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GANULA GADIRANA N. SP., A NEW HYGROMIIDAE FROM SOUTHERN SPAIN (PULMONATA: HELICOIDEA)

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ABSTRACT

Ganula gadirana Muñoz, Almodóvar & Arrébola, is proposed as a new species from the southernmost corner in the Iberian Peninsula. This species, sometimes erroneously recorded as *Helix* (= *Ganula*) *lanuginosa* Boissy, 1835, is characterized by a globose conical-depressed shell, with ovate aperture, small umbilicus, and periostracum with long, persistent hairs; it has a right ommatophore retractor between the penis and the vagina, a penial nerve arising from the right cerebral ganglion, ring-shaped glandular area on the distal penis wall, a fenestrate and elongate penial papilla, and a circumvaginal tuft of long, annulated digitiform glands. A dart-sac complex is on one side of the vagina and is formed by an outer dart-bearing stylophore and inner apically bilobed dartless stylophore; each open separately into a canaliculate deep groove that divides two large pleats, distally detached from the vaginal wall. Comparisons with *Ichnusotricha* and *Ganula* suggest that the new species may be closely related to *G. lanuginosa* (Boissy, 1835). The bilobate distal portion of the inner stylophore, the larger number of tufts in the digitiform glands, the fenestrate penial papilla, the penial glandular area, and the radular formula to distinguish *G. gadirana* from *G. lanuginosa.*

Key words: *Ganula gadirana,* Gastropoda, Stylommatophora, Hygromiidae, Spain.

INTRODUCTION

Many new generic taxa have been recently described by the Giusti-Manganelli's team for the western Mediterranean area, most of them being monotypical: *Helicotricha carusoi* from the Aeolian Islands (Giusti et al., 1992), *Cilliellopsis oglasae* from Montecristo Island (Giusti & Manganelli, 1990), *Schileykiella* for *Helix parlatoris* Bivona, 1839, and *Helix reinae* Pfeiffer, 1856, from Sicily (Manganelli et al., 1989), *Ichnusotricha berninii* and *Nienhuisiella antonellae* from Sardinia (Giusti & Manganelli, 1987), and *Tyrrheniella josephi* from Sardinia/Capraia Islands (Giusti & Manganelli, 1989). The number of new morphological patterns is striking, and more new generic taxa can be expected.

Ganula lanuginosa, according to bibliographical records, seems to be distributed in four areas: eastern Balearic Islands (type locality of *Helix lanuginosa* Boissy, 1835) Sardinia (Giusti & Manganelli, 1987), southern Spain (Servain, 1880), and northwestern Africa (Terver, 1839; Bourguignat, 1864; Letourneux & Bourguignat, 1887). This species could be of great zoogeographical value if its presence in these areas is anatomically confirmed (Giusti & Manganelli, 1984), although Balearic records could be the result of an introduction from northwestern Africa during the Middle Ages (Gasull, 1963).

Nevertheless, the anatomical confirmation has been carried out only for the Balearic Islands (Hesse, 1931; Gittenberger, 1968) and Sardinia (Giusti & Manganelli, 1987). Searching to confirm its presence in southern Spain, where it was repeatedly cited (Servain, 1880; Sacchi, 1956, 1957; Sacchi & Nos, 1958; Gasull, 1963), was unsuccessfull. In nearly identical shells, we have found snails with genitalia similar to those in *Ganula lanuginosa,* but differing in the configuration of the dart-sac complex and in a larger number of tufts in the digitiform glands. These characters support introduction of a new species from southern Spain: *Ganula gadirana.*

MATERIALS AND METHODS

Living specimens were drowned in tapwater and preserved in 70% ethanol. Removed bodies were dissected and studied by optical stereomicroscopes (Zeiss and Nikon). Genital system and other structures were drawn using a camera lucida (Zeiss and Nikon). Nerve rings were removed from the

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connective tissue with a pointed watchmaker forceps prior to drawings.

Serial microscopical sections were coloured with Mallory's stain and photographed with a Zeiss Stemi SV6 photostereomicroscope. Radulae were removed from buccal bulbs by hot digestion in KOH and then washed in pure ethanol. Some radulae were mounted on metallic blocks with electron-conductive glue, coated with gold, and photographed in a JEOL 820 SEM, and others were stained by a modified hemalumpicroindigocarmine method and observed using a Zeiss stereomicroscope. Shells were photographed with the same SEM or with a Pentax P30N camera.

Shell parameters were measured in adult specimens using a Zeiss stereomicroscope with millimetric lens. Features of the central nervous system were described according to the character states proposed by Tillier (1989: 40–42).

The nomenclature for the genital system (that used by other authors in brackets) is the following: outer stylophore (= dart sac or lower stylophore), inner dartless stylophore (= accessory sac or upper stylophore), penial papilla (= verge), digitiform glands (= mucous glands).

SYSTEMATIC DESCRIPTION

Ganula gadirana Muñoz, Almodóvar & Arrébola, n. sp.

Helix lanuginosa, Servain, 1880: 51 (*non* Boissy) ["Environs d'Algesiras"].

Fruticicola lanuginosa, Sacchi, 1956: 17 (*non* Boissy) [only. "nelle regioni tra Malaga e Algesiras"].

Fruticicola lanuginosa, Sacchi, 1957: 19 (*non* Boissy) [only: "presso Malaga e presso Algesiras"].

Fruticola lanuginosa, Sacchi & Nos, 1958: 93 (*non* Boissy) [only: "region d' Algesiras"].

Shell (Figs. 1, 2). Shell medium sized, globose-depressed, conical-convex above, inflated below, uniform light brown translucent (Fig. 1A-B). Spire low conical, consisting of 5–5 1/2 convex, regularly increasing whorls separated by deep sutures. Apex small, protruding apex; protoconch with 1 1/4–1 1/2 whorls, striated, with hair scars (Fig. 2A). Last whorl large, one and one half times broader than the penultimate whorl, rounded at periphery, and variably descending near aperture. Umbilicus very small (0.6–0.8 mm), deep, partly covered by the reflected margin of peristome. Aperture oblique, oval or nearly circular, without internal lip, but with a whitish band (reddish in external view). Peristome interrupted straight, smooth, not thickened, with very separated, non-convergent marginal edges; columellar edge gently curved, widened at origin, very reflected over umbilicus. External teleoconch surface with long (0.4 mm), erect, persistent hairs in transverse rows 0.4 mm far apart, with a density of 14–17 hairs/mm^2 (Fig. 2B); microsculpture of teleoconch formed by fine, small crests among hairs; hair scars curved.

Dimensions (n = 16): Shell diameter, 11.0–14.0 mm (holotype, 13.0 mm); shell height, 8.0–10.9 mm (holotype, 9.8 mm); aperture maximum diameter, 6.8–8.2 mm (holotype, 7.9 mm).

Foot (Fig. 2C). Sole with a tripartite appearance (also visible in preserved specimens): central zone light, lateral zones darker.

Lung roof (Fig. 3A) with an irregular pattern of small, blackish, irregular spots, which are larger over kidney borders.

Kidney (Fig. 3B) with numerous, long, raised internal pleats, more numerous on ureteric side; primary ureter broad, mostly situated on the kidney; secondary ureter, closed at first, but open 1 mm from the ureteric angle (in front of heart ventricle) to form a broad ureteric groove.

Heart oval, somewhat longer than half length of kidney. Slender primary pulmonary vein with inconspicuous secondary veins.

Mantle collar (Fig. 3C). Left lateral lobe, thin, small, with lobed upper border and straight lower border. Right lateral lobe long, thick, with an upper corner forming an anal lobe. Both left and right dorsal lobes with free marginal borders. Subpneumostomal lobe separating anal and pneumostomal orifices.

Central nervous system (Fig. 3D–F). Cerebral commissure shorter (CC3) and right cerebropedal connective somewhat longer (CPD2) than right cerebral ganglion width; both right and left cerebropedal connectives of similar length (CPR2), somewhat longer than cerebropleural connectives; both right and left pleural ganglions closer to pedal ganglions than cerebral ganglions (PLD1, PLG1); visceral ganglion in median plane of pedal ganglions (VG2); right parietal ganglion in contact with both visceral and right pleural ganglions (PAD2), apparently fused with the latter; left parietal ganglion only in contact with visceral ganglion (PAG3), both ganglia apparently fused (FG3).

Genital system (Figs. 4A–B, 5A–E, 6A–E).

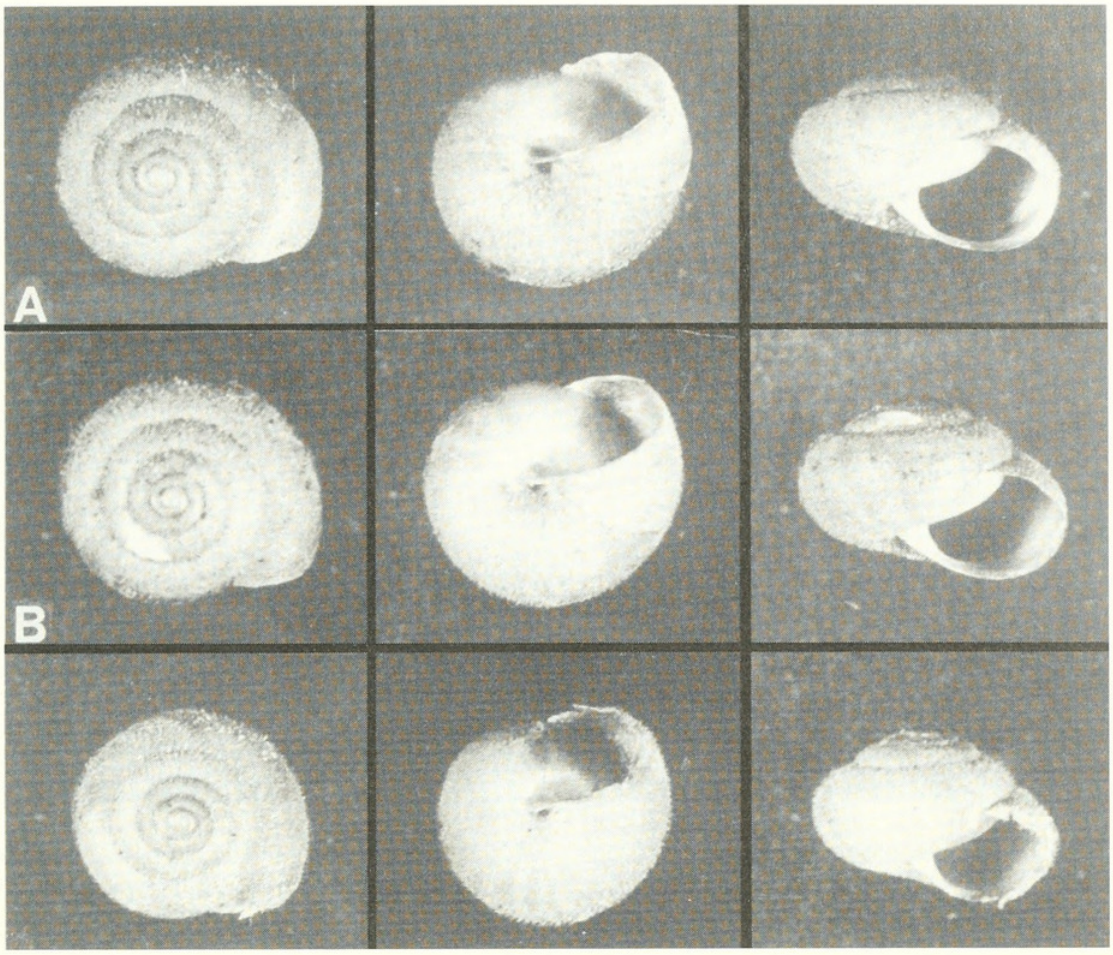

FIG. 1. Shells of *Ganula gadirana*, n. sp., from the type locality. A. Holotype; B. Two paratypes (upper collected on 30 October 1992, and lower on 14 May 1992).

Multilobate gonad and hermaphrodite duct without special features (not figured). Albumen gland relatively short. FPSC (Fig. 5A), with both seminal receptacle and fertilization pouch simple, sac-like, the former shorter, slender. Ovispermiduct (Fig. 4A), wide, circumvoluted, with prostatic and uterine parts well differentiated. Vas deferens slender.

Penial complex (Figs. 4A–B, 5D) consisting of flagellum, epiphallus (i.e., from end of vas deferens to attachment point of penial retractor muscle), and penis (i.e., from point of attachment of penial retractor muscle to genital atrium); penial retractor muscle attached to penial complex proximal to point in which base of penial papilla is contained; a strong muscular band (Fig. 4B) extends from outer penial wall of proximal penis to wall of genital atrium, bending the penial complex; flagellum short, 1/3 of epiphallus length, conical in shape, with thick walls; epiphallus cylindrical, somewhat longer than penis, its inner wall pleated; penis with distal yellowish, ring-shaped, glandular area (Fig. 5C–D); penial papilla long, cylindrical (Fig. 5B), with three fenestrations through which wide distal lacunae inside penial papilla walls communicate with penial cavity; a nearly isolated central canal traverses the penial papilla, its walls fixed by radial septa to walls of penial papilla.

Female part (Fig. 4A–B) consisting of a short free oviduct (half length of bursa copulatrix duct); bursa copulatrix large, shoe-shaped, with short pedunculus; vagina short, with digitiform glands and dart-sac complex, the latter located on one side. Digitiform glands (Fig. 5E) composed of many (14–20), long, unbranched or basally branched tubes disposed all around vagina; tubes with an annulate appearance, the inner secretory epithelium forming small ridges (Fig. 7A, G). Dart-sac complex (Figs. 6A–B, D–G, 7A–F) short, broad, composed of two stylophores; outer stylophore basally surrounded by groove of vaginal wall (Fig. 6A–B); inner stylophore broader, dartless, with thick walls and narrow inner cavity, extended into two apical

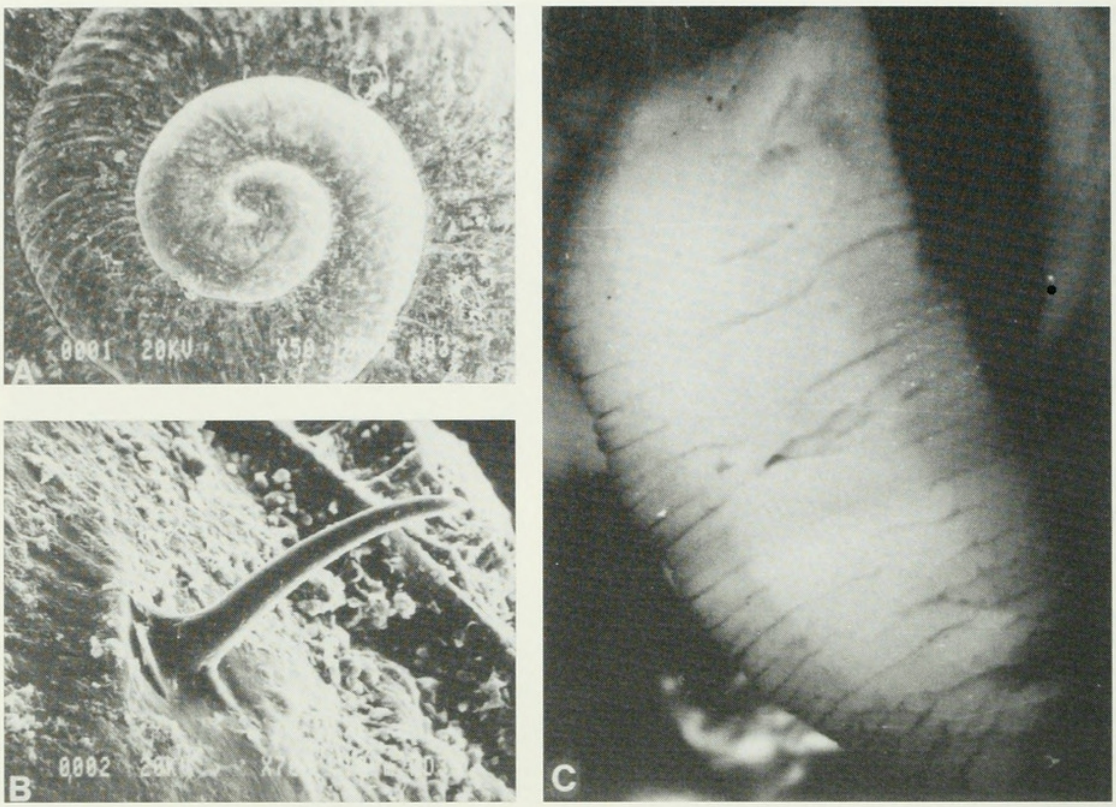

FIG. 2. Shell (SEM micrographs) and pedal sole of *Ganula gadirana,* n. sp. A. Protoconch of a paratype from Cortijo de Ahojiz; B. Microsculpture and one hair of teleoconch (same locality); C. Ventral view of pedal sole showing the tripartite sole (from type locality).

lobes (Fig. 6D, 7A). Inner stylophore opening into vagina through a wide orifice, far from outer stylophore aperture (Fig. 6B, 7C). Dart (Fig. 6C) smooth, straight, circular in section, but with flattened, keeled tip, elongate, extending out of outer stylophore. Inner vagina (Fig. 6B, F–G, 7C–F) with two thick, large pleats, which distally fuse to form a tongue-like structure, U-shaped in traverse section, its tip detached from vaginal walls; outer stylophore and inner stylophore open far apart inside groove of tongue-like structure.

Juvenile specimens (Fig. 6E–G) with dart-sac complex placed at half of vagina length, with outer stylophore shorter than bilobed inner stylophore and tongue-like structure present inside vagina.

Jaw (Fig. 3H) odontognathous, with 24 ribs, central larger.

Radula (Fig. 8) consisting of many rows of teeth each with a formula of 35–37 + C + 35–37, with the lateral/marginal transition towards the 15–16th tooth. Central tooth with wide basal plate, pointed vertices and body with large mesocone and two small ectocones nearly fused to base of mesocone. Lateral teeth with wide basal plates and body with endocone, large, pointed mesocone and short ectocone; both mesocone and ectocone progressively slender towards radular margin, mesocones with little lateral protuberance and pointed ectocones split into two points.

Other anatomical characters. Right ommatophore retractor running between penis and vagina. Penial nerve apparently arising from right cerebral ganglion.

Type Locality

Arroyo de la Cabañuela, Puerto de Bolonia, Tarifa (Cádiz, Spain, UTM: 30STE552990).

Type Material

Holotype (shell and dissected specimen) – 30 October 1992, A. Almodóvar, B. Muñoz and P. Refoyo leg. Museo Nacional de Ciencias Naturales, Madrid, Spain.

Paratypes:

– Type locality, 15 paratypes: 11 specimens (10 dissected), 30 October 1992, A. Almodóvar, B. Muñoz and P. Refoyo leg., 1 shell, 9 May 1994, A. Almodóvar leg.; 3

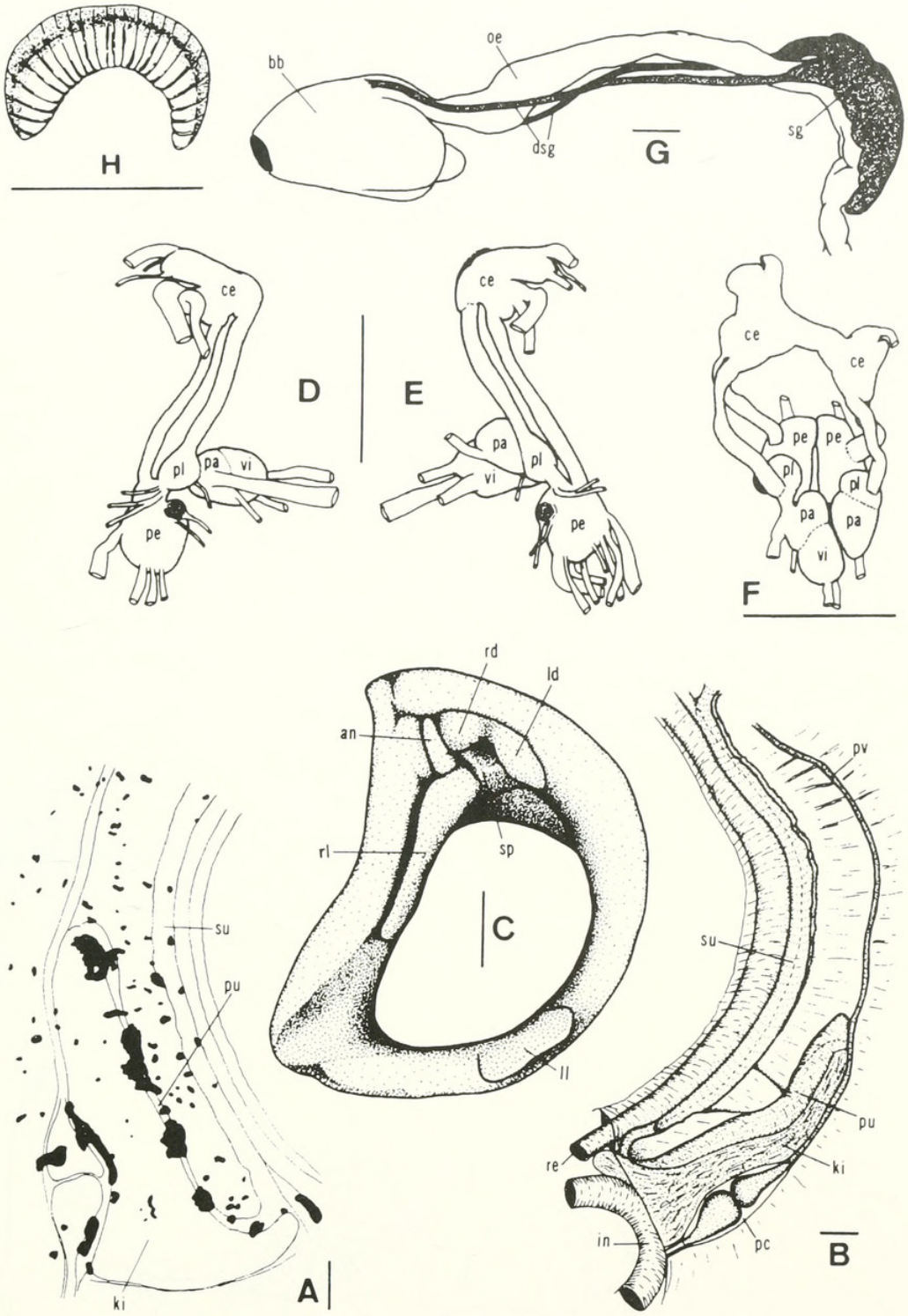

FIG. 3. Some body parts of *Ganula gadirana,* n. sp., from Los Barrios, 16 May 1993 (A–G) and the type locality (H). A. Pigmentary patches on the pulmonary cover (external view); B. Kidney, ureters and pericardium; C. Mantle collar; D–E. Left and right views of central nervous system; F. Posterodorsal view of central nervous system from another specimen; G. Position of salivary glands in respect to buccal bulb; H. Jaw. Abreviations: an, anal lobe; bb, buccal bulb; ce, cerebral ganglion; dsg, ducts of salivary glands; in, intestine; ki, kidney; ld, left dorsal lobe; ll, left lateral; oe, oesophagus; pa, parietal ganglion; pc, pericardium; pe, pedal ganglion; pl, pleural ganglion; pu, primary ureter; pv, pulmonary vein; rd, right dorsal lobe; re, rectum; rl, right lateral lobe; sg, salivary glands; sp, supneumostomal lobe; su, secondary ureter; vi, visceral ganglion. Scale bar, 1mm.

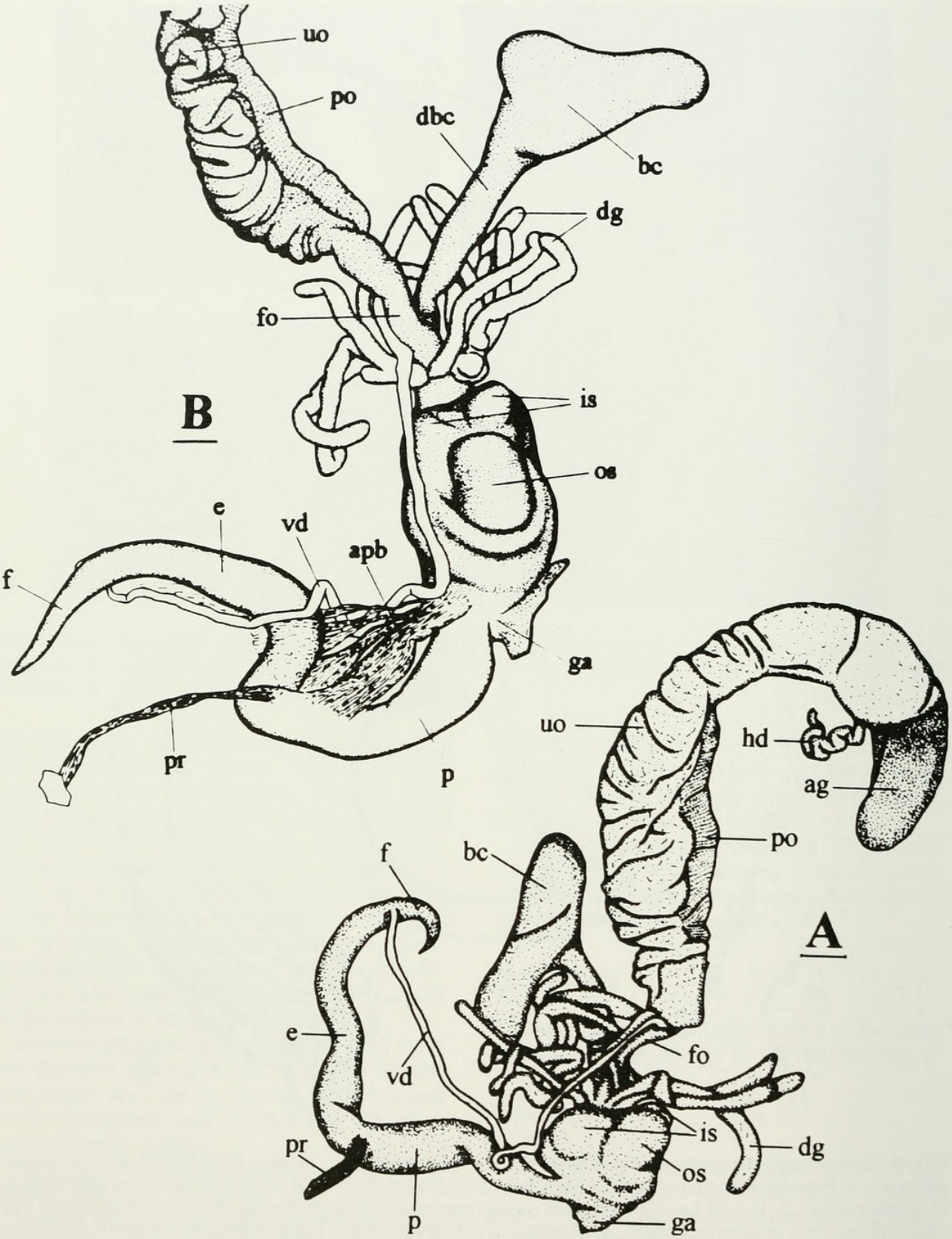

FIG. 4. Genital system of *Ganula gadirana*, n. sp. A. Specimen from type locality (gonad excluded); B. Specimen from Los Barrios (distal ducts), 3 November 1991. Abreviations: ag, albumen gland; apb, atrio-penial muscular band; is, inner stylophore; bc, bursa copulatrix; dbc, duct of bursa copulatrix; dg, digitiform glands; os, outer stylophore; dsc, dart sac complex; e, epiphallus; f, flagellum; fo, free oviduct; ga, genital atrium; hd, hermaphrodite duct; p, penis; po, prostatic part of ovispermiduct; pr, penial retractor muscle; uo, uterine part of ovispermiduct; v, vagina; vd, vas deferens. Scale bar, 1 mm.

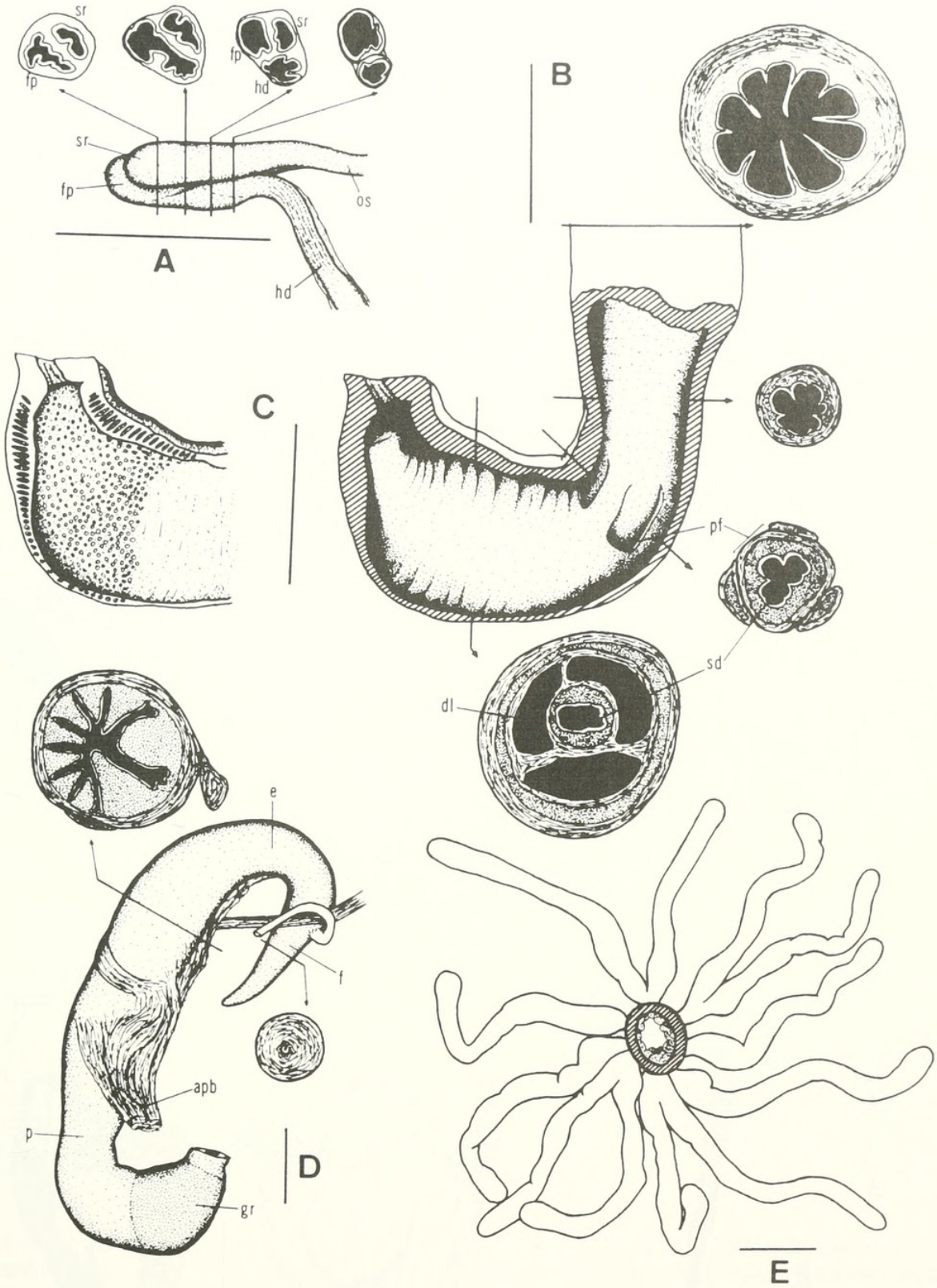

FIG. 5. Some genital parts of one specimen of *Ganula gadirana,* n. sp., from Los Barrios, 16 May 1993. A. Fertilization pouch and seminal receptacle complex (external view) and four transversal sections; B. Penial papilla within penis and transversal sections at different levels (1.33 times enlarged); C. Glandular area on distal part of penis (internal view); D. Penial complex (contracted) and transversal sections (1.5 times enlarged) of epiphallus and flagellum; E. Shape and disposition of digitiform glands on vagina. Abreviations: apb, atrio-penial muscular band; dl, distal lacuna; e, epiphallus; f, flagellum; fp, fertilization pouch; gr, glandular ring; hd, hermaphrodite duct; os, ovispermiduct; p, penis; pf, papillar fenestration; sd, seminal duct; sr, seminal receptacle. Scale bar, 1 mm.

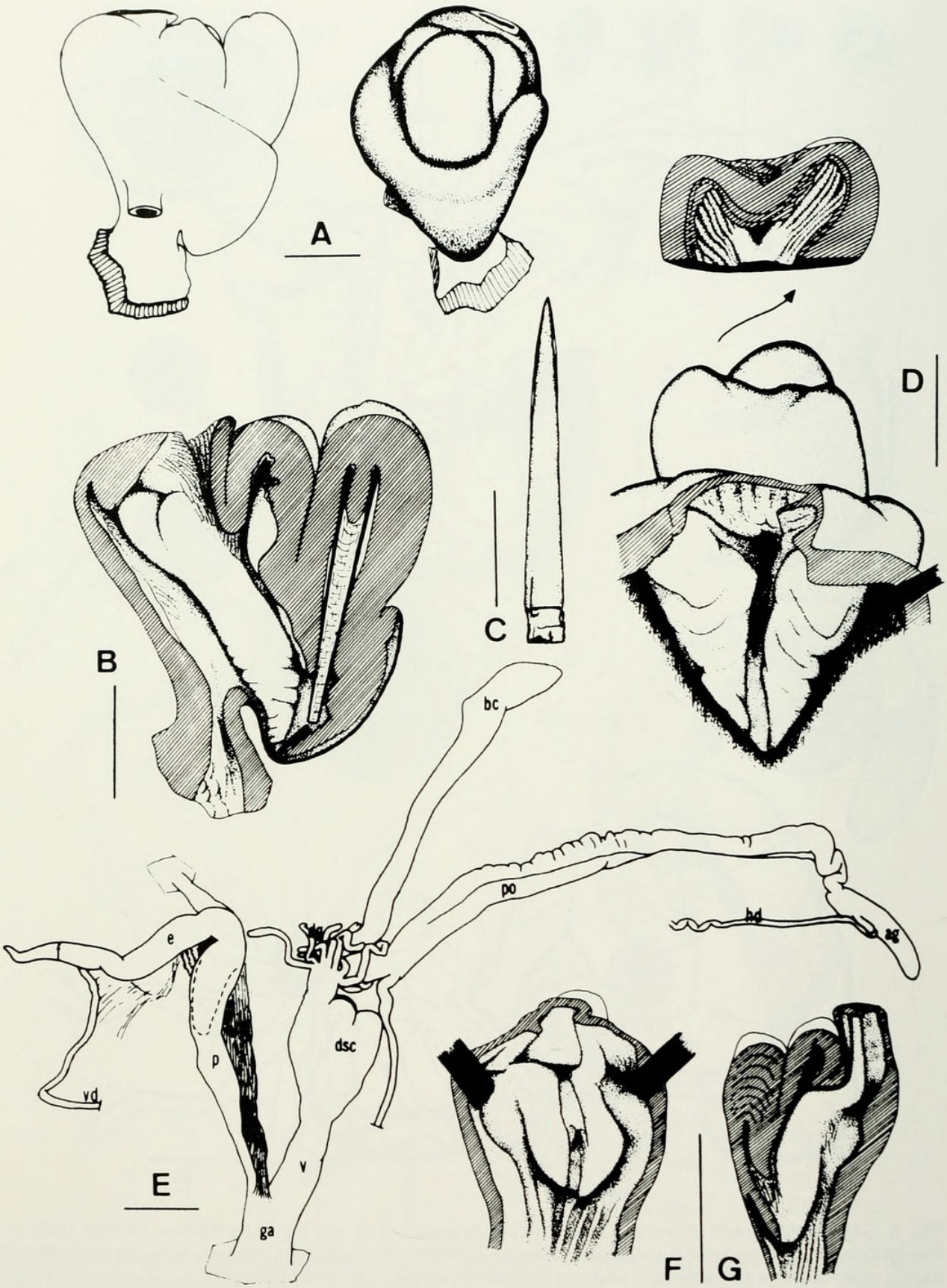

FIG. 6. Some genital parts of *Ganula gadirana,* n. sp. A. External views of dart-sac complex in a contracted specimen from Los Barrios, 16 May 1993; B. Same dart-sac complex in longitudinal section; C. Dart of a specimen from type locality; D. Inner vaginal view of dart-sac complex and cavity of bilobed inner stylophore from a specimen from Los Barrios, 5 February 1990; E. Genital system (gonad excluded) of a juvenile specimen from Los Barrios, 16 May 1993. Note position of dart-sac complex on vagina and bilobation of inner stylophore; F. Inner vaginal view; G. Longitudinal section of dart-sac complex of same juvenile specimen. Abbreviations as in Fig. 4. Scale bar, 1mm.

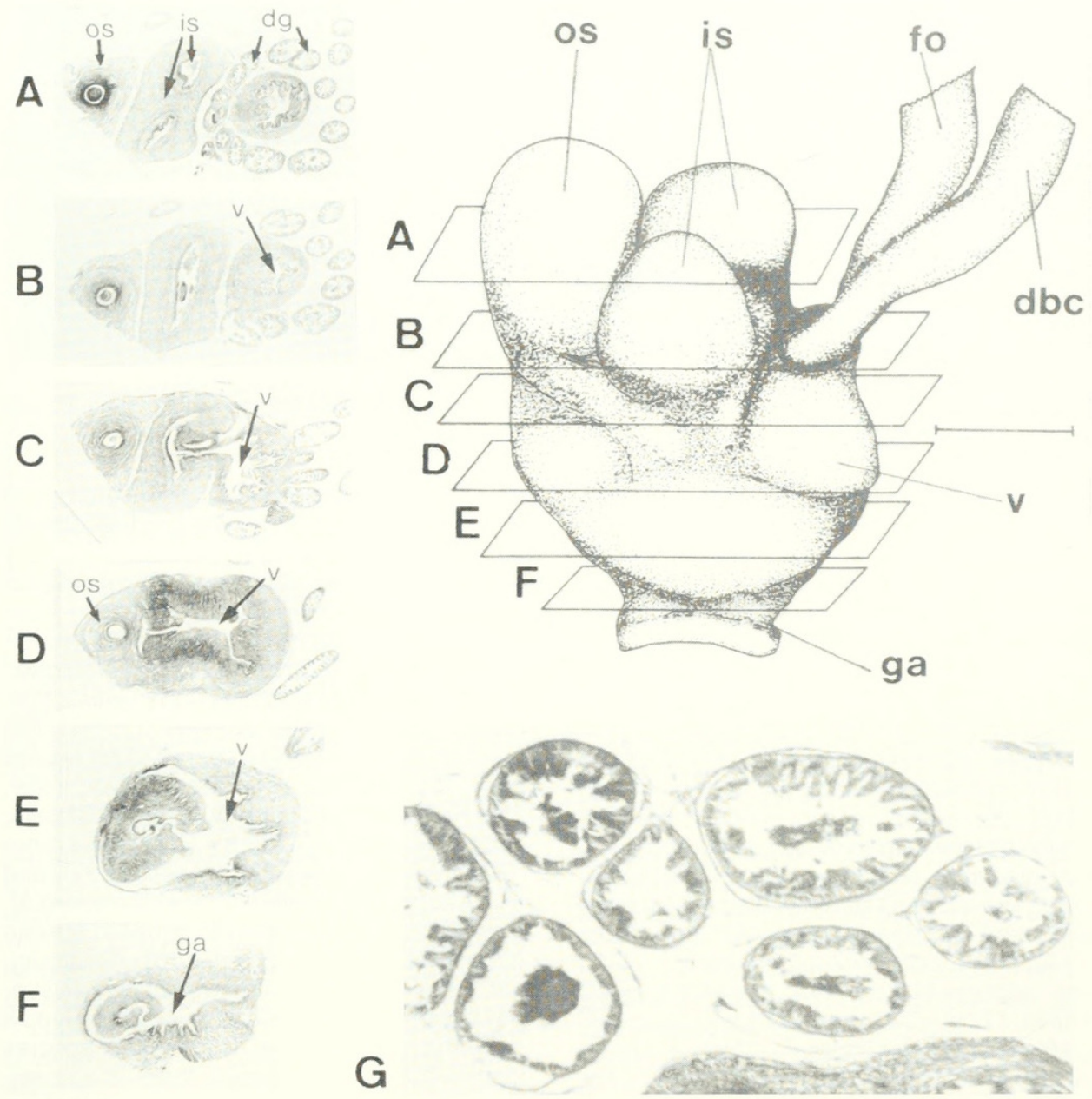

FIG. 7. Outline of dart-sac complex (digitiform glands not figured) and transversal sections at different levels. A. Bilobed cavity of inner stylophore and inner ridges of digitiform glands; B. Monoluminar cavity of inner stylophore and opening of a digitiform gland inside vagina; C. Opening of inner stylophore inside groove formed by vaginal pleats; D. Groove between inner and outer stylophores forming a functional channel; E. Opening of outer stylophore inside groove and fused pleats partially detached from vaginal wall; G. Enlarged transversal section of digitiform glands showing inner ridges and secreted mucus.

specimens (dissected), 14 May 1994, A. Almodóvar leg.

—Cortijo de Ahojiz, between km 90–91 of C-440 road to Los Barrios (Cádiz, UTM: 30STF7010), 16 paratypes: 3 specimens (one dissected), 5 February 1990; 6 specimens (2 dissected), 18 May 1991; 1 specimen (dissected), 24 March 1991; 6 specimens (3 dissected), 3 November 1991. All, J. Arrébola leg.

—'Campo de Gibraltar' sawmill, Los Barrios (Cádiz, UTM: 30STF7507), 30 paratypes: 21 specimens (mostly juveniles, 5 dissected) and 9 shells, 16 May 1993, E. Unamuno and J. C. Ruiz leg.

—Algeciras, near a shelter (Cádiz, UTM: 30STE7394), 1 paratype (damaged shell), 16 May 1993, E. Unamuno and J. C. Ruiz leg.

—2 km towards Punta Paloma from N-340 road, Tarifa (Cádiz, UTM: 30STE5694), 10 paratypes (3 dissected), 6 December 1993, J. Arrébola leg.

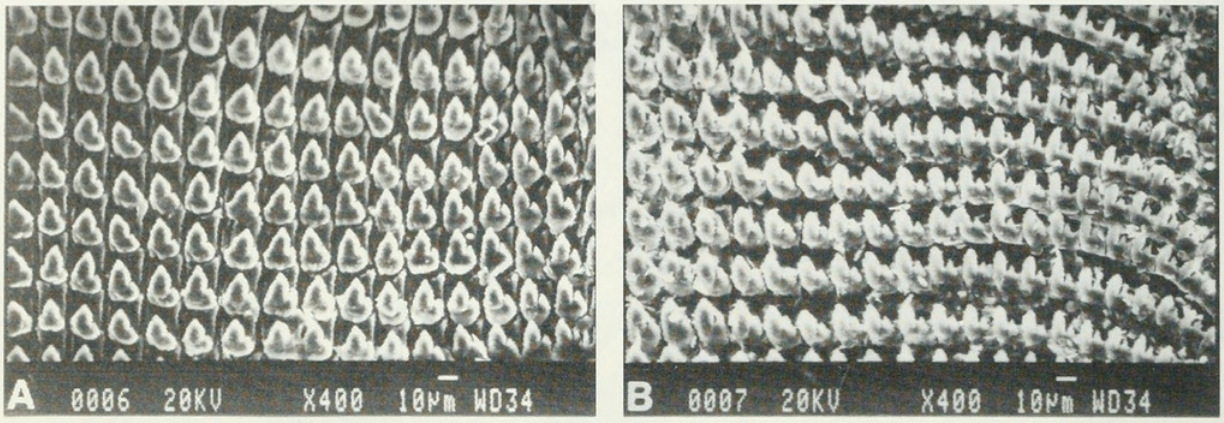

FIG. 8. SEM micrographs of the radula of *Ganula gadirana*, n. sp. A. Central tooth and lateral teeth; B. Last lateral and marginal teeth.

Derivatio Nominis

From the name of the Fenician colony Gadir, which gave origin to Cádiz, in the southernmost province of Spain, where the described snails were collected.

Ecology

Ganula gadirana has been found under stones, half buried in the ground or on herbaceous vegetation associated to mediterranean bushes (*Chamaerops humilis* and *Nerium oleander*) and close to periodically river flows. The associated malacological fauna is composed by *Rumina decollata* (Linnaeus, 1758), *Ferussacia follicula* (Gmelin, 1791), *Helix aspersa* Müller, 1774, *Cochlicella acuta* (Müller, 1774), *Cochlicella barbara* (Linnaeus, 1758), *Gasulliella simplicula* (Morelet, 1845), *Caracollina lenticula* (Michaud, 1831), *Xerotricha apicina* (Lamarck, 1822), *Cernuella virgata* (Da Costa, 1778), *Theba pisana* (Müller, 1774), *Otala lactea* (Müller, 1774), *Candidula gigaxii* (Pfeiffer, 1848), *Oestophora barbula* (Rossmässler, 1838), and *Oestophora tarnieri* (Morelet, 1854). Specimens from Los Barrios, collected on 16 July 1993, were intensively parasitized by small nematodes, which were found in all growth stages inside the pulmonary cavity.

Geographical Distribution (Fig. 9)

All known localities are in the province of Cádiz in the southernmost corner of Spain, concentrated on a small region around the northern side of the Gibraltar Strait. Because the previously recorded presence of *Ganula lanuginosa* has not been confirmed for that region after many searches (see Introduction), all records from southern Spain referred to this species have been assigned to *Ganula gadirana*.

There are older conchological records for *Helix lanuginosa* from northern Africa – from Morocco (Hidalgo, 1909: "Muluya") to northwestern Algeria (Terver, 1839; Bourguignat, 1864), but with one record from Tunisia (Letourneux & Bourguignat, 1887). Other two nominal species are considered to be related to *G. lanuginosa* – *Helix flava* Terver, 1839, and *Helix roseotincta* Forbes, 1838 (Clessin, 1881; Richardson, 1980). *Helix flava* from "Gourayah," near Bougie (Terver, 1839), and *H. roseotincta* was cited from northeastern Algeria (Bourguignat, 1864) to northern Tunisia (Letourneux & Bourguignat, 1887) (Bourguignat, 1864, considered the two species as synonymous). Taking into account that *Ganula gadirana* has been an overlooked species identified as *H. lanuginosa*, there is a possibility that some of the African records belong to *Ganula gadirana*. Further studies must be carried out to test this. Nevertheless, Giusti & Manganelli (1987) stated that *H. flava* is an Algerian species clearly distinct from *G. lanuginosa* and also from *G. gadirana* (Giusti, pers. com.).

DISCUSSION

The new species has similar features to *Ichnusotricha berninii* Giusti & Manganelli, 1987, and *Ganula lanuginosa* (Boissy, 1835). *Ichnusotricha berninii* has a similar shell shape, but the sutures are more superficial, the aperture is descendent, the umbilicus is nearly closed, and the periostracal hairs are very short. Anatomically, it differs from the new species, because *I. berninii* has a long,

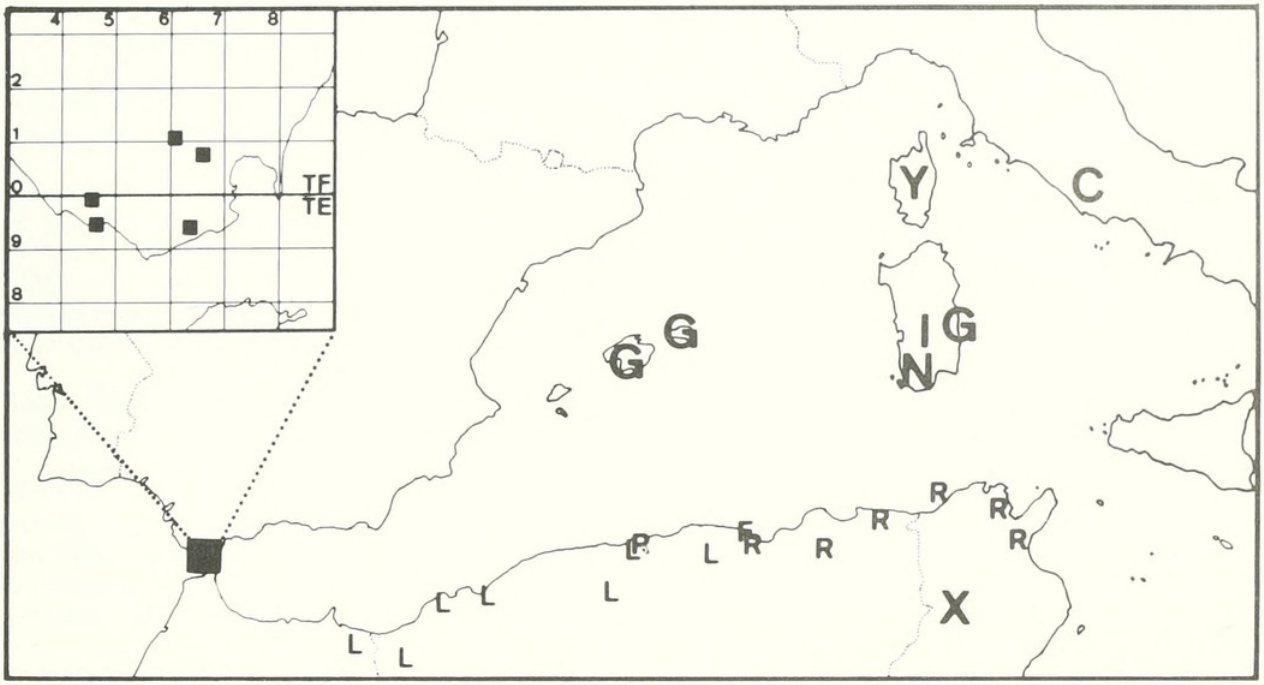

FIG. 9. Geographical distribution of *Ganula gadirana,* n. sp. (square and upper left inset) and other endemic Hygromiinae from the western Mediterranean area (larger letters): C, *Cernuellopsis ghisottii* Manganelli & Giusti, 1987; G, *Ganula lanuginosa* (Boissy, 1835); I, *Ichnusotricha berninii* Giusti & Manganelli, 1987; N, *Nienhuisiella antonellae* Giusti & Manganelli, 1987; Y, *Cyrnotheba corsica* (Shuttleworth, 1843); X, *Xeroplana lacosteana* (Bourguignat, 1864). Smaller letters from northern Africa show old conchological records for *Helix flava* Terver, 1839 (F), *Helix lanuginosa* Boissy, 1835 (L), and *Helix roseotincta* Forbes, 1838 (R).

non-fenestrated penial papilla; small, narrow dart-sac complex placed far apart; shorter digitiform glands; and long cylindrical vagina, with two long, slender pleats fused distally to form an apical tap or dart gun (Giusti & Manganelli, 1987).

Ganula lanuginosa has a nearly identical shell, although it is convex-depressed above, with more superficial sutures and less convex whorls, shorter (length, 0.3 mm; in shells from Mallorca), less spaced hairs (25–30/mm^2), wider umbilicus (1/10 of shell diameter), and descending aperture. Anatomically, *G. lanuginosa* and *G. gadirana* are very different, because *G. lanuginosa* has four bifurcated digitiform glands, standard inner stylophore, and non-fenestrated penial papilla (Gittenberger, 1968; Giusti & Manganelli, 1987). *Ganula gadirana* has 14–20 digitiform glands, and the tubes have an annulate appearance, apically bilobed inner stylophore, fenestrate penial papilla, and penial glandular area.

On the other hand, in the pedal sole *G. gadirana* appears tripartite, and the left parietal ganglion is in contact with the visceral ganglion; these features are unknown in *G. lanuginosa,* but are present in a few species of the family Hygromiidae. The tripartite appearance of the pedal sole appears frequently among helicoids (Schileyko, 1978), and is illustrated in a drawing of *Leucozonella rubens,* although we do not know other similar cases. The genera of Hygromiidae studied by Tillier (1989) have a more anterior position of the left parietal ganglion, being in contact with both visceral and left pleural ganglions.

Ganula lanuginosa has radular formula of 32 + C + 32 (Giusti & Manganelli, 1987), whereas *G. gadirana* has a formula of 35–37 + C + 35–37; both species have a similar central tooth, but *G. lanuginosa* has lateral teeth with an apex formed by a wide, robust, pointed mesocone and a short, sharp, robust ectocone, whereas the new species has lateral teeth with a large endocone, pointed mesocone, and short ectocone. Two points on the mesocone apex of the extreme marginal teeth appear occasionally in *G. lanuginosa,* whereas there is a little lateral protuberance in *G. gadirana.*

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