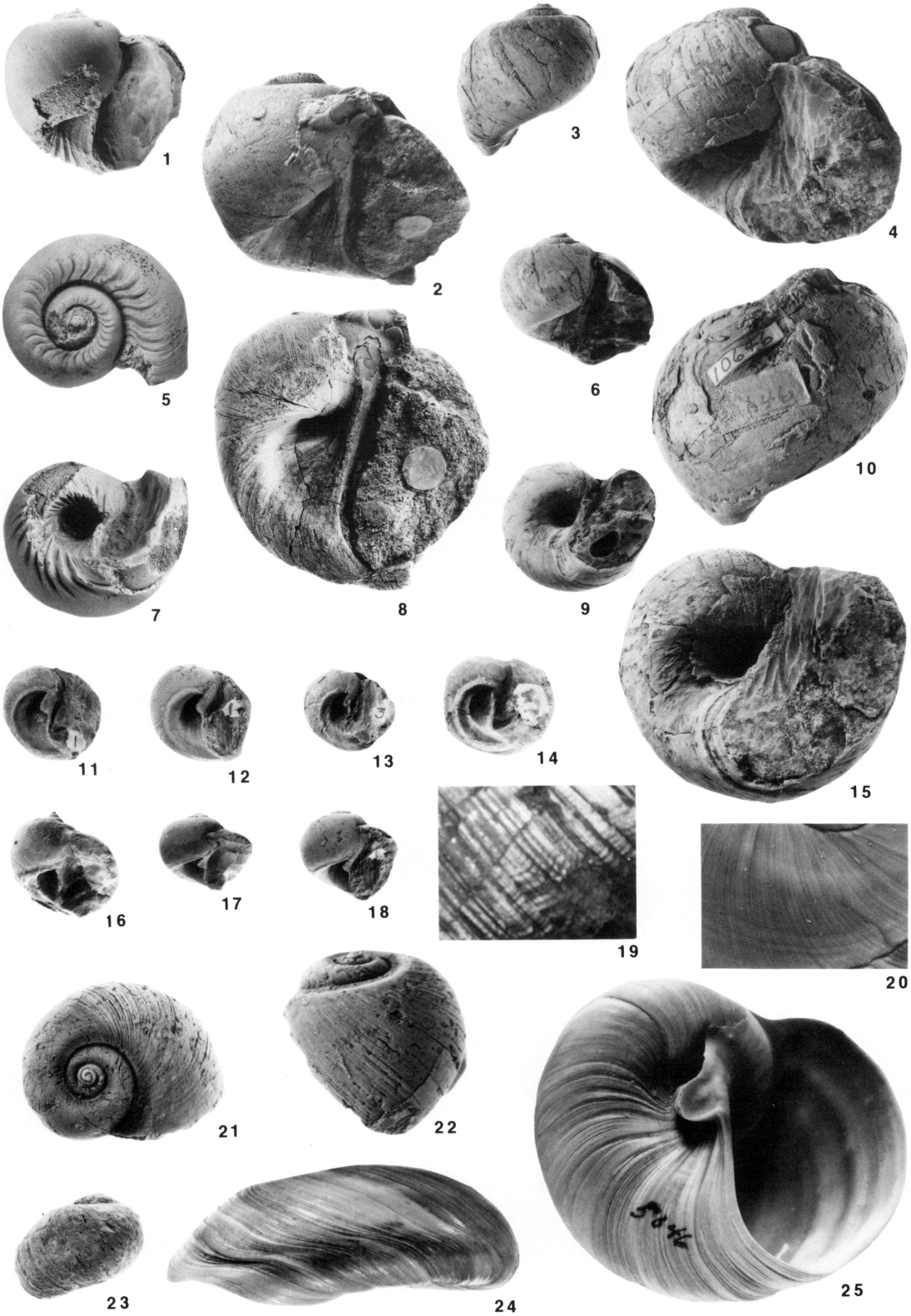
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TABLE 1—Dimensions of hypotypes of *Gyrodes* (*Gyrodes*) *dowelli* White, in mm, * = incomplete. See Figure 2 for explanation of measurements.

	h	w	s	p	e	w/h	s/h	p/h	e/h	e/p
UCLA 59441	27.6*	29.3*	4.3	13.1	3.6	1.06	0.16	0.48	0.13	0.27
UCLA 59728	41.3*	43.9	6.0*	21.0	5.8	1.06	0.15	0.51	0.14	0.28
UCLA 59729	33.2	35.0	5.0	16.8	3.8	1.05	0.15	0.51	0.11	0.23

Description.—Shell medium to moderately large, slightly wider than high, thin; spire low, 15% of total height; protoconch of about 1½ smooth whorls; suture impressed, at posterior quarter of penultimate whorl; shoulder flattened but round edged and undulately crenulate; body sides broadly, evenly convex; umbilical margin abruptly angled and obliquely crenulate; umbilical wall smooth posterior to the clearly demarked crenulate band; umbilicus somewhat narrow, steep sided, and deep; aperture obliquely suboval; growth line notched at the suture, with a strong spiral antisinus on the shoulder, prosocline across the flank, abruptly flexed backward at the outer angulation, and forming a broad U-shaped sinus within the umbilicus; outer lip thin, projected near its posterior end, abruptly roundly notched near the suture; inner lip plain.

Holotype.—USNM 20126.

Hypotypes.—CAS 10648 from CAS loc. 1293-A, 1 mile (1.6 km) north of Frazier Corners, Shasta Co.; UCLA 58441, 59728–59729 all from CIT loc. 1444, south of Woodman Creek, Redding area, Shasta Co., California.

Type locality.—Near Jacksonville, Oregon.

Distribution.—Near the base of the Nanaimo Group at Hamley Point, Sydney Island, British Columbia; Hornbrook Formation near Jacksonville, and the vicinity of Ashland, Oregon; in the Henley-Hornbrook region, and near Ager, Siskiyou Co.; Bellavista Sandstone, Frazier Silt, and Melton Sandstone of the Redding area, Shasta Co.; lower Venado Formation of Kirby on Logan Ridge, Colusa Co.; the Panoche Formation in the Dark Hole Quadrangle, near Coalinga, Fresno Co.; and the lower Ladd Formation in the Santa Ana Mountains, Orange Co., California.

Age.—Turonian.

Remarks.—This species differs from all other known Pacific Coast Cretaceous *Gyrodes* in its strongly wrinkled shoulder and umbilical margin, its relatively low and flattened spire, high and narrow last whorl, and narrow umbilicus. Its presence in association with *Cucullaea* (*Idonearca*) *gravida* (Gabb, 1864), *Glycymeris pacificus* (Anderson, 1902), *Pterotrigonia klamathonia* (Anderson, 1958), *Oonia*? *californica* (Gabb, 1864), and *Rostellinda dilleri* (White, 1889) at CGS 85511, Sydney Island, British Columbia, is the first indication of Turonian age sediments in the Nanaimo Basin (Jeletzky, 1977).

GYRODES (?GYRODES) ROBUSTUS
Waring, 1917
Figure 4.2, 4.8

Gyrodes robustus WARING, 1917, p. 84, Pl. 13, figs. 11, 12; MARINCOVICH, 1977, p. 243, Pl. 21, figs. 3–9.

←

FIGURE 4—All figures ×1 except as noted. *1, 5, 7, Gyrodes* (*Gyrodes*) *dowelli* White, 1889, hypotype, UCLA 59441, from CIT loc. 1444, Turonian. *2, 8, Gyrodes* (*?Gyrodes*) *robustus* Waring, 1917, hypotype, UCLA 59730, from UCLA loc. 2582, early Selandian. *3, 4, 6, 9, 10, 15, Gyrodes* s.l. *onensis* n. sp., from CAS loc. 1346A, Albian; *3, 6, 9,* paratype, CAS 10647; *4, 10, 15,* holotype, CAS 10646. *11–14, 16–19, 21–23, Gyrodes* (*Hypterita*) *robsauli* n. sp., Maastrichtian; *11–14, 16–18,* growth series showing development of callus tongue and umbilical angulations; *12, 17,* UCLA 59782, holotype, from UCLA loc. 5902; *11, 13, 14, 16–19, 21–23,* paratypes; *11, 18,* UCLA 59787 from UCLA 6534; *13,* UCLA 59784 from UCLA 5902; *14, 16,* UCLA 59789, from UCLA loc. 6534, ×2; *19,* UCLA 59790 from UCLA loc. 6337, fine spiral striations and relatively strong growth lines, ×9.5; *21, 22,* UCLA 59783 from UCLA loc. 5902, ×2; *23,* UCLA 59786 from UCLA loc. 6465. *20, 24, 25, Gyrodes* (*Hypterita*) *helicoides* (Gray, 1825), hypotype, UCLA 5046, from Magdalena Bay, Baja California, Mexico, Recent; *20,* fine spiral striations, ×4; *24,* growth line flexure which bounds antispiral sinus.

TABLE 2—Dimensions of *Gyrodes* (?*Gyrodes*) *robustus* Waring, in mm, * = incomplete. See Figure 2 for explanation of measurements.

	h	w	s	p	e	w/h	s/h	p/h	e/h	e/p
UCLA 59730	33.0*	44.0*	6.0*	18.5	4.2	1.3	0.18	0.56	0.13	0.23
UCLA 59731	46.5	57.0*	5.5*	24.0	3.7	1.23	0.12	0.52	0.08	0.15

Description.—Shell large, wider than high; spire about 15% of total height, suture appressed, at posterior quarter of penultimate whorl; shoulder tabulate, angulate; whorl profile broadly convexly rounded; umbilical margin sharply angulate; umbilicus wide, sloping shallow, with second weaker angulation at the greatest growth-line flexure; growth lines slightly prosocline on the shoulder becoming strongly so on the flank, forming broad antispiral sinus at the inner umbilical angulation; aperture obliquely semicircular, rounded anteriorly, angulate posteriorly; outer lip projected posteriorly; inner lip unreflected, wrapped onto the last whorl posterior to the umbilical angulation.

Lectotype.—LSJU 147.

Lectoparatype.—LSJU 148.

Hypotypes.—UCR 6899/2; UCLA 59730 from UCLA loc. 2582; UCLA 59731 from UCLA loc. 3154; all from the Simi Hills, Ventura Co., California.

Type locality.—LSJU 2697: Simi Hills, Ventura Co., California.

Distribution.—Lower Santa Susana Formation of the Simi Hills, Ventura Co.; Coal Canyon Formation of the Santa Monica Mountains, Los Angeles Co., California.

Age.—Paleocene, Selandian, *Turritella peninsularis–T. infragranulata* Zone.

Remarks.—Large specimens of *G.* (?*G.*) *robustus* are larger than those of any other species discussed in this paper. A poorly preserved individual from the Coal Canyon Formation in Santa Ynez Canyon, Santa Monica Mountains. (UCLA 6738) has a width of 100 mm. Specimens are uncommon and usually poorly preserved.

Gyrodes (?*G.*) *robustus* is not similar to early Tertiary forms from Europe assigned to *Gyrodes* (*Sigaretopsis*). From *G.* (*S.*) *infundibulum* (Watelet, 1853), the type species of *Sigaretopsis* (Cossmann, 1888), *G. robustus* differs in being large, tabulate, and angulately umbilicate. In shape it resembles *Gyrodes* s.s. It differs from *G. supraplicatus* (Conrad) in lacking the crenulations near the suture and on the umbilical margin. Its umbilicus has a shallower slope and narrower center and, although its outer umbilical angulation is strong, this angulation is not as prominent as that of *G. supraplicatus*. Unlike the inner angulation of *G. supraplicatus* that stands as a spiral chord within the umbilicus, the inner angulation of *G. robustus* is barely angulate; and the zone between the angulations is not sulcate as in *G. supraplicatus* but is flattened. The growth line of *G.* (?*G.*) *robustus* is not notched at the suture as is that of *G. supraplicatus* and *G. dowelli*.

Gyrodes robustus is most similar to *Eocernina hespericosta* Zinsmeister, 1983, also from the lower Santa Susana Formation in the Simi Hills, Ventura Co., California. *Eocernina hespericosta* is tabulate only on its early whorls and develops a slope-shouldered adult whorl profile; tabulate young *E. hespericosta* resemble *G. robustus*. Both species have a similar prosocline growth line with a strong antispiral sinus within the umbilical depression, a shallow sloping umbilicus bounded by an angulation, and a nearly straight inner lip which rounds abruptly into the basal lip at the umbilical flattening. *Eocernina hespericosta* has a thicker shell, thicker inner lip callus, and narrower umbilicus. The similarities are sufficiently strong to suggest that *Eocernina* is derived from *Gyrodes*.

SOHLELLA n. subgen.

Type species.—*Gyrodes* (*Sohlella*) *canadensis* (Whiteaves, 1903).

Diagnosis.—Species of *Gyrodes* with a usually tabulate, asymmetrically inflated whorl that is roundest anteriorly and has a biangulate to subrounded umbilical margin. The tabulation usually bears a slightly concave band.

Discussion.—*Sohlella* n. subgen. includes *G. quercus* n. sp., *G. canadensis* Whiteaves, *G. pacificus* n. sp., and *G. excavatus* (Gabb).

Also tentatively included is *G. greeni* Murphy and Rodda, *G. yolensis* n. sp., and *G. banites* n. sp. So constituted, the subgenus ranges from Cenomanian through mid Maastrichtian. The shell surface is textured by growth lines; very well-preserved specimens have a silken luster but are not polished. *Sohlella* includes forms remarkable among *Gyrodes* for having umbilical callosities. *Gyrodes* (*S.*) *quercus* and *G.* (?*S.*) *banites* have a reflected inner lip which in *G.* (?*S.*) *banites* overhangs the umbilicus and forms an umbilical callus lobe similar to that of *Banis* and *Hypterita.* Most species assigned to *Sohlella* resemble Sohl's group of *G. spillmani* Gabb in their unornamented, slightly concave, tabulate shoulder, but differ from that group in having a more angulate umbilical margin. The questionably allotted *G. greeni* has the most sharply angulate umbilical margin; it differs from all other *Sohlella* in having a single rather than double umbilical angulation.

The subgenus is named for N. G. Sohl in celebration of his contributions to the delineation of Cretaceous naticids.

GYRODES (?SOHLELLA) GREENI
Murphy and Rodda, 1960
Figure 5.1, 5.10, 5.20

Gyrodes greeni MURPHY AND RODDA, 1960, p. 843, Pl. 101, figs. 27–29.

Holotype.—UCLA 28630.

Dimensions.—h, 26.8 mm; w, 31.6 mm; s, 4.7 mm; p, 12.6 mm; e, 2.6 mm; w/h, 1.18; s/h, 0.18; p/h, 0.47; e/h, 0.1; e/p, 0.2 (see Figure 2 for explanation of measurements).

Type locality.—UCLA 3465: north fork of Cottonwood Creek, Shasta Co., California.

Distribution.—Known only from the Bald Hills Member of the Budden Canyon Formation, Ono area, Shasta Co., California.

Age.—Cenomanian.

Remarks.—*Gyrodes* (?*S.*) *greeni* resembles *G.* (?*S.*) *yolensis* in being less tabulate at maturity than in youth and in having the growth line nearly orthocline at the suture. In *G.* (?*S.*) *greeni* the inner lip is wrapped onto the penultimate whorl posterior to the umbilical angulation rather than at the angulation and the loss of tabulation at maturity is more complete than in *G.* (?*S.*) *yolensis.* Of all the *Gyrodes* spp. discussed herein the whorls of *G.* (?*S.*) *greeni* are narrowest posteriorly and widest anteriorly. It is the only species with a single umbilical angulation assigned, even tentatively, to *Sohlella.* Murphy and Rodda have commented on the resemblance of *G.* (?*S.*) *greeni* to *G.* (*S.*) *canadensis* and *G. excavatus.* Overall shape and umbilical characteristics of *G.* (?*S.*) *yolensis* are intermediate between those of *G.* (?*S.*) *greeni* and *G.* (*S.*) *quercus. Gyrodes greeni* and *G. yolensis* differ from other *Sohlella* spp. in the orthocline direction of the growth line immediately adjacent to the suture.

GYRODES (SOHLELLA?) YOLENSIS n. sp.
Figure 5.2, 5.11, 5.16, 5.21, 5.25, 5.30

Description.—Shell thin, medium sized, slightly wider than high, narrowly tabulate; spire about 15% of total shell height; suture appressed on early whorls, becoming depressed on last whorl, near posterior quarter of penultimate whorl; shoulder tabulate, angulate on early whorls, becoming rounded and obscurely noded on last whorl; whorl profile slightly concave abapical to the shoulder then roundly convexly expanded, contracted near the well-marked umbilical angulation; umbilical margin biangulate, the outer angulation sharper; umbilicus wide, sloping; growth line nearly orthocline at the suture, obliquely flexed at the shoulder, flexed at the umbilical angulations, curving into the umbilicus; aperture oblique, tear-drop shaped; outer lip thin, projected posteriorly; inner lip thin, wrapped around onto the previous whorl at the outer angulation.

Holotype.—CAS 61401.

Paratypes.—CAS 61402–61403 from CAS 31918.

Type locality.—CAS 31918: Thompson Creek, 1,200′ N, 600′ W of SE cor. sec. 20, T8N, T2W, Capay Quadrangle, Yolo Co., California.

Distribution.—Near the base of the Yolo Shale on Thompson Creek, Yolo Co.; and "Antelope Shale" of Kirby, probably slumped from basal Venado Formation, on Logan Ridge, Colusa Co., California.

Age.—Turonian.

Remarks.—This species is described from three well-preserved specimens, all of which have the outer lip broken. Two additional specimens—both leached and somewhat crushed—are from USGS M-175. The larger

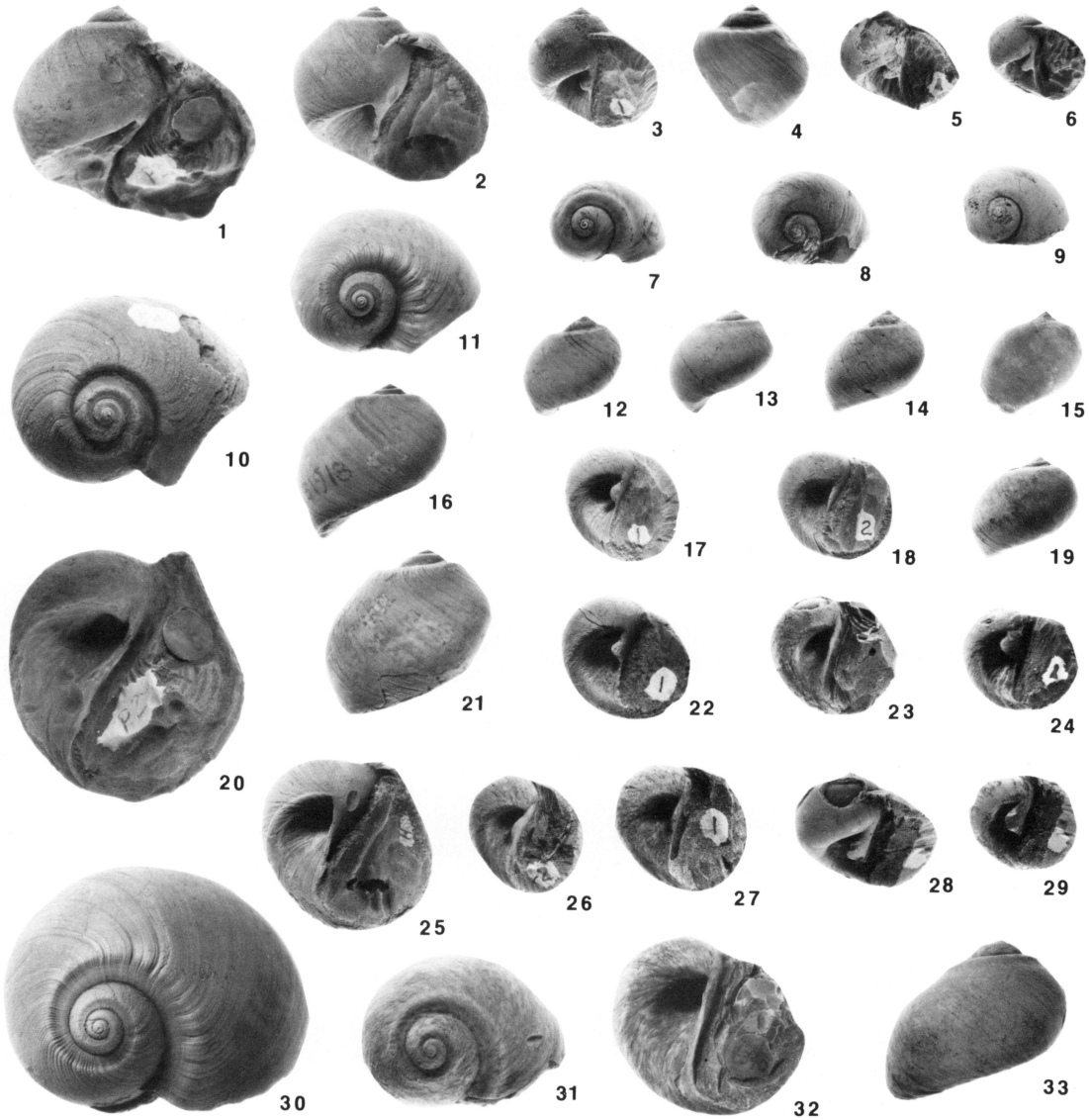

FIGURE 5—All figures ×1 except as noted. *1, 10, 20, Gyrodes* (?*Sohlella*) *greeni* Murphy and Rodda, 1960, holotype, UCLA 28630 from UCLA loc. 3465, Cenomanian. *2, 11, 16, 21, 25, 30, Gyrodes* (?*Sohlella*) *yolensis,* n. sp., from CAS loc. 31918, Turonian; *2, 11, 21, 25,* holotype CAS 61401; *16,* paratype, CAS 61402; *30,* paratype, CAS 61403, ×2. *3, 4, 7, 12, 17, Gyrodes* (*Sohlella*) *quercus* n. sp., from CIT loc. 1007, Coniacian; *3, 4, 17,* holotype, UCLA 59732; *7,* paratype, UCLA 59733; *12,* paratype, UCLA 59734. *5, 6, 8, 9, 15, 19, 24, Gyrodes* (?*Sohlella*) *banites* n. sp. s.l., hypotypes, Santonian; *5, 8, 19, 24,* UCLA 59760 from CIT loc. 1246; *6, 9,* UCLA 59761 from CIT loc. 1246; *15,* UCLA 59759 from UCLA loc. 4246. *13, 18, 22, 23, Gyrodes* (*Sohlella*) *quercus* n. sp. form "a", hypotypes, Santonian; *13, 18, 22,* from UCLA loc. 4106; *13, 18,* UCLA 59741; *22,* UCLA 59740; *23,* UCLA 59746 from CIT 1313. *14, 26, 27, Gyrodes* (*Sohlella*) *quercus* n. sp. form "b", hypotypes from UCLA 3627, Santonian; *14, 26,* UCLA 59748; *27,* UCLA 59747. *28, 29, Gyrodes* (?*Sohlella*) *banites* n. sp., paratype, UCLA 59755 from UCLA loc. 3627, Santonian; *28,* ×1.5. *31–33, Gyrodes* (*Sohlella*) *canadensis* Whiteaves, "early" form, hypotype, UCLA 59770 from UCLA loc. 4340, early Campanian.

TABLE 3—Dimensions of *Gyrodes* (*Sohlella*?) *yolensis* n. sp., in mm. See Figure 2 for explanation of measurements.

	h	w	s	p	e	w/h	s/h	p/h	e/h	e/p
CAS 61401	22.2	24.5	2.8	8.5	1.7	1.1	0.13	0.38	0.08	0.2
CAS 61402	20.5	21.8	3.1	9.5	2.5	1.06	0.15	0.46	0.12	0.26
CAS 61403	19.6	20.6	3.4	8.9	2.5	1.05	0.17	0.45	0.13	0.28

of these probably had a width of at least 30 mm and is of similar size to the holotype of *G.* (?*S.*) *greeni. Gyrodes* (?*S.*) *yolensis* differs from *G.* (?*S.*) *greeni* Murphy and Rodda in being lower spired, having obscure wrinkle-like nodes on the stronger shoulder, the slope of the inner lip at a narrower angle to the axis of coiling, and biangulate umbilical margin.

It differs from typical *Sohlella* in having its growth line orthocline at the suture, obscure wrinkle-like nodes on the shoulder, and the suture depressed at maturity.

The species is named for its occurrence in the Yolo Shale in Yolo County.

GYRODES (SOHLELLA) QUERCUS n. sp.
Figures 5.3, 5.4, 5.7, 5.12–5.14, 5.17, 5.18, 5.22, 5.26, 5.27, 6.1–6.4

Description.—Shell thin, small, wider than high; spire about 25% of total height, suture appressed, near posterior three-eighths of penultimate whorl; shoulder tabulate, angulate with shallow concave band adapically and slightly concave zone abapically; whorl profile obliquely convexly rounded anterior to the slight concavity adjacent to the shoulder; umbilical margin roundly biangulate; umbilicus narrow, steeply sloping; growth line obliquely prosocline; aperture oblique teardrop shaped; outer lip thin, projected posteriorly; inner lip thin anteriorly, with or without short posterior reflected tongue of callus overhanging the umbilicus.

Holotype.—UCLA 59732.

Paratypes.—UCLA 59733–59738 from CIT loc. 1007.

Hypotypes.—Form "a" UCLA 59740–59741 from UCLA loc. 4106, Clover Creek, Redding area, Shasta Co.; UCLA 59742–59743 from CIT loc. 1016, Chico Creek; UCLA 59744–59745 from UCLA loc. 3624, Chico Creek; UCLA 59746 from CIT loc. 1313, Chico Creek, Butte Co.; form "b" UCLA 59747–59748 from UCLA loc. 3627, Chico Creek, Butte Co., California; UCLA 59749–59750 from UCLA loc. 4217, Clover Creek, Redding area, Shasta Co., California.

Type locality.—CIT 1007: hills north of Oak Run, 1,250′ S, 1,250′ E of NW cor. sec. 16, T32N, R2W, Millville Quadrangle, Shasta Co., California.

Distribution.—Members IV, V, and VI of the Redding area, Shasta Co. (Popenoe, 1943); Chico Formation, Musty Buck Member on Mill Creek, Tehama Co.; Musty Buck Member of the Chico Formation on Chico Creek, Butte Co., California.

Age.—Coniacian and Santonian.

Remarks.—*Gyrodes* (*S.*) *quercus* differs from *G.* (?*S.*) *yolensis* in its broader, unnoded

TABLE 4—Dimensions of *Gyrodes* (*Sohlella*) *quercus* n. sp., in mm, * = incomplete. See Figure 2 for explanation of measurements.

	h	w	s	p	e	w/h	s/h	p/h	e/h	e/p
UCLA 59732	15.2	18.2	4.0	7.9	2.8	1.2	0.26	0.52	0.18	0.35
UCLA 59733	13.7	15.4*	3.0	6.8	2.6	1.12	0.22	0.5	0.19	0.38
UCLA 59734	14.5	15.5*	3.2	7.4	2.7	1.07	0.22	0.51	0.19	0.36
UCLA 59735	18.7	19.4*	4.5	8.0	3.3	1.04	0.24	0.43	0.18	0.41
UCLA 59740	16.7	17.8	3.9	7.5	2.5	1.07	0.23	0.45	0.15	0.33
UCLA 59741	13.7	15.4	2.8	6.8	1.9	1.12	0.2	0.5	0.14	0.28
UCLA 59742	11.2	12.3	2.0	5.5	1.5	1.1	0.18	0.49	0.13	0.27
UCLA 59743	10.7	13.7	3.0	6.2	1.5	1.28	0.28	0.58	0.14	0.24
UCLA 59744	13.5	15.6	3.5	7.0	1.9	1.16	0.26	0.52	0.14	0.27
UCLA 59745	12.0	14.1	2.8	6.1	1.7	1.18	0.23	0.51	0.14	0.28
UCLA 59747	15.8	17.8	4.2	7.8	2.8	1.13	0.27	0.49	0.18	0.37
UCLA 59748	14.7	16.0	4.4	6.9	2.4	1.09	0.3	0.47	0.16	0.35
UCLA 59749	12.0	14.2	3.0	5.8	2.2	1.18	0.25	0.48	0.18	0.38
UCLA 59750	9.9	11.0	2.5	5.0	2.0	1.11	0.25	0.51	0.2	0.4