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Bogidiella indica, a new species of subterranean Amphipod Crustacean (Bogidiellidae) from wells in Southeastern India, with remarks on the biogeographic importance of recently discovered Bogidiellids on the Indian subcontinent

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ABSTRACT

Bogidiella indica, new species, is described from three water wells in southeastern India, including a bore-well on the campus of Acharya Nagarjuna University in Nagarjunanagar, a water well in Guntur town, and an agricultural well in the Godavari and Krishna Basin, all in the state of Andhra Pradesh, India. The new species is assigned to the genus *Bogidiella* Hertzog and to a newly designated species group within the genus. Despite the near circum-global distribution of the family Bogidiellidae, only a single, partially intact specimen of a bogidiellid had been collected from the Indian subcontinent prior to the discovery of specimens from the well in Nagarjunanagar. Including the new taxon described in this paper, the family Bogidiellidae contains 35 genera and 106 species. Although *B. indica* is closely similar to other species presently assigned to the genus *Bogidiella,* it is easily distinguished by a proportionately shorter and relatively heavily spinose pereopod 5. The sexes are generally similar except that the male bears a large, distally modified apical spine on the inner ramus of uropod 1. The location of the well sites within 45 to 50 km of the eastern coast of India strongly suggests that they lie in an area that was submerged under shallow marine water within the last 1 million years.

Key words: subterranean amphipods, *Bogidiella*, bore-well, groundwater, stygobitic

INTRODUCTION

During recent ongoing investigation of subterranean groundwaters in the state of Andhra Pradesh, one of us (YRR) collected blind, unpigmented amphipods from a bore-well on the campus of Acharya Nagarjuna University in Nagarjunanagar. Subsequently, additional collections were made from a well in Guntur town, approximately 13 km southwest of Acharya Nagarjuna University, and an agricultural well in Doddigunta village in the Godavari-Krishna basin, about 165 km northeast of the university. These specimens represent a new species of the subterranean amphipod genus *Bogidiella* Hertzog (1933), which is described below. Prior to this discovery only a single, poorly preserved, broken specimen of *Bogidiella* was known to us from India. This specimen was collected with a suction pump from groundwater near Chidambaram, approximately 550 km south of Acharya Nagarjuna University, and was deposited in the U. S. National Museum of Natural History (USNM 262176) by S. Swaminathan in 1965.

The description of this new species brings the total number of described species in the family Bogidiellidae to 106. The occurrence of bogidiellid amphipods on the Indian subcontinent is not surprising in view of the globally widepread distribution of the family. However, the overall distribution is discontinuous, with large concentrations of species in southern North America, South America, and southern Europe. A significant number of species also occur in parts of Asia Minor, eastern Africa, the Arabian Peninsula, Asia, and Australia (Iannilli et al 2006). More than one-half of the species are recorded from subterranean freshwaters, but a significant number are found in anchialine habitats in coastal areas and interstitial habitats in marine sediments.

The only other stygobitic amphipod recorded from India is *Indoniphargus indicus* (Chilton), which is taxonomically very different from *Bogidiella* and reported from various groundwater habitats (e.g., springs, well water, mine pit) in the northeastern states of Bihar, Orissa and West Bengal. This species was originally described by Chilton (1923) from specimens collected from a 100 meter-deep pit in a coal mine in Asansol, West Bengal and placed in the genus *Niphargus*; it was later redescribed and moved to the genus *Neoniphargus* by Stephensen (1931). Subsequently, Straškraba (1967) added new data on its taxonomy and distribution and reassigned the species to the new genus *Indoniphargus*.

SYSTEMATICS

Bogidiella indica, sp. nov.
(Figs 1- 5)

Material examined

INDIA. Andhra Pradesh, Nagarjunanagar: bore-well

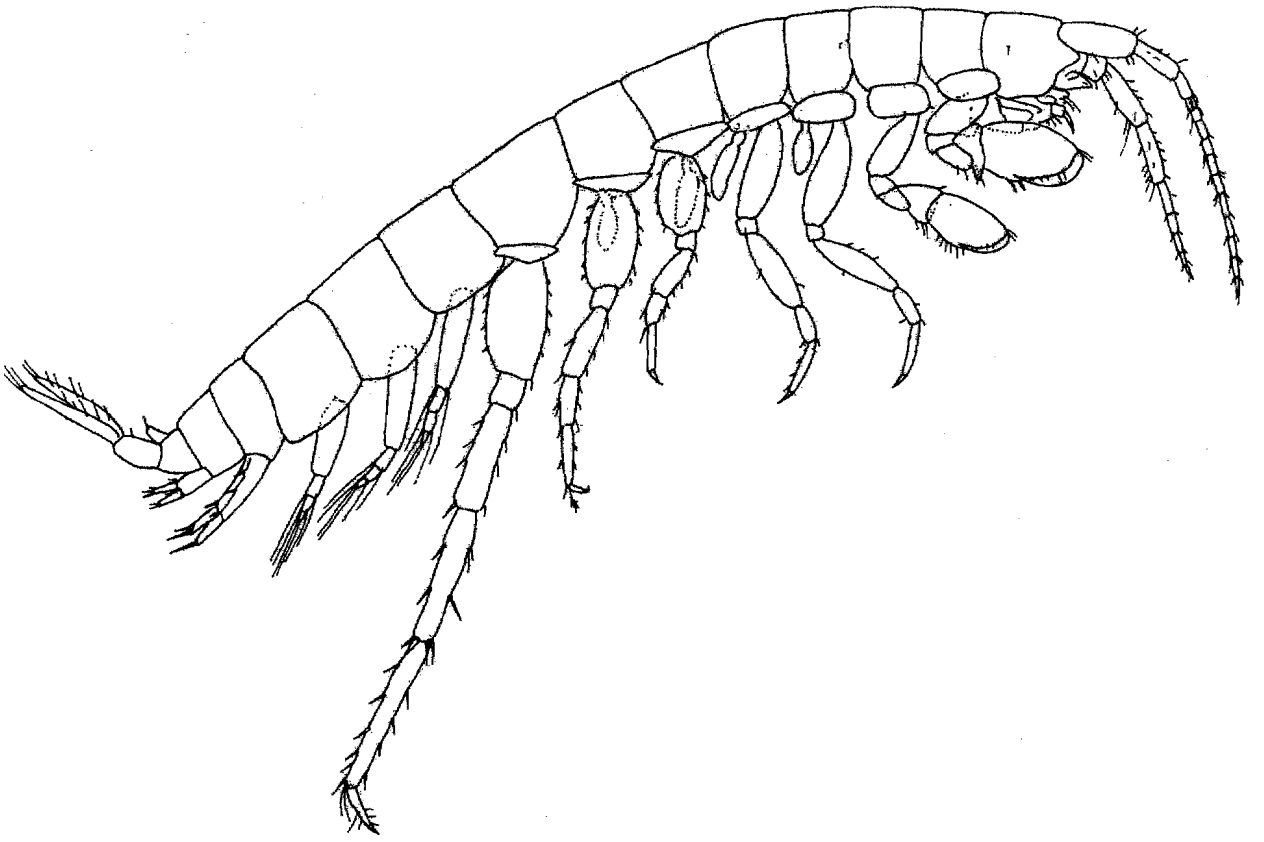

Fig. 1- *Bogidiella indica,* new species, male paratype (5.3 mm), well at Guntur town, Andhra Pradesh State, India: entire animal from right side.

at Block II on campus of Acharya Nagarjuna University, ca. 13 km ENE of Guntur town, 25 paratypes (males, females, juveniles), Y. Ranga Reddy, Nov. 1998-July 2005; male holotype (5.5 mm) and male paratype (5.5 mm), Y. Ranga Reddy, 8 Sept. 2005; 2 paratypes (ca. 4.5 mm), Y. Ranga Reddy, 19 Sept. 2005. Guntur town: water well, 1 male paratype (5.3 mm); agricultural well in Doddigunta village (Godavari-Krishna basin), 38 paratypes (mostly females; largest ones ca.3.5 – 4.0 mm), Y. Ranga Reddy, late 2005/early 2006.

The holotype is deposited in the National Museum of Natural History (Smithsonian Institution) under the catalog number of the former United States National Museum (USNM 1088540); paratypes are deposited in the National Museum of Natural History (USNM 1088541) and the research collections of J. Holsinger (JRH 4317 & 4351) and M. Messouli.

Diagnosis

Bogidiellid amphipod of stygomorphic facies (Fig. 1), distinguished by reduced accessory flagellum with single, short article; greatly reduced mandibular molars; proportionately short pereopod 5 with relatively large basis and strong spines on segments 5 and 6; coxal gills on pereopods 2, 3, 4, 5, and 6; tiny suboval brood plates on pereopods 2, 3, 4, and 5; and sexually dimorphic inner ramus of uropod 1 of male, which bears an elongate, curved, distally dentate apical spine. Largest males 5.3 – 5.5 mm; largest female 5.0 mm.

Female (5.0 mm)

Interantennal (lateral) lobe (Fig. 2A) of head distinct, rounded apically. Antenna 1 (Fig. 2B) ca. 33–35 % length of body, ca. 2x length of antenna 2, primary flagellum with 10 segments, aesthetascs present on some flagellar segments; accessory flagellum 1-segmented, not exceeding length of accompanying flagellar segment. Antenna 2 (Fig. 2C) with up to 5 flagellar segments, last one greatly reduced. Right mandible (Fig. 2D): molar tiny, vestigial, indicated by 3 short, lightly plumose spines; incisor 5-dentate, lacinia mobilis also 5-dentate, spine row with 3 lightly plumose spines; palp 3-segmented, 2nd segment longest and bearing 1 seta distally on inner margin, 3rd segment with single long seta on apex. Left mandible (Fig. 2E): molar vestigial, cone shaped, bearing 3 lightly plumose spines; incisor 5-dentate, lacinia mobilis consisting of 2 small plates of unequal size, with serrated upper margins, spine row with 3 lightly plumose spines; palp similar to that of right mandible. Lower lip (Fig. 2F): outer lobes separate by distinct gap; inner lobes much lower than outer but relatively well developed. Maxilla 1 (Fig. 2G): inner plate bearing 4 naked apical setae; outer plate with 6 apical serrate (comb-like) spines; palp 2-segmented, 2nd segment with 2 apical

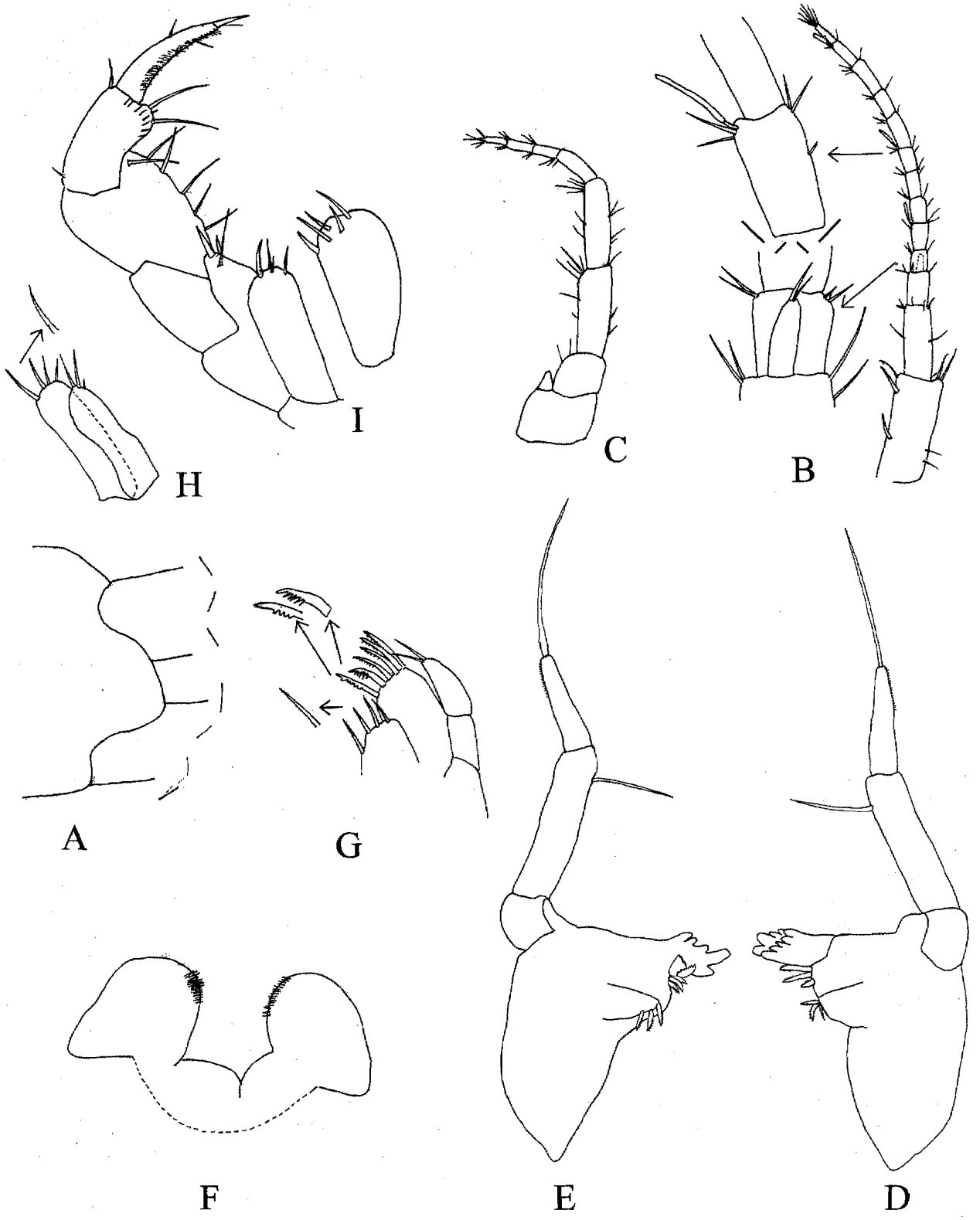

Fig. 2 - *Bogidiella indica*, new species, female paratype (4.5 mm), bore-well, Acharya Nagarjuna University, Andhra Pradesh State, India: A, anterior part of head; B, antenna 1(accessory flagellum, asethetascs and accompanying flagellar segments enlarged); C, antenna 2; F, lower lip; G, maxilla 1; H, maxilla 2; I, maxilliped. Female paratype (4.0 mm), agriculture well at Doddigunta village, Andhra Pradesh State: D, right mandible; E, left mandible. Mouthparts other than mandibles drawn to same scale, mandibles drawn to larger scale; antennae and head drawn to smaller scales.

setae. Maxilla 2 (Fig. 2H): inner plate shorter than outer, with 3 naked apical setae; outer plate bearing 4 naked setae apically. Maxilliped (Fig. 2I): inner plate weakly armed apically with 4 or 5 naked setae; outer plate with

2 apical spines and 1 subapical setae; palp 4-segmented, segment 2 expanded and bearing row of 5 naked setae on inner margin, segment 3 shorter and only about half as wide as preceding segment, bearing few setae apically, segment 4 subfalcate, narrowing distally, inner margin pubescent, nail long and sharply pointed.

Gnathopod 1 (Fig. 3A): basis broadest proximally, bearing 2 setae; carpus triangular- shaped, with 2 setae of unequal length on pointed, pubescent posterior lobe; propodus prominent, approximately 40% longer than broad, approximately 30% larger than propodus of gnathopod 2, palmar margin slightly convex, nearly 2x longer than posterior margin, armed with 4 weak spines and 2 long setae on outside, several tiny setules on inside, and 2 larger spines marking closure of dactylus nail with propodus, posterior margin slightly convex and naked except for 1 submarginal spine; dactylus about 65% length of propodus, demarcation of nail not apparent. Gnathopod 2 (Fig. 3B): basis longer than broad, bearing only single short seta at distoposterior corner; carpus posteriorly pubescent and bearing few rather short setae; propodus longer than carpus but smaller than propodus of gnathopod 1, palmar margin oblique, subequal in length to posterior margin, bearing row of about 5 weak spines and 2 or 3 long setae, posterior margin with 3 sets of 2 setae each, and several single setae; dactylus little more than 50% length of propodus, nail closing just beyond defining angle, which is indicated by 1 long seta, demarcation of nail not apparent. Coxa of gnathopod 1 more than 2x wider than deep, bearing 2 short setae on rounded distoanterior corner; coxa of gnathopod 2 also wider than deep, posterior margin convex.

Pereopods 3 and 4 subequal (Fig. 3C): coxae about 50% wider than deep, weakly armed with 1 or 2 setae; bases rather long and narrow, that of pereopd 3 without marginal setae or spines, that of pereopod 4 with 2 setules on posterior margin; dactyli about 33% length of corresponding propodi. Pereopod 5 (Fig. 4A) very short, only about 33% length of pereopod 7 and 50% length of pereopod 6; basis rather broad, less than 50% broader than long, posterior margin nearly straight, bearing 6 relatively long setae; carpus (segment 5) short and stocky, armed with conspicuous lateral spines; propodus (segment 6) longer and narrower than carpus, with 3 spines (1 very large) apically; dactylus (segment 7) ca. 40% length of corresponding propodus. Pereopod 6 (Fig. 4B) 65% length of pereopod 7, carpus less stocky but armed similarly to that of pereopod 5, propodus lacking lateral spines but bearing 4 spines (1 very large) apically; dactylus about 33% length of corresponding propodus. Pereopod 7 (Fig. 4C) about 35% longer than pereopod 6, basis subrectangular, ca. 50% longer than wide, anterior and posterior margins with 1 short spine each; carpus subequal in length to merus; propodus lacking large apical spines; dactylus ca. 40% length of corresponding propodus. Coxae of pereopods 5-7 small, wider than deep, each with 1 short seta on posterior lobe. Oostegites (brood plates) (Fig. 4D) very small, ca. ½ size of coxal gills, present on pereopods 2-5 (not setose in material examined). Coxal gills (Fig. 4D) on pereopods 2-6, typically with stalk, larger than brood plates. Lenticular organs absent from all pereopods.

Pleonal plates (Fig. 5A) lacking setules/spines on ventral and posterior margins, distoposterior corner of plate 3 acute, corners of plates 1 and 2 indistinct, subrounded. Pleopods 1-3 (Fig. 5A) similar, lacking inner ramus; peduncle narrow, rod-like, 2x longer than combined length of outer ramus, with 2 tiny coupling spines apically; outer ramus 3-segmented, with 2 terminal plumose setae per segment.

Uropod 1 (Fig. 5B): outer ramus shorter than inner ramus, about 25% length of peduncle, armed with 4 apical spines (1 rather longer); inner ramus ca. 50% length of peduncle, armed with 4 apical spines (1 rather longer); peduncle with 2 distodorsal spines and 1 dorsolateral spine. Uropod 2 (Fig. 5C): inner and outer rami subequal in length, ca. 80% length of peduncle, each armed apically with 4 spines (1 relatively large); peduncle with 1 distodorsal spine and 1 distolateral spine. Uropod 3 (Fig. 5D) 8-10% length of body, with subequal rami; peduncle about 50% length of rami, armed with 2 apical spines; outer ramus with 5 singly inserted lateral and 3 apical spines; inner ramus with 3 singly inserted lateral and 3 apical spines. Telson (Figs. 3D, 5D) subquadrate but dorsally concave, 10% wider than deep; apical margin uneven but very slightly convex overall, bearing 1 spine and 2 setae each on widely separated corners.

Male (Fig. 1)

Differing slightly from the female as follows: 1 large apical spine on inner ramus of uropod 1 (Fig. 3E) bowed, tapered to sharp point, with tiny serrations or teeth on upper surface.

Etymology

The proposed epithet *indica* refers to the occurrence of this species in India and denotes the first published description of a bogidiellid amphipod from the Indian subcontinent.

Variation

The mature male (5.3 mm) from the well at Guntur town differed to some extent from the majority of specimens in samples from the other wells. The principal differences include: more narrowly rounded lateral lobe of head; presence of penicillate rather than naked setae on the telson, peduncule of antenna 2, and some of the pereopod dactyli; 7 instead of 6 apical spines on outer plate of maxilla 1; pereopod 7 more spinate; all three pleonal plates with acute corners and single setules on posterior margins; uropod 3 proportionately longer and with more lateral spines; possibly a double instead of single row of tiny teeth or serrations on the sexually dimorphic apical spine of male uropod 1. Despite these morphological differences, none of which appears to be highly significant, we have assigned the

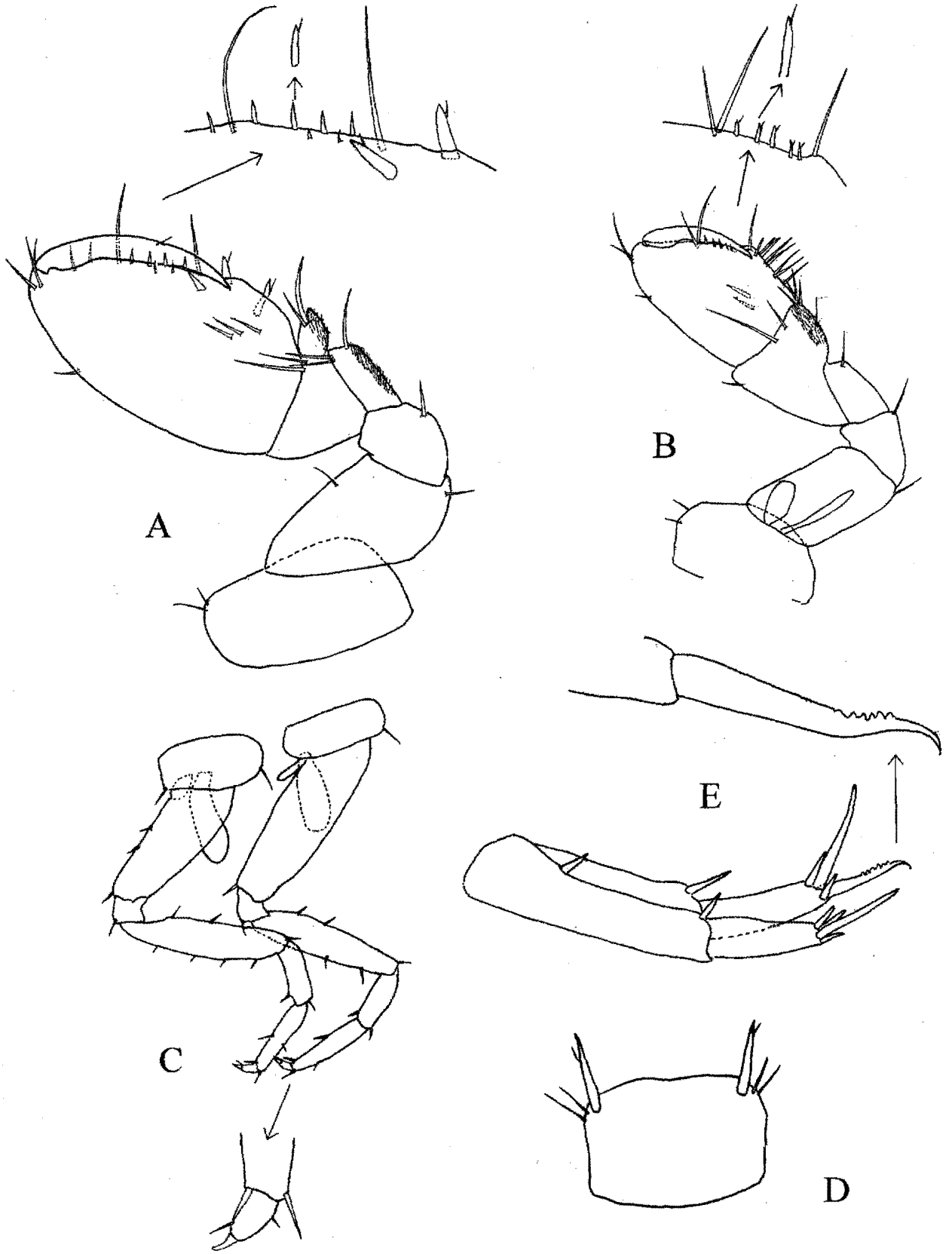

Fig. 3 - *Bogidiella indica*, new species, female paratype (4.5 mm), bore-well, Acharya Nagarjuna University, Andhra Pradesh State, India: A, gnathopod 1 (palmar margin enlarged); B, gnathopod 2 (palmar margin enlarged); C, pereopods 3 & 4 (dactylus of 3 enlarged); D, telson. Male paratype (5.0 mm): E, uropod 1 (sexually dimorphic spine greatly enlarged). Gnathopods, uropod, and telson drawn to same scale; pereopods 3 & 4 drawn to smaller scale.

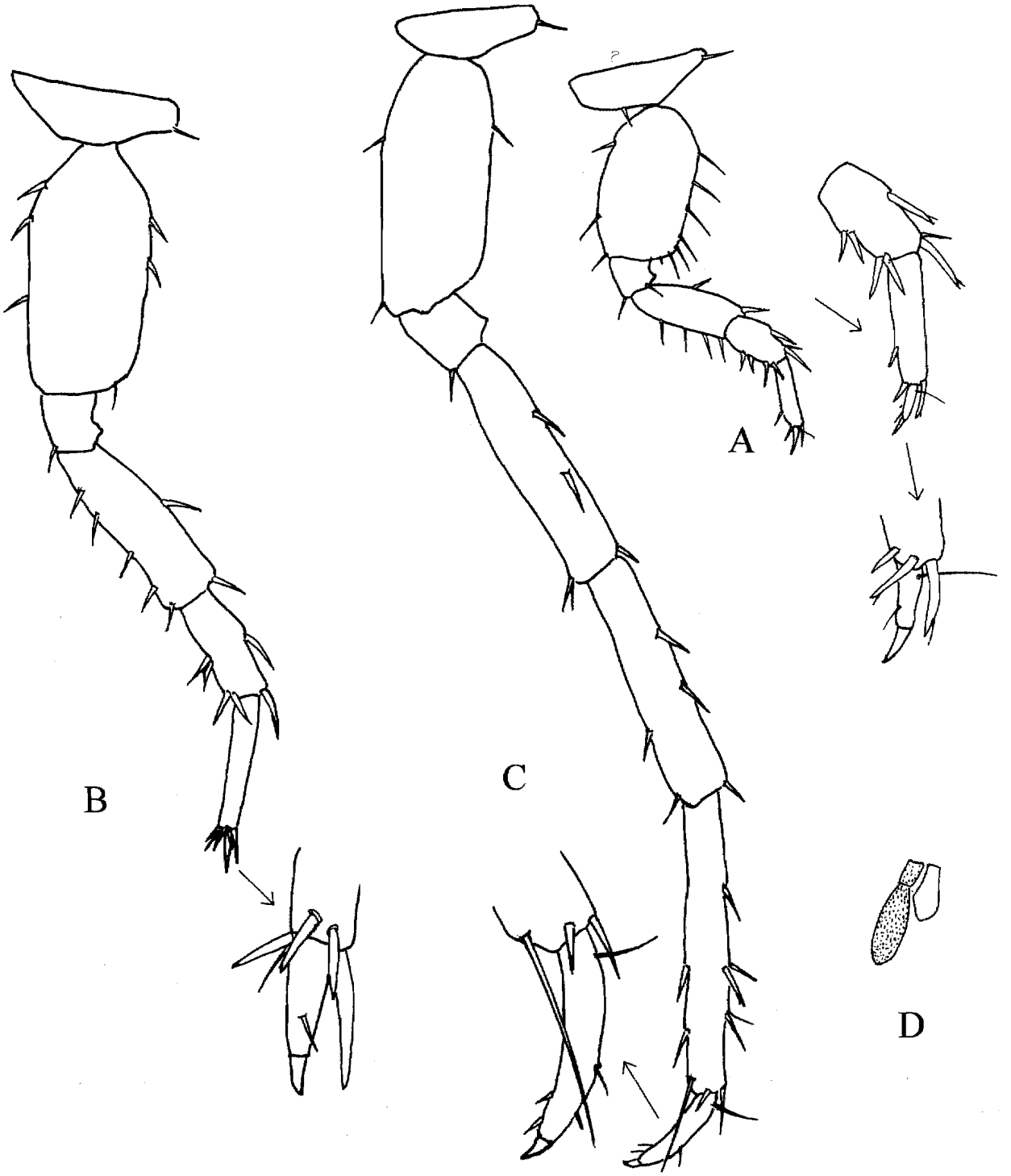

Fig. 4 - *Bogidiella indica*, new species, male paratype (4.5 mm), bore-well, Acharya Nagarjuna University, Andhra Pradesh State, India: A, pereopod 5 (merus, carpus and dactylus enlarged); B, pereopod 6 (dactylus enlarged); C, pereopod 7 (dactylus enlarged). Female paratype (4.5 mm): D, coxal gill (left) and brood plate of pereopod 5. All structures drawn to same scale.

single male from Guntur town to *Bodgidiella indica* and designated it a paratype.

Type-locality

Bore-well at Block II on campus of Acharya Nagarjuna University, Nagarjunanagar, 13 km ENE of Guntur town (16° 18' N; 80° 29' E) in the state of Andhra Pradesh, India (Fig. 6). The well is approximately 55 meters deep and samples were obtained by filtering groundwater through a plankton net (mesh size 70 μm) tied to the inlet delivery tube that opens into an overhead storage tank.

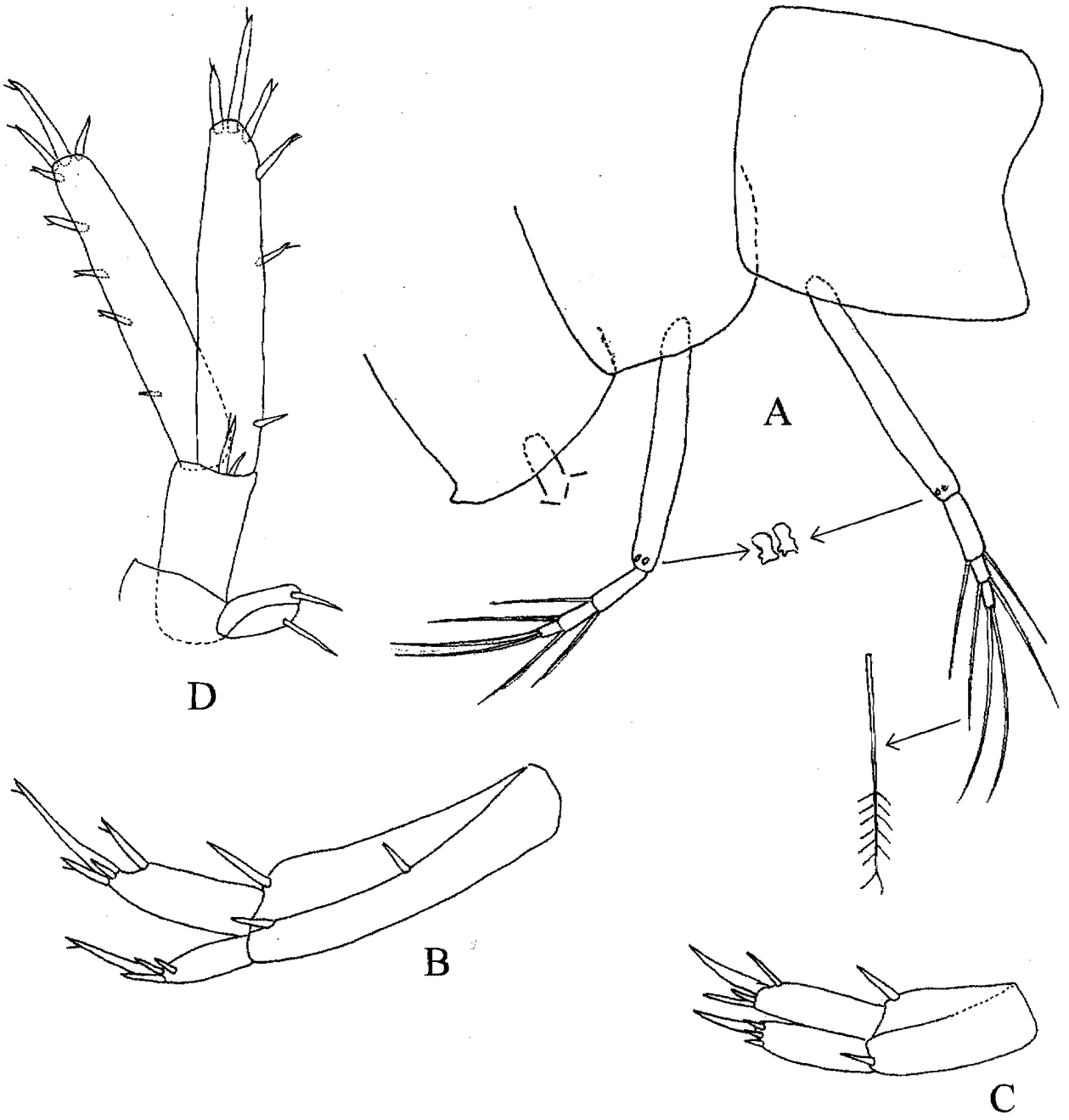

Fig. 5 - *Bogidiella indica*, new species, female paratype (4.5 mm), bore-well, Acharya Nagarjuna University, Andhra Pradesh State, India: A, pleonal plates 1-3 (right to left) and pleopods 1 & 2 (coupling spines and plumose seta enlarged), B, uropod 1; C, uropod 2; D, uropod 3 and telson (lateral view). Uropods drawn to same scale; pleonal plates and pleopods drawn to smaller scale.

Distribution and ecology

To date this species has been found in three water wells in southeastern India (Fig. 6). The samples from the type-locality contained a total of 30 amphipods and also 10 to 12 specimens of a new species of stygobitic phreatoicid isopod crustacean in the family Nichollsidae. Other subterranean crustaceans found in this well include the parabathynellid *Habrobathynella nagarjunai* Ranga Reddy, a new bathynellid species, the most reduced free-living cyclopoid copepod, *Haplocyclops (Kiefercyclops) fiersi* Karanovic & Ranga Reddy, harpacticoid copepods represented by *Parastenocaris* n. sp., *Nitocrella n.* sp., and *Nitokra* sp., and two ostracod species: *Strandesia purpurascens* (Brady), and a new darwinulid species. Unidentified mites and nematodes also co-occurred with the new species.

The bore-well at the type-locality accesses a groundwater aquifer developed in garnet-sillimanite gneiss ("khondalite") bedrock, belonging to the Eastern Ghats group, which is approximately 3, 000 M.Y. old. Physical/chemical parameters of the well water at the time of

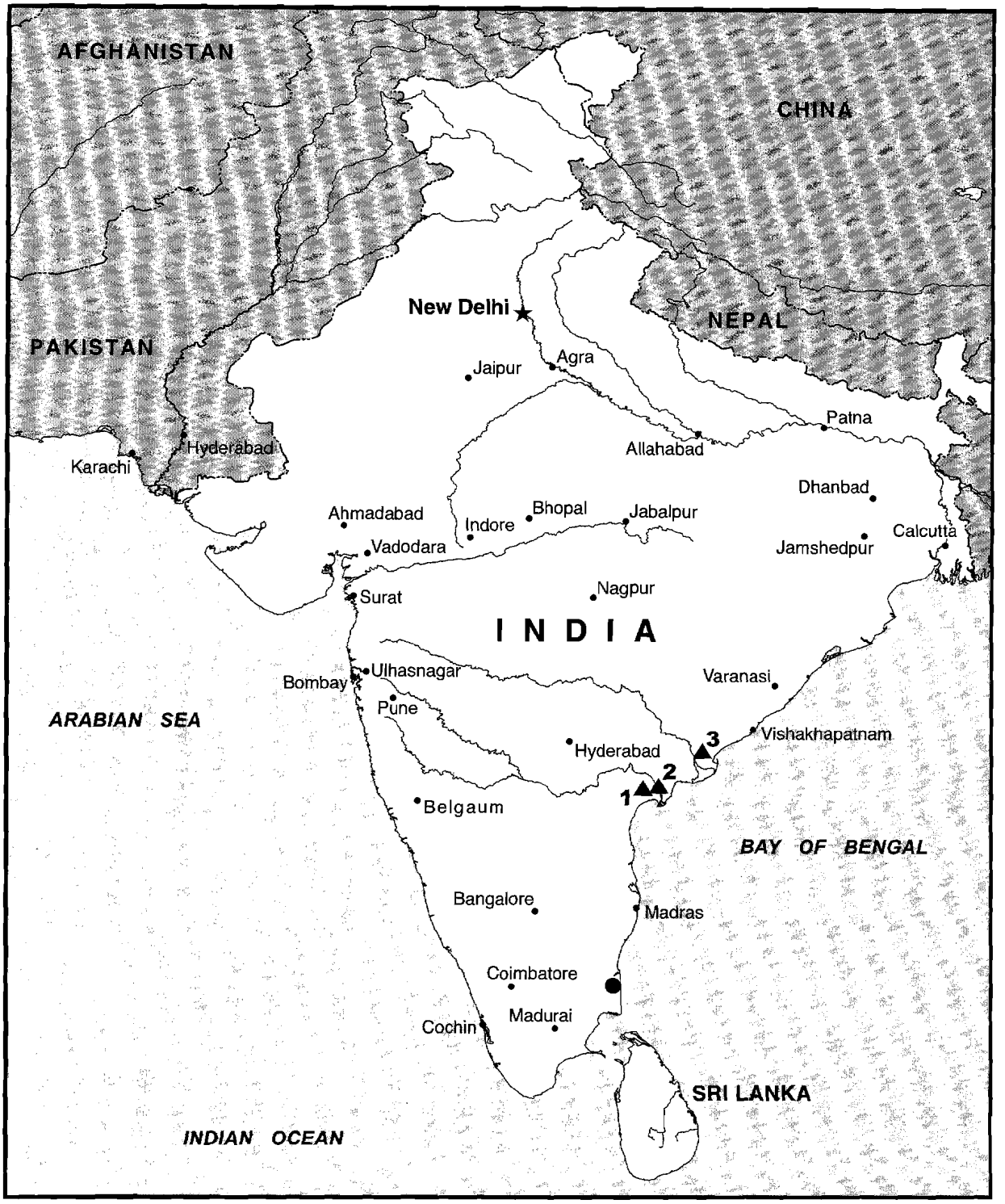

Fig. 6 - Geographic distribution of bogidiellid amphipods in India. Closed triangles: *Bogidiella indica*, new species from water wells at (1) Guntur town, (2) Nagarjunanagar (type-locality) and (3) Doddigunta village, Andhra Pradesh State. Closed circle: *Bogidiella* sp. from pumped groundwater near Chidambaram, Tamil Nadu State.

sampling were as follows: temperature 20-30°C; dissolved oxygen 6-8 mgl^{-1}; total hardness 90-120 mg l^{-1}; total alkalinity 300-400 mg l^{-1}; free CO_2 3-4 mg l^{-1}; pH 7.5-8.2; chlorides 1.0-1.5 mg l^{-1}. The majority of specimens collected from the agricultural well in the Godavari-Krishna basin were females. The single specimen from the well at Guntur town is a mature male and, as mentioned above, differs slightly in several morphological structures from specimens elsewhere in the currently known range.

DISCUSSION

With exception of a single, poorly preserved specimen collected in the early 1960s from a well, presumably freshwater, near the coast of India in the vicinity of Chidambaram in the southeastern Indian state of Tamil Nadu, bogidiellid amphipods were unknown from the Indian subcontinent until specimens were recently collected from three freshwater wells in the eastern part of the Indian state of Andhra Pradesh and described herein as *Bogidiella indica*. Although several important structures are missing from the Chidambaram specimen, as pointed out below enough of its morphology is present to suggest a close taxonomic affinity with *B. indica* from much farther north. In a recent phylogenetic analysis and taxonomic revision of the family Bogidiellidae, four species groups within the genus *Bogidiella* s. str. were designated by Koenemann & Holsinger (1999), including: (A) *albertimagni*, (B) *skopljensis*, (C) *niphargoides*, and (D) *lindbergi*. A number of other more strongly differentiated species clusters in the family were elevated to generic level. Although *Bogidiella indica* does not differ enough morphologically from other bogidiellid amphipods to merit recognition as a separate genus, it is clearly different enough to warrant recognition as a new species group, which we herein designate the *indica* group (group E). This newly recognized group is defined by a structurally unique pereopod 5 that is proportionately shorter, stockier and more heavily spinate than that of any other described bogidiellid taxon, and the possession of an apical, elongate, sexually dimorphic spine on the inner ramus of uropod 1 of the male. It should be noted that, although several diagnostic structures are missing from the Chidambaram material, pereopod 5 of this specimen is closely similar to that of *B. indica*.

The presently known range of *B. indica* extends approximately 180 km from Guntur town northeast to Doddigunta village, which is just northeast of the Godavari River (Fig. 6). All three well sites occur within 45 km of the present coastline, and there is good evidence that these sites were exposed to marine waters at one or more times during the Cenozoic. The region around the type-locality well at Acharya Nagarjuna University and the nearby Guntur town is underlain by an ancient metamorphic basement rock called Charnockite. Relatively recent (Holocene) lateritic formations up to 6 meters thick occur above the basement formation, and exposed remnants of Upper Gondwana formations (sandstones ca. 90 million M. Y. old) occur approximately 12 km southeast of the study site. Based on studies of onshore sediments in the nearby Repalle area (Appajee and Prabhakar 1985) and paleostrandline (ancient beach ridges) positions in the Krishna River delta as delineated by aerial photography (Nageswara Rao and Vaidyanadhan 1978), it is clear that the sampling sites were submerged under shallow marine waters during the Holocene. Additional satellite image studies and surface expressions in the form of beach ridges (cf. Gupta 1989) indicate that marine transgressions occurred in the vicinity of the basin between the Krishna and Godavari rivers and extended inland up to 40 km from the present coastline of the Bay of Bengal. Lithologically, the area around the agricultural well in Doddigunta village is composed of Rajahmundry sandstone (275 m thick) of Miocene/Pliocene age. It is unconformably underlain by the Kateru Volcanic Trap (65 M. Y. old) and overlain directly by a deltaic alluvium approximately 1 M. Y. old. The occurrence of a variety of fossil marine invertebrates in limestone beds of the upper volcanic trap is indicative of the encroachment of marine waters into the study area during the Paleocene.

The discovery of the new Indian species from water wells in Andhra Pradesh, combined with the occurrence of another bogidiellid species approximately 550 km to the south in the state of Tamil Nadu, fills a huge gap in the global distribution of the family. Moreover, during the last year (2006) additional specimens, unfortunately in very poor shape but apparently representing another undescribed bogidiellid species, were sampled from a bore-well at Araveetikota, ca. 30 km north of Giddalur town in Prakasam District, and ca. 250 km south of Guntur town. The presence of what are apparently several species of bogidiellid amphipods in the states of Andhra Pradesh and Tamil Nadu is strong evidence that the family Bogidiellidae is well established on the Indian subcontinent and that even more species will be discovered with subsequent investigation of subterranean groundwater habitats. Moreover, the presence of these species near the coast of the Bay of Bengal in areas that sustained marine transgressions during the Cenozoic is further evidence in support of the earlier hypothesis that freshwater bogidiellids have evolved from marine ancestors (see Ruffo 1973; Notenboom 1991; Iannilli et al 2006).

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