Sociobiology 62(3): 426-438 (September, 2015) DOI: 10.13102/sociobiology.v62i3.793

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - TERMITES

# Global Elevational, Latitudinal, and Climatic Limits for Termites and the Redescription of *Rugitermes laticollis* Snyder (Isoptera: Kalotermitidae) from the Andean Highlands

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**Article History**

**Edited by**
Gilberto M. M. Santos, UEFS, Brazil
Received 14 April 2015
Initial acceptance 18 June 2015
Final acceptance 11 August 2015

**Keywords**
Termites, Andean Highlands, *Rugitermes Laticollis* Snyder, Redescription.

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**Abstract**

We compile, map, and discuss global elevational, latitudinal, thermal, and rainfall extremes of termite localities from literature sources and unpublished records. *Rugitermes laticollis* from Ecuador and Bolivia occurs at higher elevation (2700-3600 m) than any other termite species. Termites span the globe from 54.3°N (*Zootermopsis angusticollis* in British Columbia (B.C.), Canada) to 48.9°S (*Porotermes quadricollis* in Magdalena, Chile). The coldest locality supporting termites (*Reticulitermes* sp.) is at Churn Creek, B.C., where the mean annual temperature is 4°C. Lake Havasu City, Arizona, where *Heterotermes aureus* and *Gnathamitermes perplexus* occur, has the highest recorded temperature maximum (52°C) for a termite locality. *Cryptotermes brevis* and *Neotermes chilensis* are endemic to the Pacific Coast of Peru and Chile where rain is essentially absent. We further provide locality extremes for six termite families from six zoogeographical regions. In addition, the winged imago of *Ru. laticollis* is redescribed and the soldier is described for the first time.

## Introduction

Taxonomic diversity declines for most organisms as climatic temperatures decrease either from increasing elevation (Rahbek, 1995) or increasing latitude (Willig et al., 2003; Mittelbach et al., 2007). Termites also show reduced diversityas elevation increases above ca. 800 m (Inoue et al., 2006; Palin et al., 2011; Gathorne-Hardy et al., 2001) and as latitude becomes extra-tropical (Emerson, 1952; Cancello et al., 2014). Termite diversity is overwhelmingly greatest in the tropics (≤23.5° N and S) where several hundred genera are recorded compared to five found in the temperate regions (≥40° N and S, Jones & Eggleton, 2011). In addition to elevational and latitudinal extremes, some termite species also occupy environments in hot or arid deserts and in near-freezing climates (Emerson, 1936; Emerson, 1955).

Among T.E. Snyder's last taxonomic publications was a note on a new termite from Bolivia (Snyder, 1957). Therein, he briefly describes winged adults of *Rugitermes laticollis* from a sample which he "found" in the Smithsonian collection where he worked. What is especially noteworthy was Snyder's account of the type locality of his new species as


ISSN: 0361-6525

follows: "La Paz, Bolivia. Described from 6 winged adults, 4 males and 2 females, collected at the type locality by R. Pérez Alcalá, 1947."

Unaware of *Ru. laticollis*, one of the authors (AJM) traveled to Quito, Ecuador, after departing from a 2010 termite expedition to the Ecuadorian Amazon. After reuniting, AJM reported finding a kalotermitid species in a tree at a city park in Quito. Having found very few termites in the neotropics above 1600 m, we were astonished to learn of AJM's find at an elevation of 2800 m! On our return, we determined that the Quito sample was indeed *Ru. laticollis* Snyder. We now surmise that Snyder (1957) did not realize the altitudinal significance of the La Paz locality for *Ru. laticollis* which is even more elevated than Quito by some 400 to 1400 m. Furthermore, after reviewing the UF collection holdings, a third high-elevation sample of *Ru. laticollis* was identified from Luribay, Bolivia (2700 m).

Prompted by our unexpected collection of *Ru. laticollis* and the lack of a compilation of termite localities at the limits of termite habitation, we herein review published records and provide new data on the elevational, latitudinal, thermal, and rain fall limits of representative termite taxa worldwide. Furthermore, we describe for the first time, the soldier of *Ru. laticollis* and redescribe its winged imagos.

## Materials and Methods

Elevation and locality coordinates (Appendix) were taken from published data or from our database (University of Florida (UF) Termite Collection, Davie, Florida) listed as "current paper" in Appendix. Most specimens in the UF collection were taken during week-long expeditions in which the goal was to acquire maximum regional diversity. In some cases, published elevation, geographic coordinates, and locality names were confirmed or corrected using Google Earth and web resources. Climatic data were taken from http://www.weatherbase.com/.

*Rugitermes laticollis* localities and those reported or selected for other termite taxa were mapped (Fig 1) using ArcGIS Desktop 10.2 software. Figures 2 and 3 were taken as multilayer montages using a Leica M205C stereomicroscope controlled by Leica Application Suite version 3 software. Montage specimens were taken from 85% ethanol and positioned in Purell® Hand Sanitizer contained within a transparent plastic Petri dish bottom. Field photographs of *Ru. laticollis* (Figs 4 and 5) were taken with a Nikon 7SC digital camera in macro flash (Fig 4) or non-macro (Fig 5) mode. Measurements (Tables 1 and 2) were taken with an Olympus SZH stereomicroscope with an ocular micrometer.

**Table 1.** Measurements of *Rugitermes laticollis* winged imagos (n=7).

| | females (n=3) | | males (n=4) | |
|---|---|---|---|---|
| | mean | range | mean | range |
| Head width max. (without eyes) | 1.73 | 1.50-2.00 | 1.64 | 1.60-1.75 |
| Pronotum width | 1.96 | 1.88-2.06 | 2.02 | 1.83-2.13 |
| Eye diam. max | 0.37 | 0.36-0.38 | 0.38 | 0.37-0.39 |
| Body length | 8.89 | 8.66-9.00 | 8.93 | 8.75-9.10 |
| Right forewing length | 9.35 | 9.05-9.75 | 9.54 | 9.25-9.90 |
| Body length with wings | 11.77 | 11.30-12.25 | 12.20 | 12.00-12.65 |

## Results

### Elevational Maxima

In most of the world's tropics, termite diversity and abundance are greatest from sea level to about 1200 m (Inoue et al., 2006). Palin et al. (2011) reported a decrease in termite diversity and abundance with increased elevation in Peru and found no termites above 1550 m. Atkin and Proctor (1988) found no termites at 1500m or above on a Costa Rican volcano. On Mount Giting-Giting, Philippines, Thomas and Proctor (1997) found a few termite species at 1240 m elevation and none at 1540 m. Collins (1980) reported the upper limit of termites at 1850 m on the West Ridge of Gunung (Mount) Mulu, Sarawak. Gathorne Hardy et al. (2001) found the least termite diversity (five species) at 1400 m compared to 11-35 species at lower elevations on the island of Sumatra. In our New World sampling efforts, Scheffrahn et al. (unpublished data) have observed a similar elevational decline in termite diversity. The Appendix provides a summary of 33 reported and 24 new global elevational maxima for selected termite taxa.

The most elevated locality reported for any termite is 3900 m for "Kunwari Pass", Chamoli State, India, for the damp wood termite, *Archotermopsis wroughtoni* (Roonwal et al., 1984). This elevation is 1100 m higher than the next highest of the 35 localities reported by these authors. The name and elevation of this western Himalayan site, however, could not be confirmed on Google Earth, the Web, or maps of northern India. When queried for "Kunwari Pass", internet resources only yielded the town of Joshimath (1860 m) which is at the trail head of "Kauri Pass". Shedding further doubt on the "Kunwari Pass" locality, Imms (1920) is quoted: "In June, 1910, I first came across this insect in a decaying fallen trunk of *Pinus excelsa*, in a forest area situated between the Kuari Pass and Ramni, at an altitude of about 8,500 feet, in the Himalayas of British Garwhal." Imms (1920) further

**Table 2.** Measurements of *Rugitermes laticollis* soldiers (n=10).

| | mean | range |
|---|---|---|
| Head length to lateral mandible base | 3.08 | 2.50-3.33 |
| Head widthmax. | 2.06 | 1.83-2.43 |
| Head height with gula max. | 1.64 | 1.40-1.83 |
| Pronotum length | 1.08 | 1.00-1.17 |
| Pronotum width | 2.21 | 1.93-2.76 |
| No. antennal articles | 15 | 14-16 |

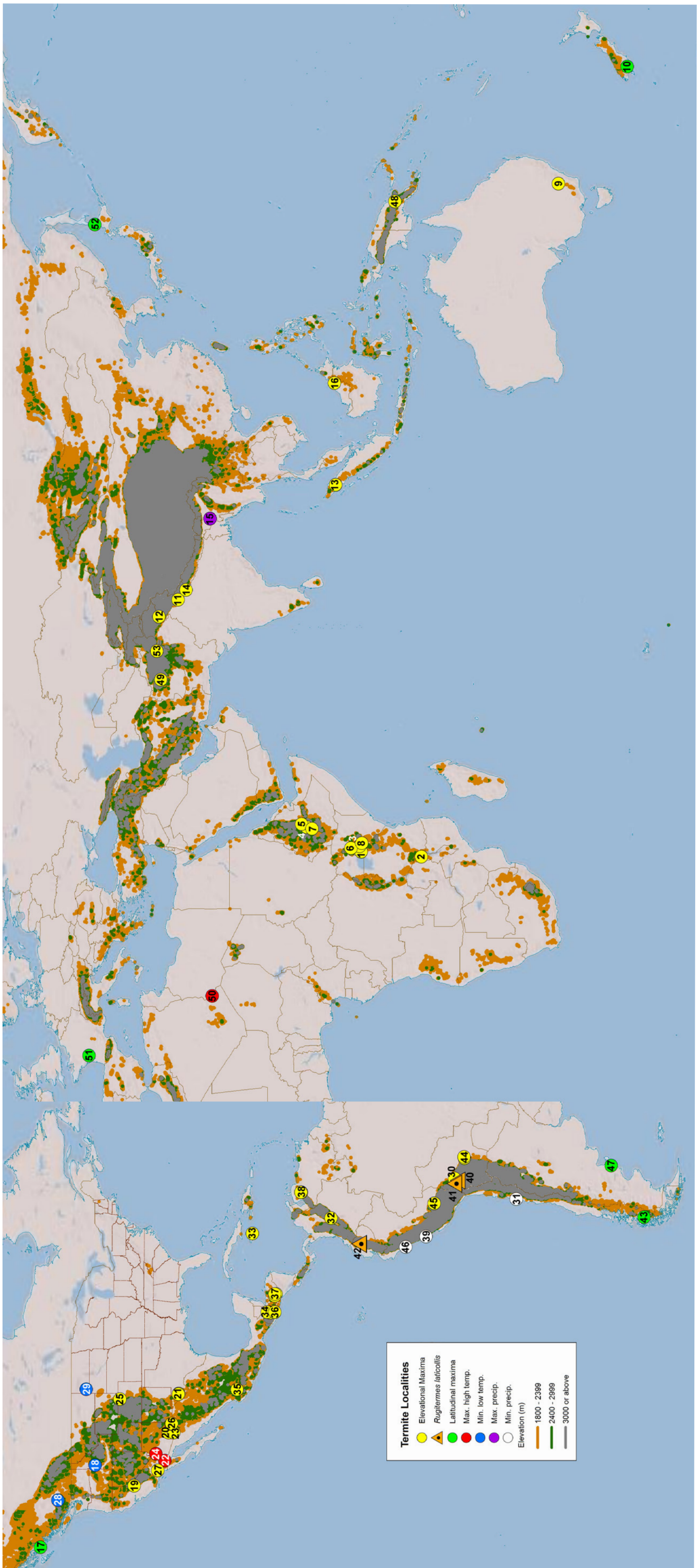


**Fig 1.** Distribution map for *Rugitermes laticollis* and termite geographical limits referenced by number from Table 1.

notes that N.C. Chatterjee provided him with material taken at 2743 m in Deoban, Uttar Pradesh. Deoban, is the second highest *Ar. wroughtoni* site listed at 2800 m by Roonwal et al. (1984) and is very likely the same sample referenced by Imms (1920). Google Earth gives the elevation of Deoban village at over 400 m lower (2280 m). This leaves the highest confirmed locality of material examined by Roonwal et al. (1984) as Gulmarg, Jammu and Kashmir Province (2700 m). Although the exact locality in La Paz from which Snyder's (1957) original *Ru. laticollis* sample was collected cannot be determined, the elevational range for this city is between 3400-4000 m (http://travel.state.gov/travel/ cis_pa_tw/cis/cis_1069.html) with the old central plaza at 3600 m. The recorded elevational mean and range for *Ru. laticollis* iscurrently more elevated and narrower (2700-3600 m) than that of *Ar. wroughtoni* (1000-2743 m, Roonwal et al., 1984).

Elevational records for the Afrotropics are limited to the higher termites (family Termitidae) which reach a maximum elevation in the highlands surrounding the Great Rift Valley of Ethiopia and Kenya. Here, all Afrotropical subfamilies except Nasutitermitinae have been recorded at 1900 m or above (Appendix). The epigeal mounds of *Cubitermes* and *Odontotermes* colonies are conspicuous in these more barren highlands. In Ethiopia, Cowie et al. (1990) reported that "above 2000m the fauna is very restricted, but *Odontotermes*is found in Addis Ababa (ca. 2300 m) and a single worker of a completely subterranean *Odontotermes* species was seen (but not collected) near Debre Birhan at about 3200m". Google Earth, however, gives the elevation of the Debre Birhan plateau at 2800 m. Sjöstedt's 1905 record of *Odontotermes apollo* at 2600 m from Eburru, Kenya, is the elevational maximum for the family Termitidae. Donovan et al. (2002) collected 11 genera of Termitidae, many of which are soldierless soil feeders in the subfamily Apicotermitinae, at 1900 m on the Nyika Plateau of Malawi. The nasutitermitine genus *Trinervitermes*, although reported to be very rare in the area, was recorded at 1650m at Adami Tullu, Ethiopia (Debelo & Degaga, 2014).

The only significant elevational records for the Australian Region include the Family Stolotermitidae (*Porotermes adamsoni* and *Stolotermes vitoriensis*) from the Brindabella Range near Canbarra (1300 m, Lacey et al., 2010). The highest report for termites in Papua New Guinea is that of *Pericapritermes* cf. *schultzei* collected in the Bismarck Range at 1650 m (Bourguignon et al., 2008). In addition to the elevation records for *Ar. wroughtoni* noted above, the Himalayan foothills also support *Odontotermes distans* at 2250m (Thakur, 1981). Elevational records in the eastern Indomalayan region include two nasutermitine genera, *Bulbitermes* and *Longipeditermes,* from Sumatra (1400 m) and *Bulbitermes* from Malaysia (1860 m, Appendix).

Since 2004, the neotropical mainland has been the subject of largely unpublished termite biodiversity surveys (*cf.* UF Collection) with the Kalotermitidae generally occupying higher elevations than other families of the region (Appendix). Aside from *Ru. laticollis* and the exotic *Cryptotermes brevis*, members of the kalotermitid genera *Comatermes, Glyptotermes, Incisitermes, Marginitermes*, and *Neotermes* have been recorded above 1500 m in the highlands of Guatemala and Honduras (Appendix). A new species of *Neotermes* was collected at 1831 m from a damp log in Parque Nacional de Yacumba, Venezuela. *Coptotermes testaceus* and *Heterotermes convexinotatus* (Rhinotermitidae) have also been found at elevations above 1500 m in the Central American highlands. In South America, mostly Termitidae have been recorded above 1400 m including *Anoplotermes turricola* and *Procornitermes lespesii* (Bolivia) and *Nasutitermes guayanae* and *Na. octopilus* (Peru, Palin et al., 2011). The highest elevation for termites in the West Indies is currently at 1239 m for *Glyptotermes liberatus* in the Blue Mountains of eastern Jamaica. We expect, however, that the West Indian elevational record actually lies in the poorly accessible Cordillera Central of the Dominican Republic which rises to Pico Duarte at 3098 m.

In the Nearctic Region, only *Reticulitermes* sp. (Rhinotermitidae) and *Zootermopsis* sp. (Archotermopsidae) have been found above 2000 m (Appendix). A colony of the western drywood termite, *Incisitermes minor*, was sampled from a pine log in the Davis Mountains of Texas at an elevation of 1772 m. *Gnathamitermes* nr. *perplexus* and *Amitermes*nr *californicus* [not a synonym of *Am. wheeleri* (Desneux) Scheffrahn unpubl. obs.] were collected near *I. minor* at slightly lower elevation. *Tenuirostritermes tenuirostris*, the only nasutitermitine of the Nearctic, was collected at 1765 m in the Chiricahua Mountains of southeastern Arizona. Winter snowfall accumulations are common in these mountains. In the Palearctic, both elevational records are from Afghanistan. *Anacanthotermes septentrionalis* is reported at 2000 m in Jija, a record for the family Hodotermitidae. *Microcerotermes gabrielis* was collected at 1850 m in Kabul (Weidner, 1960).

It should be mentioned that two termite species have been found along the Red Sea where elevation below sea level is a global minimum. *Angulitermes quadriceps* was collected around Jericho and Sdom, Israel, at about -252 m (Harris, 1964), and *Microcerotermes palestinensis* was found in Ein Gedi, Israel, at about -282 m (Spaeth, 1964).

*Latitudinal Maxima*

The northern global limits of termite distribution are reported by Vickery and Kevan (1985) who recorded *Zootermopsis angusticollis* at 54.3°N (Prince Rupert, British Columbia) and *Z. nevadensis* at 53.3°N (Dunkley, BC, near Quesnel). Coastal southern Alaska needs to be surveyed for the possibility of a more northerly record for *Zootermopsis* sp. (R.A. Cannings pers. comm.). A *Reticulitermes* sp. was collected as far north inland as 51.3°N (Churn Creek Protected Area near Dog Creek, BC; coll. RJH) and near Kamloops, British Columbia (50.7°N, Vickery & Kevan, 1985;).The southern limits for termites are ca. 48.9°S for *Porotermes quadricollis* (Magallanes Province, Chile, Constantino, 1998) followed by *Stolotermes ruficeps* at ca. 46°S ("widespread throughout New Zealand", Bain & Jenkin 1983). For a higher termite, *Onkotermes brevicorniger* holds the record at 43.3°S (Rawson, Chubut Province, Argentina, Constantino et al., 2002).

*Precipitational and Thermal Extremes*

The Pacific coast of Peru and northern Chile receives the least rainfall of any nonpolar region on earth. However, due to riparian habitats nurtured by Andean snowmelt, both the Peruvian and the Atacama deserts support woody growth and termites. This remarkably cool and humid desert coastline is the endemic habitat of *Cryptotermes brevis* (Scheffrahn et al., 2009) and *Neotermes chilensis*, the latter occurring in both dead wood and inside living trees (Scheffrahn pers. obs.).*Amitermes lunae* was discovered in soil at a Moche archeological site near Trujillo, Peru (Scheffrahn & Huchet, 2010) which receives a mere 0.5 cm of rainfall annually. Termites are common to very wet circum-tropical climates. The village of Cherrapunji at the base of the Himalayas in Assam Province, India, receives more rain, at 10.6 m per annum, than any place on earth. Roonwal and Chhotani (1962) report four termitid genera from Cherrapunji (Appendix).

The termite localities with the highest recorded temperature maxima include Lake Havasu City, Arizona (52°C, *Heterotermes aureus* and *Gnathamitermes perplexus*), Imperial California (51°C, *Marginitermes hubbardi*), and Ghat, Libya (51°C, *Psammotermes hybostoma*, Harris, 1966). The coldest annual mean (record minima) where termites occur include Churn Creek, B.C. 4°C (-40°C ) for *Reticulitermes* sp.; New Meadows, Idaho,5°C (-45°C) for *Z. angusticollis*; Dunkley, B.C. 5.5°C (-47°C) for *Z. nevadensis*; and Amidon, North Dakota, 6°C (-40°C), for *R. tibialis* (Emerson, 1936).

**Discussion**

The nesting and foraging habits of most termites should protect colonies from excesses of air, soil, or substrate temperatures found at elevational or latitudinal extremes. However, only two genera, *Zootermopsis* and *Reticulitermes*, live in climates where the mean annual temperatures ranges between 4-6°C, while *Porotermes quadricollis* and *Stolotermes ruficeps* occur at 8 °C (Puerto Aisen, Chile) and 10° C (Intercargil, New Zealand) respectively. Cabrera and Kamble (2001) showed that *Reticulitermes flavipes* foragers avoid the coldest periods by harboring in warmer soil refugia. Cook and Smith (1942) reported that the metabolism of the protist symbionts of *Zootermopsis* were similar at 9° to 29°C, but stopped at 4°C leading to starvation of the termites. Lacey et al. (2010) have recently shown that trehalose is used as a cryoprotectant in both *Porotermes* and *Stolotermes* in Australian climates which are much warmer than those of either southern Chile or New Zealand. It is unclear why termites, especially *Reticulitermes*, do not reside naturally in northern Europe or the British Isles (Harris, 1962) where mean/minimum temperatures (e.g. Warsaw, Poland, 8°/-30° C; Edinburgh, Scotland, 9°/-17°C; and London, England, 10°/-13°C) are above the temperatures where *Reticulitermes* and *Zootermopsis* occur in the northern United States and Canada.

Termites appear to inhabit all geographic regions with high thermal maxima or mean temperatures as long as food and ground moisture are sufficiently available. The overwhelming majority of termites live in humid tropical environments (Jones & Eggleton, 2011). In seasonally hot regions termites move into cooler, deeper soils to avoid periods of excessive maximum surface temperatures (*Heterotermes aureus* and *Gnathamitermes perplexus*, Collins et al., 1973) or into cooler deeper or lower wood substrata (*Incisitermes fruticavus* Rust, Rust et al., 1979). *Paraneotermes simplicicornis*is the only example of a kalotermitid that has adapted to hot seasonal climates by evolving a completely subterranean habit (Light, 1937).

Regarding elevation (e.g., *Cr. brevis* in Bogota Colombia, 2600 m), anthropogenic introductions of exotic termites within buildings often exceed latitudinal limits. For example, a *Na. corniger* colony was observed building foraging tubes from a potted plant near the swimming pool of a fitness club in East Kilbride, Scotland (57.213°N, 5.997°W, Scheffrahn et al., 2002). The plant had been imported from Barbados. *Cryptotermes brevis* was collected in Anchorage, Alaska (61.21N, -149.89W), from a bookcase originally transported from Hawaii (Scheffrahn unpubl. data).

Worldwide, *Z. angusticollis* shows the greatest adaptation of any termite to climatic and geographic variability. This species occupies a 93°C temperature range from New Meadows, Idaho (-45°Cmin. record) to Riverside, California (48°C max. record). In addition, the vast elevational range of *Z. angusticollis* from 2124 m in the Sierra Nevada mountains of California (Weesner, 1965) to sea level (Los Angeles, Banks and Snyder 1920; Santa Monica CA, Scheffrahn unpublished), a large precipitation range (197 cm Tatoosh Island, Washington State, Thorne et al., 1993) to Riverside, CA, (26 cm) and a vast geographical range extending 3,000 km from Guadeloupe Is., Mexico (Light, 1933), to Prince Rupert, B.C., attest to the remarkable climatic tolerance of this species.

**Taxonomic Summary**

*Rugitermes laticollis* Snyder 1957

DESCRIPTION

Imago (modified from Snyder, 1957, Figs 2, 4; Appendix). Head capsule very dark brown to black except for dark ferruginous border around antennal sockets. Dorsum of body, including pronotum, concolorous with head capsule. Postclypeus yellowish, labrum light brown. Compound eyes


**Fig 2.** *Rugitermes laticollis*.Oblique lateral and dorsal views of the imago head and pronotum.

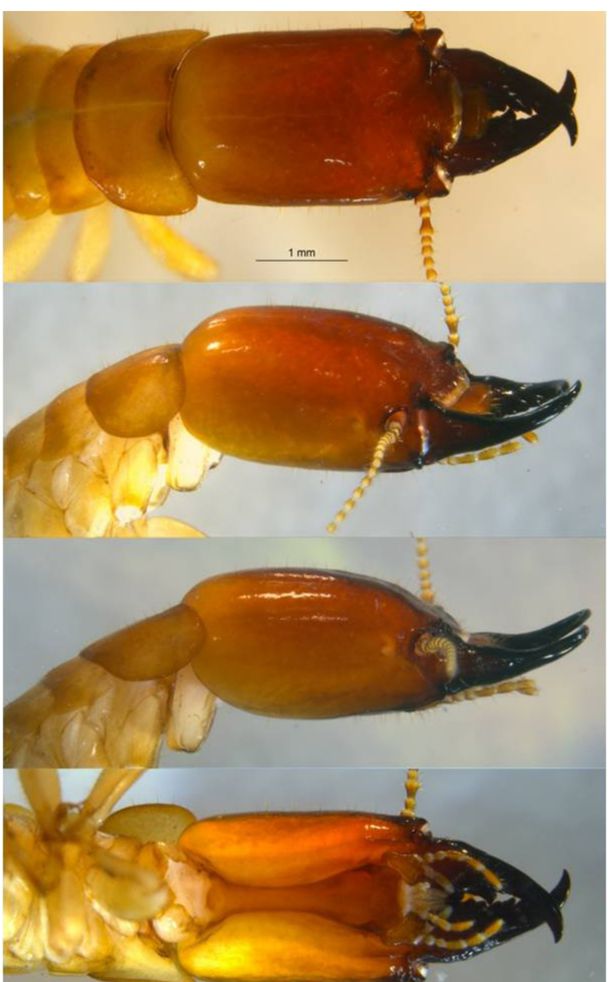


**Fig 3.** *Rugitermes laticollis*.Dorsal, oblique, lateral, and ventral views of the soldier head and pronotum.

and ocelli very dark gray; compound eyes small; occupying mid one-third of lateral head capsule aspect. Pronotum wider than head capsule. Antennae with 15 articles; basal articles concolorous with labrum, becoming darker toward apex. Head, pronotum, and wing scale generously covered with both long and short setae. Setae widely dispersed on abdominal tergites, and sternites. Pronotum with scattered long and short setae; anterior margin weakly concave, posterior emarginate in middle. Compound eyes subcircular; eye margins broadly subrectate along antennal sockets. Ocelli hyaline, slightly protruding, suboval; well separated from eyes. Wing membrane smoky brown with bronze and greenish prismatic sheen in live specimens (Fig 4); membrane covered with tiny punctuations; sclerotized veins dark brown. Venation as in Fig 13 of Krishna (1961). In forewing, all major veins emerge from scale independently; sclerotized median vein joins radial sector about one-eight distance to wing tip; cubitus unsclerotized and running parallel with radial sector to tip of wing. Hind wing without median vein. Arolia present.

Comparisons. Unlike many species of *Rugitermes* that are bicolored (usually pronotum and/or wings contrast with head coloration), the imago of *R. laticollis* is evenly and very darkly concolorous. The imago of *Rugitermes niger* Oliveira 1979 is also uniformly very dark (dark brown to black) but it is much smaller (head width 1.26-1.34 mm).

Soldier (Figs 3, 4; Table 2). Monomorphic. Head capsule rectangular; lateral margins parallel in dorsal view. Antenna with 14 articles 2<3>4=5; third article clavate and twice the length of second. Mandibles orange-brown near base, grading to castaneus before first marginal tooth and black to apical tooth. Pronotum pale yellow at posterior margin grading to reddish orange from anterior fourth to anterolateral margins. Mandibles project about one-half length of head capsule; without basal hump. Anterolateral corners of genae prominent; forming angular corners when viewed from above. Antennal ridge robust over antennal sockets but gives way to weakly rugose concavity formed by frons. Head capsule slightly wider than pronotum.Pronotum collar-like; anterior margin evenly concave; posterior margin evenly convex with small concavity in middle. Gula slender in middle, about one-third width of anterior portion.

**Fig 4.** Habitus of a soldier, imagoes, and nymphs of *Rugitermes laticollis*.

Comparisons. Soldiers of *Ru. laticollis* cannot be confidently separated from congeners using the soldier caste alone, however, for those species with uniformly dark imagoes, the soldiers of *Ru. laticollis* are the largest.

Material Examined. Bolivia, Depto. de La Paz: Luribay (-17.05994 lat., -67.66363 long.; elev ca. 3600 m), DEC 1986, col. R. Subieta, UF collection no. SA1, (2 soldiers and pseudergates; ex. live branch of peach (*Prunus*) tree). Ecuador, Distr. Pichincha: Quito, Parque La Carolina, (-0.18845, -78.48595; elev 2780 m), 3 JUN 2011, col. A Mullins, EC1465 (alates, soldiers, nymphs; ex. dead portion of live tree, Fig 5).Adjacent Quito locality (-0.18879, -78.48556) 4 JUN 2011, col. Krecek, Mullins, Scheffrahn; EC1466 (alates, soldiers, nymphs), ex. dead portion of live tree Fig 5).Adjacent Quito locality (-0.18879, -78.48556) 4 JUN 2011, col. Krecek, Mullins, Scheffrahn; EC1467 (soldiers and nymphs), ex. dead portion of live tree.

Biology. *Rugitermes laticollis* colonizes live or dead wood occasionally exposed to freezing temperatures in the upper montane zone of Andes (2300 to 3630 m as defined by Young & Keating, 2001). Alates in Quito were found in June but the timing of flight season is uncertain. The dark coloration suggests daytime flight which may improve alate mobility compared to cool nighttime mountain temperatures. Although known from only three locations, *Ru. laticollis*may well occur over a large area of Andean highlands which support woody growth.

## Acknowledgements

We thank Tiago F. Carrijo, John Warner, and Ben Gillenwaters for their reviews. Termites collected under permit no. 06-2011-FAU-DPAP-MA, Ministerio del Ambiente, Quito Ecuador.

**Fig 5.** Collection site of *Rugitermes laticollis* in Quito, Ecuador.

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**Appendix**. Elevational, latitudinal, thermal and precipitational geographic limits for termites.

| Map no. | Category | Region[1] | Family | Subfamily | Genus | Species | Meters | Country, Province | Locality | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | elev | Africotropical | Termitidae | Apicotermitinae | *Adaiphrotermes* | sp. | 1900 | Kenya | Kisii | -0.5500 | 34.8100 | Kooyman & Onck 1987 |
| 1 | elev | Africotropical | Termitidae | Apicotermitinae | *Astralotermes* | sp. | 1900 | Kenya | Kisii | -0.5500 | 34.8100 | Kooyman & Onck 1987 |
| 2 | elev | Africotropical | Termitidae | Apicotermitinae | numerous genera[1] | numerous sp.[1] | 1900 | Malawi | Nyika Plateau, Vitumbi | -10.8190 | 33.9350 | Donovan et al. 2002 |
| 3 | elev | Africotropical | Termitidae | Cubitermitinae | *Cubiteremes* | *ugandensis* Fuller | 2400 | Kenya | Molo | -0.2500 | 35.7300 | Williams 1966 |
| 4 | elev | Africotropical | Termitidae | Macrotermitinae | *Macrotermes* | *subhyalinus* Rambur | 2000 | Ethiopia | Bishoftu | 8.7500 | 38.9800 | Ruelle 1970 |
| 6 | elev | Africotropical | Termitidae | Macrotermitinae | *Odontotermes* | sp. | 2400 | Kenya | Cherangani Hills | 1.2200 | 35.4300 | Darlington 1985 |
| 5 | elev[2] | Africotropical | Termitidae | Macrotermitinae | *Odontotermes* | sp. | 2800 | Ethiopia | nr. Bebre Birhan | 9.6800 | 39.5300 | Cowie et al. 1990 |
| 7 | elev | Africotropical | Termitidae | Nasutitermitinae | *Trinervitermes* | sp. | 1650 | Ethiopia | Adami Tullu | 7.86 | 38.707 | Debelo & Degaga 2014 |
| 8 | elev | Africotropical | Termitidae | Termitinae | *Odontotermes* | *apollo* Sjöstedt | 2600 | Kenya | Eburru | -0.6500 | 36.2700 | Sjöstedt 1905 |
| 9 | elev | Australian | Stolotermitidae | | *Porotermes* | *adamsoni* Froggatt | 1298 | Australia, ACT | Brindabella Range nr Canberra | -34.2280 | 148.9880 | Lacey et al. 2010 |
| 10 | lat | Australian | Stolotermitidae | | *Stolotermes* | *ruficeps* Brauer | 100 | New Zealand | South Island | -46.0000 | 169.0000 | Bain & Jenkin 1983 |
| 9 | elev | Australian | Stolotermitidae | | *Stolotermes* | *vitoriensis* Hill | 1298 | Australia, ACT | Brindabella Range nr Canberra | -35.3800 | 148.8000 | Lacey et al. 2010[4] |
| 11 | elev | Indomalayan | Archotermopsidae | | *Archotermopsis* | *wroughtoni* Desneux | 2743 | India | Deoban | 30.75 | 77.85 | Imms 1920 |
| 12 | elev[3] | Indomalayan | Archotermopsidae | | *Archotermopsis* | *wroughtoni* | 2700 | India | Gulmarg | 34.0300 | 74.9500 | Roonwal & Chho-tani 1989 |
| 13 | elev | Indomalayan | Rhinotermitidae | | *Parrhinotermes* | *buttel-reepeni* Holmgren | 1400 | Indonesia | Sumatra, Kemiri | 3.8230 | 97.5180 | Gathorne-Hardy et al. 2001 |
| 13 | elev | Indomalayan | Rhinotermitidae | | *Parrhinotermes* | sp. | 1400 | Indonesia | Sumatra, Kemiri | 3.8230 | 97.5180 | Gathorne-Hardy et al. 2001 |
| 14 | elev | Indomalayan | Termitidae | Macrotermitinae | *Odontotermes* | *distans* Holmgren & Holmgren | 2250 | India | Kumaon Hills | 29.4100 | 79.5500 | Thakur 1981 |
| 15 | wet | Indomalayan | Termitidae | Macrotermitinae | *Odontotermes* | *kapuri* Roonwal & Chhotani | 1311 | India | Cherrapunji | 25.3000 | 91.7000 | Roonwal & Chhotani 1962 |
| 13 | elev | Indomalayan | Termitidae | Nasutitermitinae | *Bulbitermes* | *constrictoides* (Holmgren) | 1400 | Indonesia | Sumatra, Kemiri | 3.8230 | 97.5180 | Gathorne-Hardy et al. 2001 |
| 16 | elev | Indomalayan | Termitidae | Nasutitermitinae | *Bulbitermes* | sp. | 1860 | Malaysia | Gunung Mulu, Sarawak | 4.0500 | 114.9000 | Collins 1980 |

**Appendix**. Elevational, latitudinal, thermal and precipitational geographic limits for termites (Continuation).

| Map no. | Category | Region[1] | Family | Subfamily | Genus | Species | Meters | Country, Province | Locality | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | elev | Indomalayan | Termitidae | Nasutitermitinae | *Longipeditermes* | *kistneri* Akhtar and Ahmad | 1400 | Indonesia | Sumatra, Kemiri | 3.8230 | 97.5180 | Gathorne-Hardy et al. 2001 |
| 15 | wet | Indomalayan | Termitidae | Nasutitermitinae | *Nasutitermes* | *cherraensis* Roonwal and Chhotani | 1311 | India | Cherrapunji | 25.3000 | 91.7000 | Roonwal & Chhotani 1962 |
| 15 | wet | Indomalayan | Termitidae | Termitinae | *Pericapritermes* | *durga* Roonwal & Chhotani | 1311 | India | Cherrapunji | 25.3000 | 91.7000 | Roonwal & Chhotani 1962 |
| 15 | wet | Indomalayan | Termitidae | Termitinae | *Pseudocapritermes* | *tikadar* Roonwal & Chhotani | 1311 | India | Cherrapunji | 25.3000 | 91.7000 | Roonwal & Chhotani 1962 |
| 18 | cold | Nearctic | Archotermopsidae | | *Zootermopsis* | *angusticollis* Hagen | 1180 | Idaho | New Mead-ows | 44.9690 | -116.2840 | current paper |
| 19 | elev | Nearctic | Archotermopsidae | | *Zootermopsis* | *angusticollis* | 2124 | U.S., California | Sierra Nevada Mts. | 38.3000 | -119.8000 | Weesner 1965 |
| 17 | lat | Nearctic | Archotermopsidae | | *Zootermopsis* | *angusticollis* | 20 | Canada | Prince Rupert | 54.3000 | -130.3000 | Vickery & Kevan 1985 |
| 20 | elev | Nearctic | Archotermopsidae | | *Zootermopsis* | *laticeps* Banks | 2120 | U.S., Arizona | Rose Canyon Lake | 32.3900 | -110.7100 | Thorne et al. 1993 |
| 21 | elev | Nearctic | Kalotermitidae | | *Incisitermes* | *minor* (Hagen) | 1772 | U.S., Texas | Davis Mts. | 30.6960 | -104.0800 | current paper |
| 23 | elev | Nearctic | Kalotermitidae | | *Marginitermes* | *hubbardi* (Banks) | 1222 | U.S., Arizona | Pategonia | 31.5370 | -110.7590 | current paper |
| 22 | hot | Nearctic | Kalotermitidae | | *Marginitermes* | *hubbardi* | -50 | California | Imperial | 33.0451 | -115.5003 | current paper |
| 24 | hot | Nearctic | Rhinotermitidae | | *Gnathamitermes* | *perplexus* (Banks) | 209 | Arizona | Lake Havasu City | 34.5544 | -114.3578 | current paper |
| 24 | hot | Nearctic | Rhinotermitidae | | *Heterotermes* | *aureus* (Snyder) | 209 | Arizona | Lake Havasu City | 34.5544 | -114.3578 | current paper |
| 25 | elev | Nearctic | Rhinotermitidae | | *Reticuliteremes* | *tibialis* (Banks) | 2133 | U.S. Colorado | "northern" | 40.7000 | -105.0000 | Weesner 1965 |
| 26 | elev | Nearctic | Rhinotermitidae | | *Reticulitermes* | *flavipes* Kollar | 2134 | U.S., Arizona | Pinery Canyon Road | 31.9320 | -109.2710 | current paper |
| 27 | elev | Nearctic | Rhinotermitidae | | *Reticulitermes* | *hesperus* Banks | 1719 | U.S., California | San Bernardi-no Mts. | 34.2340 | -117.1870 | Banks and Snyder 1920 |
| 28 | cold | Nearctic | Rhinotermitidae | | *Reticulitermes* | sp. | 1200 | Canada | Churn Creek Park | 51.3000 | -122.3000 | Higgins pers. comm. |
| 29 | cold | Nearctic | Rhinotermitidae | | *Reticulitermes* | *tibialis* | 880 | N. Dakota | Amidon | 46.4800 | -103.3200 | Emerson 1936 |
| 26 | elev | Nearctic | Termitidae | Nasutitermitinae | *Tenuirostritermes* | *tenuirostris* (Desneux) | 1765 | U.S., Arizona | S Paradise | 31.8669 | -109.2168 | current paper |
| 21 | elev | Nearctic | Termitidae | Termitinae | *Amitermes* | *nr. californicus* Banks | 1727 | U.S., Texas | Davis Mts. | 30.7470 | -104.1620 | current paper |
| 21 | elev | Nearctic | Termitidae | Termitinae | *Gnathamitermes* | *nr. perplexus* | 1727 | U.S., Texas | Davis Mts. | 30.7470 | -104.1620 | current paper |

**Appendix**. Elevational, latitudinal, thermal and precipitational geographic limits for termites (Continuation).

| Map no. | Category | Region[1] | Family | Subfamily | Genus | Species | Meters | Country, Province | Locality | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | elev | Neotropical | Kalotermitidae | | *Comatermes* | *perfectus* Krishna | 1646 | Bolivia | Espia | -16.5000 | -67.3000 | Snyder 1926 |
| 31 | dry | Neotropical | Kalotermitidae | | *Cryptotermes* | *brevis* (Walker) | 49 | Chile | Caldera | -27.0695 | -70.8193 | Scheffrahn et al. 2009 |
| 32 | elev | Neotropical | Kalotermitidae | | *Cryptotermes* | *brevis* | 2600 | Colombia | Bogota (exotic) | 4.6000 | -74.1000 | Scheffrahn et al. 2009 |
| 33 | elev | Neotropical | Kalotermitidae | | *Glyptotermes* | *liberatus* (Snyder) | 1239 | Jamaica | Holleywell Park | 18.0860 | -76.7260 | current paper |
| 34 | elev | Neotropical | Kalotermitidae | | *Glyptotermes* | n. sp. | 1668 | Guatemala | Biotopo Quetzal | 15.2130 | -90.2170 | current paper |
| 35 | elev | Neotropical | Kalotermitidae | | *Incisitermes* | *marginipennis* (Latreille) | 1524 | Mexico | La Venta | 20.7000 | -103.4000 | Light 1933 |
| 37 | elev | Neotropical | Kalotermitidae | | *Incisitermes* | *nishimurai* Scheffrahn | 1658 | Honduras | P.N. La Tigre | 14.2200 | -87.0830 | Scheffrahn 2014 |
| 34 | elev | Neotropical | Kalotermitidae | | *Marginitermes* | *cactiphagus* Myles | 1653 | Guatemala | Matanzas | 15.1160 | -90.1750 | current paper |
| 38 | elev | Neotropical | Kalotermitidae | | *Neotermes* | n. sp. | 1831 | Venezuela | P.N. Yacambu | 9.7070 | -69.6510 | current paper |
| 39 | dry | Neotropical | Kalotermitidae | | *Neotermes* | *nr. chilensis* (Blanchard) | 36 | Peru | Chacra y Mar | -11.6080 | -77.2394 | current paper |
| 36 | elev | Neotropical | Kalotermitidae | | *Proneotermes* | *perezi* (Holmgren) | 1277 | Guatemala | E Cuilapa | 14.2540 | -90.1260 | current paper |
| 40 | elev lati | Neotropical | Kalotermitidae | | *Rugitermes* | *laticollis* Snyder | 2700 | Bolivia | Luribay | -17.0619 | -67.6608 | current paper |
| 41 | elev lati | Neotropical | Kalotermitidae | | *Rugitermes* | *laticollis* | 3600 | Bolivia | La Paz | -16.5000 | -68.2000 | Snyder 1957 |
| 42 | elev lati | Neotropical | Kalotermitidae | | *Rugitermes* | *laticollis* | 2800 | Ecuador | Quito | -0.1888 | -78.4856 | current paper |
| 37 | elev | Neotropical | Rhinotermitidae | | *Coptotermes* | *testaceus* (Linnaeus) | 1607 | Honduras | Zamorano | 14.0360 | -87.0750 | current paper |
| 36 | elev | Neotropical | Rhinotermitidae | | *Heterotermes* | *convexinotatus* (Snyder) | 1533 | Guatemala | W San Jeronimo | 15.0690 | -90.2680 | current paper |
| 37 | elev | Neotropical | Rhinotermitidae | | *Prorhinotermes* | *simplex* (Hagen) | 991 | Honduras | Amarateca | 14.2250 | -87.3770 | current paper |
| 43 | lat | Neotropical | Stolotermitidae | | *Porotermes* | *quadricollis* (Rambur) | 130 | Chile | Reg. Magdallena | -48.9000 | -73.9000 | Constantino 1998 |
| 35 | elev | Neotropical | Termitidae | Apicotermitinae | *Anoplotermes* | ca. *fumosus* | 1524 | Mexico | La Venta | 20.7000 | -103.4000 | Light 1933 |
| 34 | elev | Neotropical | Termitidae | Apicotermitinae | *Anoplotermes* | n. sp. | 1408 | Guatemala | Alta Verapaz | 15.5670 | -90.1430 | current paper |
| 44 | elev | Neotropical | Termitidae | Apicotermitinae | *Anoplotermes* | *turricola* Silvestri | 1920 | Bolivia | El Fortin | -18.1787 | -63.8214 | current paper |
| 38 | elev | Neotropical | Termitidae | Apicotermitinae | *Ruptitermes* | *silvestrii* (Emerson) | 1220 | Venezuela | Sanare area | 9.7901 | -69.6420 | current paper |
| 37 | elev | Neotropical | Termitidae | Nasutitermitinae | *Nasutitermes* | *corniger* (Motschulsky) | 1125 | Honduras | SE San Juancito | 14.2290 | -87.0501 | current paper |
| 34 | elev | Neotropical | Termitidae | Nasutitermitinae | *Nasutitermes* | *ephratae* (Holmgren) | 1408 | Guatemala | Alta Verapaz | 15.5670 | -90.1430 | current paper |
| 45 | elev | Neotropical | Termitidae | Nasutitermitinae | *Nasutitermes* | *guayanae* (Holmgren) | 1500 | Peru | San Pedro Cloud Forest | -13.0490 | -71.5370 | Palin et al. 2011 |

**Appendix**. Elevational, latitudinal, thermal and precipitational geographic limits for termites (Continuation).

| Map no. | Category | Region[1] | Family | Subfamily | Genus | Species | Meters | Country, Province | Locality | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | elev | Neotropical | Termitidae | Nasutitermitinae | *Nasutitermes* | *octopilis* Banks | 1500 | Peru | San Pedro Cloud Forest | -13.0490 | -71.5370 | Palin et al. 2011 |
| 44 | elev | Neotropical | Termitidae | Syntermitinae | *Procornitermes* | *lespesii* (Mueller) | 1402 | Bolivia | P. N. Los Vol-canes | -18.11968 | -63.60881 | current paper |
| 46 | dry | Neotropical | Termitidae | Termitinae | *Amitermes* | *lunae* Scheffrahn | 57 | Peru | Huaca de la Luna | -8.1350 | -78.9910 | Scheffrahn & Huchet 2010 |
| 36 | elev | Neotropical | Termitidae | Termitinae | *Microcerotermes* | *septentrionalis* Light | 1277 | Guatemala | E Cuilapa | 14.2540 | -90.1260 | current paper |
| 47 | lat | Neotropical | Termitidae | Termitinae | *Onkotermes* | *brevicorniger* (Sil-vestri) | 10 | Argentina | nr. Rawson | -43.3000 | -65.1000 | Constantino 1998 |
| 38 | elev | Neotropical | Termitidae | Termitinae | *Termes* | *fatalis* Linnaeus | 1220 | Venezuela | Sanare area | 9.7901 | -69.6420 | current paper |
| 48 | elev | Oceanian | Termitidae | Termitinae | *Pericapritermes* | *cf. schultzei* (Holmgren) | 1650 | Papua New Guinea | Eastern High-lands, Asirangka | -6.3000 | 145.9000 | Bourguignon et al. 2008 |
| 49 | elev | Palearctic | Hodotermitidae | | *Anacanthotermes* | *septentrionalis* | 2000 | Afghanistan | Jija | 33.7000 | 64.2000 | Weidner 1960 |
| 50 | hot | Palearctic | Rhinotermitidae | | *Psammotermes* | *hybostoma* | 670 | Libya | Ghat | 24.9600 | 10.1800 | Harris 1966 |
| 51 | lat | Palearctic | Rhinotermitidae | | *Reticulitermes* | *grassei* Clément | 85 | France | Charente | 46.0000 | -0.0200 | Austin 2002 |
| 52 | lat | Palearctic | Rhinotermitidae | | *Reticulitermes* | *speratus* (Kolbe) | 130 | Japan | Hokkaido | 45.0000 | 142.0000 | Mori et al. 2002 |
| 53 | elev | Palearctic | Termitidae | Termitinae | *Microcerotermes* | *gabrielis* Weidner | 1850 | Afghanistan | Golbagh (Kabul) | 34.4000 | 69.1000 | Weidner 1960 |

[1] as defined by Udvardy (1975).
[2] Cowie et al. report 3200 m (see text).
[3] Kunwari Pass (not Kauri Pass)" listed at 3900 m. This locality could not be confirmed (see text).
[4] coordinates of 34.22°S, 148.98°E given by Lacey et al. 2010 incorrect.