An Assessment of the Taxonomy of *Reticulitermes* (Isoptera: Rhinotermitidae) from the Southeastern United States Based on Cuticular Hydrocarbons

by

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ABSTRACT

Collections of *Reticulitermes* samples from disparate locations in 4 soil provinces in Georgia are identified to species by morphological characters of soldiers and alates. These species determinations are correlated with cuticular hydrocarbon phenotypes. The consensus of various students of the termites of North America is that there are 3 extant species in the southeastern United States: *Reticulitermes flavipes* (Kollar), *R. virginicus* Banks, and *R. hageni* Banks. We identified 11 distinct hydrocarbon phenotypes in *Reticulitermes* from Georgia. Termites that key to *R. flavipes* comprise 3 hydrocarbon phenotypes, *R. virginicus* is represented by only one hydrocarbon phenotype, and termites that we diagnose morphologically as *R. hageni* separate as one hydrocarbon phenotype. Specimens of unknown species of *Reticulitermes* comprise 6 separate hydrocarbon phenotypes. Two of these were identified as *R. hageni* based on the soldier key and as *R. virginicus* based on the alate key. The remaining 4 hydrocarbon phenotypes were interpreted as *R. hageni* because the soldier pronotum is less than 0.7mm in width. We have no alate specimens for these 4 hydrocarbon phenotypes. On the basis of cuticular hydrocarbons we suggest that there are 6 to 8 undescribed taxa of *Reticulitermes* in Georgia.

INTRODUCTION

In our studies of the behavior and foraging ecology of subterranean termites in the genus *Reticulitermes*, one of the first obstacles we encountered was an inability to unequivocally identify all of our "colonies" to species. We are studying *Reticulitermes* in wildland and residential sites in Georgia. According to the most recently accepted biogeographical information, only three species, *Reticulitermes flavi-*

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pes (Kollar), *R. virginicus* Banks, and *R. hageni* Banks are reported from Georgia or the southeastern United States (Nutting 1990, Weesner 1965, 1970). An additional species, *R. malletti* Clément, has been suggested on the basis of soldier defense secretions, but has not been fully described to date (Clément *et al.* 1985, 1986). In studies of soldier mandibles and labra, Hostettler *et al.* (1995) found a morph from Florida that they assigned to an unknown species of *Reticulitermes*, but no new species name was assigned.

Commonly used keys to alates and soldiers of *Reticulitermes* from the southeastern United States were not reliable for identifying our samples to species (Snyder 1954, Weesner 1965, Nutting 1990, Scheffrahn & Su 1994). Alates are found only seasonally and rarely in foraging groups, thus could not be used to determine species for every collection or colony we were studying. Some of our collections, from 3 soil provinces, have soldiers that are in the size range for *R. hageni* and produce alates of a dark color. In short, determination of species of *Reticulitermes* based on morphology (or geographic origin) of the sample is difficult and often equivocal.

The first comprehensive study of the taxonomy of the termites of North America was a revision of the Nearctic termites by Nathan Banks with notes on the biology and geographic distributions by Thomas E. Snyder (Banks & Snyder 1920). In this early monograph they recognize 3 species *R. flavipes*, *R. virginicus*, and *R. hageni* from the southeastern United States (essentially the states of Arkansas, Louisiana, West Virginia, Maryland, Kentucky, Virginia, Tennessee, North Carolina, Mississippi, Alabama, Georgia, South Carolina, Florida, and eastern/coastal Texas). Subsequent treatments of the taxonomy of *Reticulitermes* of this region, with lists of species and/or keys to the alates and soldiers, added no new taxa (Light 1934, Light & Pickens 1934, Snyder 1934, Emerson & Miller 1943, Banks 1946, Miller 1949, Snyder 1949, Weesner 1965, 1970, Nutting 1990, Scheffrahn & Su 1994). At the present time, we believe that the accepted taxonomy still reflects the early work of Banks & Snyder (1920) with no modern revisions to this taxonomic scheme.

Most of the studies of the taxonomy of *Reticulitermes* have been based on morphology of the alates and soldiers. We examined a completely different set of characters, cuticular hydrocarbons of workers, among *Reticulitermes* from the southeastern United States. Howard *et al.* (1978) first characterized the cuticular hydrocarbons of *R. flavipes* from portions of 4 colonies from southern Mississippi. The cuticular hydrocarbon mixture of *R. flavipes* was qualitatively different from that later characterized for 3 colonies of *R. virginicus* collected from the same general area (Howard *et al.* 1982). The cuticular hydrocarbon mixture of *R. hageni* has not been reported previously.

There is a growing body of evidence suggesting that termites have species specific mixtures of cuticular hydrocarbons (Brown *et al.* 1990, 1996a, b, Watson *et al.* 1989, Bagnères *et al.* 1990, 1991, Haverty *et al.* 1990b, 1991a,b, 1992, 1997, Howard & Blomquist 1982, Howard *et al.* 1988, Kaib *et al.* 1991). The cuticular hydrocarbons of the dampwood termites, *Zootermopsis*, are correlated with existing taxonomy based on morphology (Haverty *et al.* 1988). An additional, previously undescribed taxon, *Z. nevadensis nuttingi* Haverty & Thorne, was discovered in these studies and has been substantiated through studies of behavior, genetics, and biogeography (Haverty & Thorne 1989, Thorne & Haverty 1989, Thorne *et al.* 1993, Korman *et al.* 1991, Broughton 1995).

With this potentially powerful technique available, we decided to investigate some of the taxonomic problems in *Reticulitermes*. We report here a chemotaxonomic study of the cuticular hydrocarbons of *Reticulitermes* from the southeastern United States. Our primary goal is to make initial separations of groups based on these chemical characters then search for additional useful characters, such as morphology and soldier defense secretions, for future taxonomic studies.

METHODS

Samples of termites were collected from infested wood or from termite monitoring stations. Permanent field sites were established in each of 4 soil provinces in Georgia: Blairsville (Blue Ridge), Griffin and vicinity (Piedmont), Plains (Coastal Plain), and Sapelo Island (Atlantic Coastal Flatwoods). These sites and other serendipitous and directed collections provided the colonies used in this study (Table 1). Voucher specimens for each colony were placed in 70% ethanol and are maintained by the authors. For each collection morphological determinations of species were made using the key to soldiers in Scheffrahn & Su (1994) and/or the key to alates in Weesner (1965).

Cuticular hydrocarbon characterizations were completed without prior knowledge of the species determinations. Cuticular hydrocarbons were characterized by extracting groups of 100 to 200 workers that had been dried at 70°C for up to 6 hours (Haverty *et al.* 1996). Cuticular lipids were extracted by immersing termites in 10ml *n*-hexane (EM Science "OmniSolv," suitable for HPLC, GC, and residue analysis) for 10 minutes. The lipid extracts were pipetted through 4cm of activated BioSil-A (silica gel, BioRad Laboratories, 100-200 mesh) in Pasteur pipette mini-columns (5mm id) in order to isolate the hydrocarbon compo-

Table 1. Collection localities for *Reticulitermes* samples used to characterize cuticular hydrocarbon phenotypes from 4 soil provinces in Georgia, U.S.A.[a]

Colony[b]	Source[c]	Locality	County
Blue Ridge			
Clark	ms	Blairsville	Union
N GA 1[d]	wog	Mountain Branch Expt. Stn.	Union
N GA 2[d]	wog	Mountain Branch Expt. Stn.	Union
N GA 3[d]	wog	Mountain Branch Expt. Stn.	Union
N GA 4[d]	wog	Brasstown Bald	Union
N GA 5[d]	wog	Brasstown Bald	Union
N GA 6[d]	wog	Brasstown Bald	Union
N GA 7[d]	wog	Vogel State Park	Union
N GA 8[d]	wog	Vogel State Park	Union
N GA 9[d]	wog	Mountain Branch Expt. Stn.	Union
Peach 2	ms	Mountain Branch Expt. Stn.	Union
Piedmont			
2	wog	Westbrook Farm[e]	Spalding
8	wog	Westbrook Farm[e]	Spalding
18	wog	Westbrook Farm[e]	Spalding
21	wog	Westbrook Farm[e]	Spalding
24	wog	Westbrook Farm[e]	Spalding
25	wog	Westbrook Farm[e]	Spalding
28	wog	Westbrook Farm[e]	Spalding
29	wog	Westbrook Farm[e]	Spalding
31	wog	Westbrook Farm[e]	Spalding
34	wog	Westbrook Farm[e]	Spalding
35	wog	Westbrook Farm[e]	Spalding
38	wog	Westbrook Farm[e]	Spalding
40	wog	Westbrook Farm[e]	Spalding
42	wog	Westbrook Farm[e]	Spalding
43	wog	Westbrook Farm[e]	Spalding
56	wog	Westbrook Farm[e]	Spalding
60	wog	Westbrook Farm[e]	Spalding
63	wog	Westbrook Farm[e]	Spalding
85	wog	Westbrook Farm[e]	Spalding
87	wog	Westbrook Farm[e]	Spalding
93	wog	Westbrook Farm[e]	Spalding
94	wog	Westbrook Farm[e]	Spalding
95	wog	Westbrook Farm[e]	Spalding
97	wog	Westbrook Farm[e]	Spalding
101	wog	Westbrook Farm[e]	Spalding
Andy	ms	Barnesville	Lamar
Barn	ms	Barnesville	Lamar
Bledsoe W.S.	ms	Bledsoe Farm[e]	Pike
Chris 8	ms	Bledsoe Farm[e]	Pike
France 1	ms	Aldora	Lamar
France 2	ms	Aldora	Lamar
House 19/2	ms	Aldora	Lamar
House 26/1	ms	Aldora	Lamar

Table 1 (con't). Collection localities for *Reticulitermes* samples used to characterize cuticular hydrocarbon phenotypes from 4 soil provinces in Georgia, U.S.A.[a]

Colony[b]	Source[c]	Locality	County
Ryan 3	ms	Bledsoe Farm[e]	Pike
Stowe	ms	Barnesville	Lamar
Stowe 2	wog	Barnesville	Lamar
Tyler	ms	Barnesville	Lamar
Coastal Plain			
Hell Hole 7	ms	Plains	Sumter
Hell Hole 9	ms	Plains	Sumter
Plains 9	ms	Plains	Sumter
Plains 16	ms	Plains	Sumter
Mac 1	ms	Plains	Sumter
GA 1[d]	wog	Providence Canyon State Park	Stewart
GA 2[d]	wog	Providence Canyon State Park	Stewart
GA 3[d]	wog	Providence Canyon State Park	Stewart
GA 4[d]	wog	Plains	Sumter
GA 5[d]	wog	Plains	Sumter
GA 6[d]	wog	Plains	Sumter
GA 7[d]	wog	Plains	Sumter
Atlantic Coastal Flatwoods			
Bamboo 2	ms	Coastal Area Extension & Res. Ctr.	Chatham
Big House 1	ms	Sapelo Island	McIntosh
Big House 6	ms	Sapelo Island	McIntosh
Big House 9	ms	Sapelo Island	McIntosh
Big House 13	ms	Sapelo Island	McIntosh
Davis 1	ms	Sapelo Island	McIntosh
Davis 2	ms	Sapelo Island	McIntosh
Mary 3	ms	Sapelo Island	McIntosh
Nina 4	ms	Sapelo Island	McIntosh
Pine 6	ms	Sapelo Island	McIntosh
GA 8[d]	wog	Okefenokee Swamp State Park	Charleton
GA 9[d]	wog	Okefenokee Swamp State Park	Charleton
GA 10[d]	wog	Okefenokee Swamp State Park	Charleton

[a]Soil provinces are: Blue Ridge, Piedmont, Coastal Plain, and Atlantic Coastal Flatwoods.
[b]Each collection is from a discrete colony which is numbered or given a unique name or moniker.
[c]Termites were collected from a monitoring station (ms) or wood-on-ground (wog).
[d]These collections were made during trips by Forschler and Haverty to expand the geographic base of our survey.
[e]University of Georgia research farm.

nents. The resulting hydrocarbon extracts were evaporated to dryness under nitrogen and re-dissolved in 60µl of *n*-hexane for gas chromatography-mass spectrometry (GC-MS) analyses.

GC-MS analyses were performed on a Hewlett-Packard (HP) 5890 gas chromatograph equipped with a HP 5970B Mass Selective Detector interfaced with a HP Chemstation computer. The GC-MS was equipped

Table 2. Diagnostic ions for cuticular hydrocarbons found in *Reticulitermes* colonies collected from disparate sites in 4 soil provinces in Georgia, U.S.A.

Hydrocarbon[a]	Diagnostic Ions
n-C21	296
11-meC21	168/169
n-C22	310
2-meC22	281
C23:2	320
C23:1	322
n-C23	324
9-; 11-meC23	140/141, 224/225; 168/169, 196/197
7-meC23	112/113, 252/253
2-meC23	295
3-meC23	309
C24:1	336
n-C24	338
C24:2	334
11-; 12-meC24	168/169, 210/211; 182/183, 196/197
2-meC24	309
3-meC24	323
C25:2	348
C25:1	350
n-C25	352
9-; 11-; 13-meC25	140/141, 252/253; 168/169, 224/225; 196/197
5-meC25	84/85, 308/309
2-meC25	323
9,13-; 11,15-dimeC25	140/141, 196/197, 211, 267; 168/169, 239
3-meC25	337
C25:3	346
C26:2	362
C26:1	364
n-C26	366
5,9,15-trimeC25	84/85, 140/141, 155, 267, 281, 337
3,7-dimeC25	280/281, 127, 351
11-; 12-; 13-meC26	168/169, 238/239; 182/183, 224/225; 196/197,210/211
2-meC26	337
C27:3	374
C27:2	376
C27:1	378
C26:3	360
n-C27	380
11-; 13-meC27	168/169, 252/253; 196/197, 224/225
11,13-dimeC27	168/169, 224/225, 211, 267
5-meC27	84/85, 336/337
2-meC27	351
11,15-dimeC27	168/169, 196/197, 239, 267
3-meC27	365
C28:2	390
C28:1	392
n-C28	394
10-; 11-; 12-; 13-; 14-meC28	154/155, 280/281; 168/169, 266/267; 182/183,252/253; 196/197, 238/239; 210/211, 224/225
11,15-dimeC28	168/169, 210/211, 239, 281
C29:3	402
C29:2	404
C29:1	406
n-C29	408
C30:2	418
C30:1	420
11-; 13-; 15-meC29	168/169, 280/281; 196/197, 252/253; 224/225
13,15-dimeC29	196/197, 224/225, 239, 267
11,15-dimeC29	168/169, 224/225, 239, 295
3,7-dimeC29	336/337, 127, 407
11-; 14-; 15-meC30	168/169, 294/295; 210/211, 252/253; 224/225, 238/239
11,15-dimeC30	168/169, 238/239, 239, 309
C31:2	432
C31:1	434

Table 2 (continued). Diagnostic ions for cuticular hydrocarbons found in *Reticulitermes* colonies collected from disparate sites in 4 soil provinces in Georgia, U.S.A.

Hydrocarbon[a]	Diagnostic Ions
11-; 13-; 15-meC31	168/169,308/309;196/197,280/281;224/225,252/253
11,15-dimeC31	168/169, 252/253, 239, 323
C33:2	460
C33:1	462
11-; 12-; 13-; 14-; 15-meC32	168/169,322/323;182/183,308/309;196/197,294/295; 210/211,280/281;224/225,266/267
12,16-dimeC32	182/183,252/253,253,323
6,16-dimeC32	98/99, 252/253, 253, 407
11-; 13-; 15-; 17-meC33	168/169, 336/337; 196/197, 308/309; 224/225, 280/281; 252/253,;
11,13-dimeC33	168/169, 308/309, 211, 351
11,15-dimeC33	168/169, 280/281, 239, 351
7,11-dimeC33	112/113, 336/337, 183, 407
7,11,15-trimeC33	112/113, 280/281, 183, 253, 351, 421
11-; 12-; 13-; 14-meC34	168/169, 350/351; 182/183, 336/337; 196/197, 322/333; 210/211, 308/309
11,15-dimeC34	168/169, 294/295, 239, 365
C35:3	486
C35:2	488
C35:1	490
11-; 13-; 15-; 17-meC35	168/169, 364/365; 196/197, 336/337; 224/225, 308/309; 252/253, 280/281
11,15-; 13,17-dimeC35	168/169, 308/309, 239, 379; 196/197, 280/281, 267, 351
9,13-dimeC35	140/141, 336/337, 211, 407
7,11-dimeC35	112/113, 364/365, 183, 435
C36:2	502
5,17-dimeC35	84/85, 280/281, 267, 463
C37:4	512
C37:3	514
C37:2	516
C37:1	518
7,11,15-trimeC35	112/113, 308/309, 183, 253, 379, 449
5,9,17-trimeC35	84/85, 280/281, 155, 281, 407, 477
12-; 14-meC36	182/183, 364/365; 210/211, 336/337
11,15-; 12,16-dimeC36	168/169, 322/333, 239, 393; 182/183, 308/309, 253, 379
6,18-dimeC36	98/99, 280/281, 281, 463
5,17-dimeC36	84/85, 294/295, 267, 477
11-; 13-; 15-; 17-meC37	168/169, 392/393; 196/197, 364/365; 224/225, 336/337; 252/253, 308/309
11,15-; 13,17-dimeC37	168/169, 336/337, 239, 407; 196/197,308/309, 267, 379
7,x-dimeC37	112/113, 463
5,17-; 5,15-dimeC37	84/85, 308/309, 267, 491; 84/85, 336/337, 239, 491
5,9,17-trimeC37	84/85, 308/309, 155, 281, 435, 505
C39:4	540
C39:3	542
C39:2	544
12-; 13-; 14-meC38	182/183, 392/393; 196/197, 378/379; 210/211, 364/365
11,15-; 12,16-dimeC38	168/169, 350/351, 239, 421; 182/183, 336/337, 253, 407
6,18-;6,16-dimeC38	98/99,308/309,281,491;98/99,336/337,253,491
5,17-dimeC38	84/85,322/333,267,505
11-; 13-; 15-; 17-; 9-meC39	168/169,420/421;196/197,392/393;224/225,364/365; 252/253,336/337;280/281,308/309
11,15-; 13,17-dimeC39	168/169, 364/365, 239, 435; 196/197, 336/337, 267, 407
7,x-dimeC39	112/113,491
5,17-dimeC39	84/85,336/337,267,519
11-; 13-; 15-; 17-meC41	168/169,448/449;196/197,420/421;224/225,392/393;252/253,364/365
11,15-;13,17-dimeC41	168/169,392/393,239,464;196/197,364/365,267,435
5,17-dimeC41	84/85,364/365,267,547
11,15-; 13,17-dimeC43	168/169, 420/421, 239, 491
dimeC43 5, 17	84/85, 392/393, 267, 575

[a]Presented in order of elution.

with an HP-1, fused silica capillary column (30m x 0.2mm ID) and operated in split mode (with a split ratio of 8:1). A 3μl aliquot was injected into the GC/MS. Each mixture was analyzed using a temperature program from 200°C to 320°C at 3°C/minute with a final hold of 16 minutes. Electron impact (EI) mass spectra were obtained at 70eV. *n*-Alkanes were identified by their mass spectra. Mass spectra of methylalkanes were interpreted as described by Blomquist *et al.* (1987) to identify methyl branch locations. Alkenes were identified by their mass spectra. A typical mass spectrum of an alkene shows a molecular ion and a series of fragments at 14-mass unit intervals (e.g. 69, 83, and 97), similar to those displayed by *n*-alkanes, less 2 mass units. Interpretation of the mass spectra of dienes and polyunsaturated hydrocarbons was extrapolated from this pattern, i.e. for each double bond, the molecular ion is decreased by 2 mass units. Diagnostic ions for all hydrocarbons are presented in Table 2.

In the text and tables, we use shorthand nomenclature to identify hydrocarbons. This shorthand uses a descriptor for the location of methyl groups (X-me), the total number of carbons (CXX) in the molecule exclusive of methyl branches, and the number of double bonds follows a colon (CXX:Y). Thus *n*-pentacosane becomes *n*-C25; 13-methylheptacosane becomes 13-meC27; 5,17- dimethylheptacosane becomes 5,17-dimeC27; and heptacosadiene becomes C27:2. Double bond positions were not determined. Hydrocarbons are presented in the tables in the order of elution on our GC/MS system. Equivalent chain lengths (ECL) were calculated for all unsaturated components to facilitate separation of the various isomers.

Integration of the total ion chromatogram was performed by the data analysis software (HP59974J Rev. 3.1.2) in the HP Chemstation. GC-MS peak areas were converted to percentage of the total hydrocarbon fraction. These percentages for each hydrocarbon peak are represented in categories for trace or <0.3%, 0.3% to 1.0%, 1.0% to 3.0%, and >3.0%.

RESULTS

We identified 11 distinct cuticular hydrocarbon phenotypes from collections of *Reticulitermes* from the four soil provinces in Georgia (Tables 3-8; Figs. 1-11). Within each soil province we made collections from two or more locations (Table 1). Species determinations were made on all 73 colonies collected using the Scheffrahn & Su (1994) key to soldiers (Table 9). With this key we identified 32 colonies as *R. flavipes*, 20 colonies as *R. virginicus*, and 21 colonies as *R. hageni*. Alates were also collected from 24 colonies and were used to identify 12 *R. flavipes*, 8 *R. virginicus*, and 4 *R. hageni* colonies using Weesner's (1965) key. However, comparing the species determinations from colonies that contained both soldier and alate specimens, we found 3 colonies which contained alates identified as *R. virginicus* and soldiers identified as *R. hageni* (Table 9).

Specimens unequivocally keying to each of the 3 extant species were only collected in the Piedmont soil province (Tables 1 & 9). We have not yet collected specimens definitively identified as *R. virginicus* from the Blue Ridge soil province or as *R. hageni* from the Blue Ridge, Coastal Plain, or Atlantic Coastal Flatwoods soil provinces. We collected colonies identified as *R. hageni* based on soldier morphology from all soil provinces, but do not have alate specimens to confirm these diagnoses. Specimens of *Reticulitermes* with species determinations that differ based on soldier vs. alate diagnoses have been collected in the Blue Ridge, Piedmont, and Atlantic Coastal Flatwoods soil provinces.

We assigned letters to the various hydrocarbon phenotypes in the order that they were determined (A through J), thus a consecutive series of letters does not necessarily correspond to one recognized taxon. One phenotype, AB, was given a two-letter designation because it appeared to be intermediate between A and B. Specimens representing 3 hydrocarbon phenotypes (A, AB, and B) key to *R. flavipes*. Only phenotype C keys to *R. virginicus*. Phenotype D keys to *R. hageni* based on alates. Phenotypes E, F, G, H, I, and J key to *R. hageni* based on keys to soldiers. Alates and soldiers from two colonies of phenotype E and one colony of phenotype F contained alates that key to *R. virginicus* and soldiers that key to *R. hageni*.

Cuticular Hydrocarbons of *Reticulitermes* from Georgia

Hydrocarbon classes observed include normal alkanes, olefins (alkenes, alkadienes, alkatrienes, alkatetraenes), and mono-, di-, and trimethylalkanes. Normal alkanes occur in all phenotypes; *n*-C23 and *n*-C25 are the most abundant (Table 3). The diversity of the olefin components was extreme. Numerous, separable isomers of the alkenes, alkadienes, and alkatrienes were found among the 10 of the 11 phenotypes. For example, C27:2, C29:2, and C31:2 each have six distinct isomers, and C25:3 and C27:3 each have 4 distinct isomers (Table 4). We did not locate the positions of the double bonds for any of these olefins nor did we observe spectra (Table 2) that would indicate branched alkenes as reported for *Drepanotermes* (Brown *et al.* 1996a). No particular olefin appeared to be ubiquitous in the 10 phenotypes with an olefin component.

Terminally branched monomethylalkanes were common with 2-meC24 and 3-meC25 being abundant in all samples (Table 5). These monomethylalkanes often co-elute with olefins. Internally branched monomethylalkanes were found in all phenotypes; in a few of these

Table 3. Normal alkanes found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]										
Hydrocarbon[a]	A	AB	B	C	D	E	F	G	H	I	J
n-C21				tr			+	tr			
n-C22			tr	tr	tr	tr	tr	tr	tr	tr	
n-C23	++	++	+++	+++	++	+++	+++	+++	+++	+++	tr
n-C24	++	++	++	++	+	+	+	+	+	+	+
n-C25	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
n-C26				tr	+	+	tr	+	+	+	tr
n-C27	tr	tr	tr	tr	+	++	tr	++	++	++	tr
n-C28				tr				tr	tr		
n-C29						tr		tr	+	+	

[a]Presented in order of elution.
[b]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

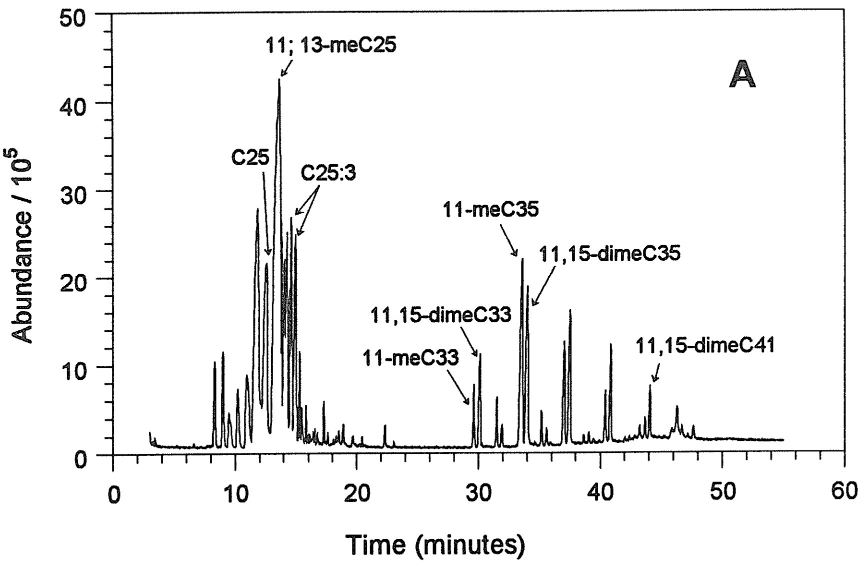

Fig. 1. Total ion chromatogram of cuticular hydrocarbons from Phenotype A specimens from Westbrook Farm, Spalding County, Georgia, identified as *Reticulitermes flavipes* from soldiers and alates.

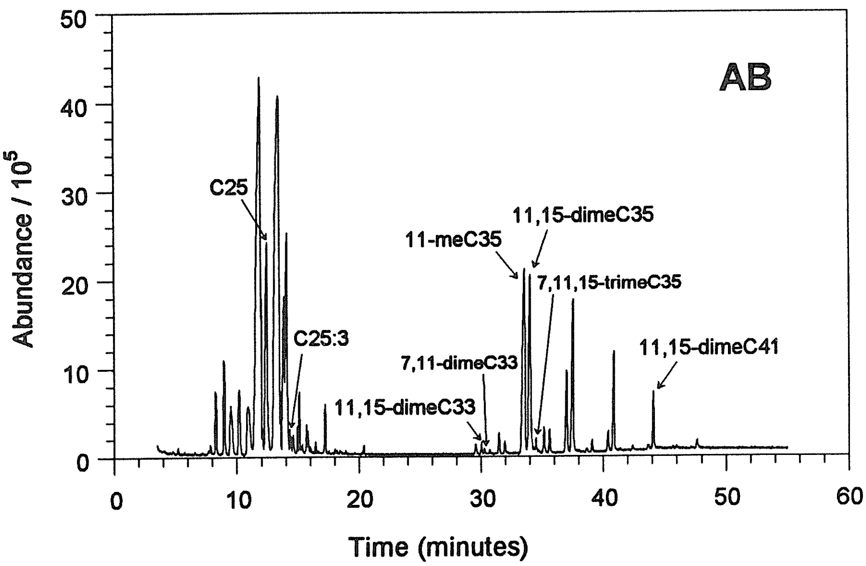

Fig. 2. Total ion chromatogram of cuticular hydrocarbons from Phenotype AB specimens from Sapelo Island, McIntosh County, Georgia, identified as *Reticulitermes flavipes* from soldiers and alates.

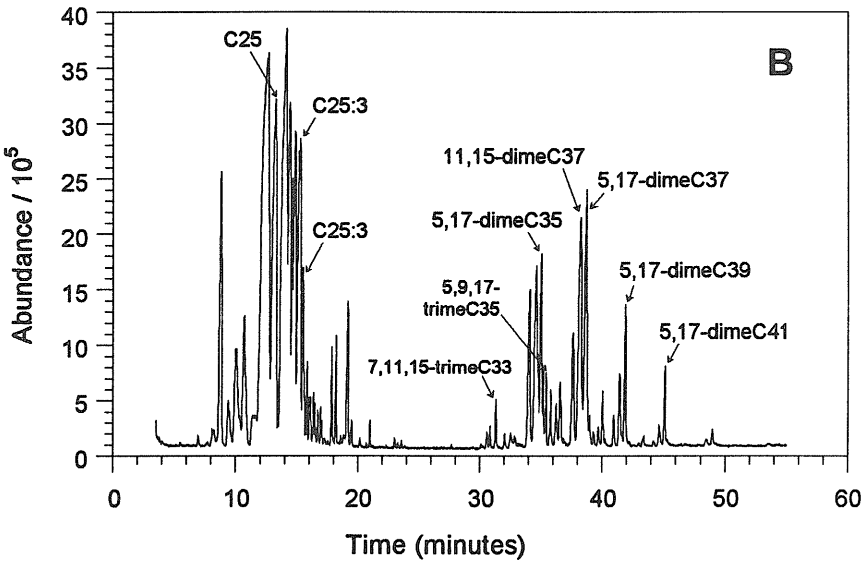

Fig. 3. Total ion chromatogram of cuticular hydrocarbons from Phenotype B specimens from Westbrook Farm, Spalding County, Georgia, identified as *Reticulitermes flavipes* from soldiers and alates.

phenotypes these alkanes were the most abundant compounds (Figs. 1, 4, & 11). Internally branched monomethylalkanes with 29 or more carbons in the parent chain are often paired with an internally branched dimethylalkane of the same parent chain length and occur as a homologous series (Tables 6 & 7; Figures 1, 2, 3, 4, & 11).

Dimethylalkanes were abundant in phenotypes A, AB, B, C, and J (Table 7). The great majority of the dimethylalkanes are internally branched with 3 methylene units between methyl branches, although 5,17-dimethylalkanes were abundant or consistently present in phenotypes B and E. Trimethylalkanes were rare and found in small quantities (< 1.0% of the total hydrocarbon) only in phenotypes AB and B.

Reticulitermes flavipes

Hydrocarbon phenotypes A and B are separable primarily by the presence of 5,17-dimethylalkanes (C35-C43), and several trimethylalkanes, in phenotype B. These hydrocarbons are completely absent in phenotype A, whereas phenotype A has much greater amounts of 11-meC33 and 11,15-dimeC33 than phenotype B(Tables 6-8; Figs. 1 and 3). Phenotype AB is somewhat intermediate (Fig. 2). It appears closer to phenotype A in that there are no 5,17-dimethylalkanes or 5,9,17-trimethylalkanes, but it does produce 7,11-dimethylalkanes

Table 4. Olefins found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

		Reticulitermes Hydrocarbon Phenotype[c]										
Hydrocarbon[a]	ECL[b]	A	AB	B	C	D	E	F	G	H	I	J
Monoenes												
C23:1	22.70		tr	tr	tr							
C24:1	23.70			+								
C25:1	24.70	+++	+++	+++	++	++	+		tr	++	+	
C25:1	24.80										+	
C26:1	25.70						tr				+	
C27:1	26.30	+		+								
C27:1	26.70		+	+		+++	+++	+	++	+++		
C27:1	26.85									+	+++	
C28:1	27.70						++	tr			++	
C29:1	28.80						+++	++	tr	+++	+++	
C30:1	29.70						+					
C31:1	30.30						+					
C31:1	30.70						+			tr	+	
C33:1	32.50									tr	+	
C33:1	32.70						tr					
C35:1	34.50					tr					tr	
C35:1	34.70					tr	++					
C37:1	36.70					tr	++					
Dienes												
C23:2	22.60				+							
C23:2	23.01							+				
C23:2	23.30			tr								
C24:2	24.30			tr								
C25:2	24.75		++		+							
C25:2	25.01							++				
C25:2	25.40		++	+++	++							
C25:2	25.60	++	tr	++	tr							
C26:2	25.75					tr			tr	+		
C26:2	26.01							++				

Table 4 (continued). Olefins found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

		Reticulitermes Hydrocarbon Phenotype[c]										
Hydrocarbon[a]	ECL b	A	AB	B	C	D	E	F	G	H	I	J
C26:2	26.30		tr	+								
C27:2	26.75		+		tr	+++			+++	+++		
C27:2	27.00							+++				
C27:2	27.10								+			
C27:2	27.20							+	tr	+++		
C27:2	27.40			++				+				
C27:2	27.50									tr		
C28:2	27.60			++		tr			++	+		
C28:2	27.75								+			
C28:2	28.01							+				
C28:2	28.30							tr				
C29:2	28.40						+++			+	+++	
C29:2	28.50						+++				+++	
C29:2	28.75					tr			+++	+++		
C29:2	29.01							+++				
C29:2	29.17									tr		
C29:2	29.27							+++				
C30:2	29.40						tr				tr	
C30:2	29.70									tr		
C30:2	30.01							tr				
C31:2	30.26						tr					
C31:2	30.40						++				++	
C31:2	30.50									tr	++	
C31:2	30.60										tr	
C31:2	30.75									+		
C31:2	31.01							++				
C33:2	32.40							tr		+	+++	
C35:2	34.40									+	++	
C35:2	34.60					+						

Table 4 (continued). Olefins found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

Hydrocarbon[a]	ECL[b]	*Reticulitermes* Hydrocarbon Phenotype[c] A	AB	B	C	D	E	F	G	H	I	J
C36:2	35.75					tr						
C37:2	36.40					+++	+++					
C39:2	38.50						+					
Trienes												
C25:3	25.98	+++	tr									
C25:3	26.07		tr	+++	tr							
C25:3	26.19	+++		+++								
C27:3	26.28					++						
C25:3	26.47	+	tr	+								
C26:3	26.81			+								
C26:3	27.15	tr										
C27:3	28.03	tr		++								
C27:3	28.24	tr		++								
C29:3	28.31					+				++		
C29:3	28.42									+		
C27:3	28.54			tr								
C31:3	30.36									++		
C31:3	30.44									+		
C33:3	32.32										tr	
C33:3	32.40									+		
C35:3	34.30										tr	
C35:3	34.40										+	
C35:3	34.63					tr						
C37:3	36.38					+++						
C39:3	38.25					++						
Tetraenes												
C37:4	35.90					+						
C39:4	37.90					+						

[a]Presented in order of elution within olefin class.
[b]Equivalent chain length (approximate).
[c]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

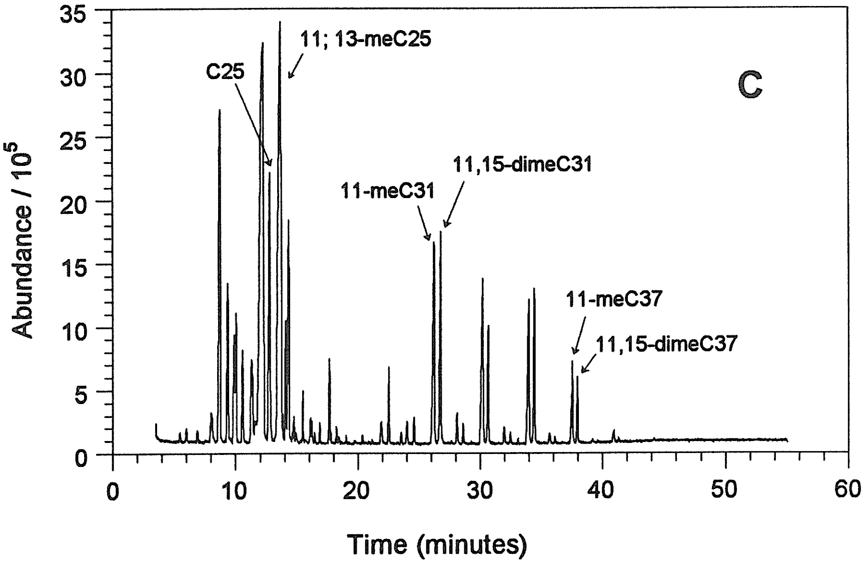

Fig. 4. Total ion chromatogram of cuticular hydrocarbons from Phenotype C specimens from Westbrook Farm, Spalding County, Georgia, identified as *Reticulitermes virginicus* from soldiers and alates.

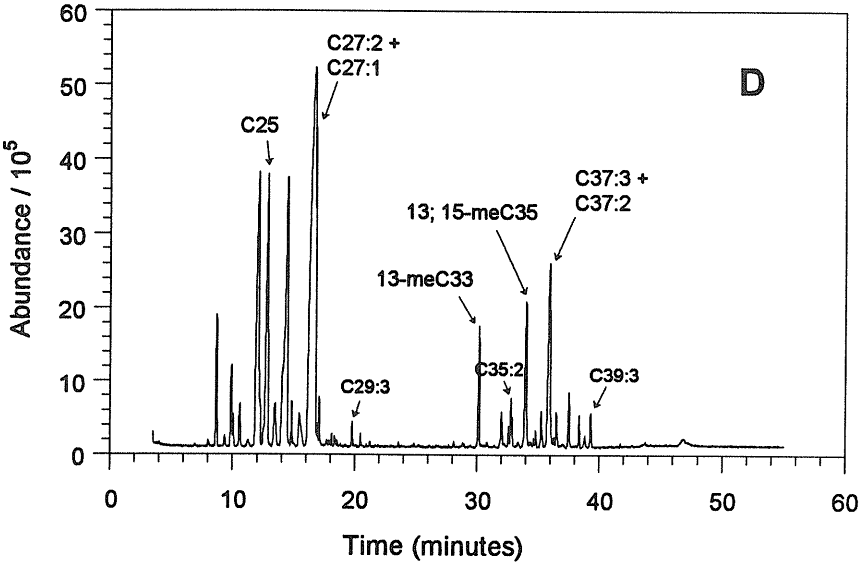

Fig. 5. Total ion chromatogram of cuticular hydrocarbons from Phenotype D specimens from Aldora, Lamar County, Georgia, identified as *Reticulitermes hageni* from soldiers and alates.

Table 5. Terminally branched monomethyl alkanes found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]										
Hydrocarbon[a]	A	AB	B	C	D	E	F	G	H	I	J
2-meC22			tr	+	tr		tr	tr		tr	
2-meC23	+	+	++	++	++	+	+	+	++	++	tr
3-meC23	+	+	++	++	+	tr	+	+	++	++	tr
2-meC24	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
3-meC24		tr	tr	tr	+					+	tr
5-meC25			+								+
2-meC25	+++	+++	+++	++	++	+	+	++	+	++	++
3-meC25	+++	+++	+++	+++	+++	++	++	++	+++	++	+++
2-meC26	+	+	+	tr			++				+
5-meC27					tr						tr
2-meC27							tr				
3-meC27	tr			tr	tr		tr		tr		

[a]Presented in order of elution.
[b]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

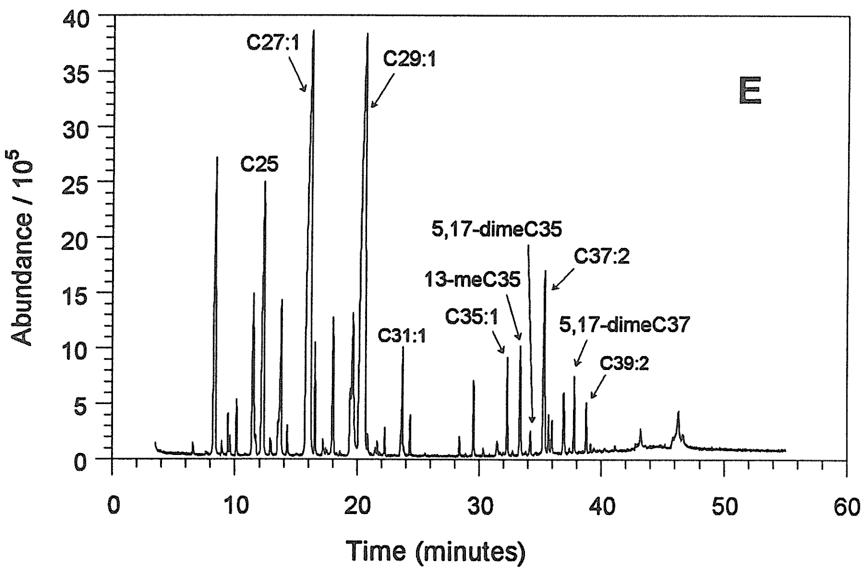

Fig. 6. Total ion chromatogram of cuticular hydrocarbons from Phenotype E specimens from Plains, Sumter County, Georgia, identified as *Reticulitermes hageni* from soldiers and as *R. virginicus* from alates.

and 7,11,15-trimethylalkanes, and very little 11-meC33 and 11,15-dimeC33, similar to phenotype B. The major difference between phenotypes A and B with phenotype AB is the presence of abundant quantities of C25:3 in phenotypes A and B and its virtual absence in phenotype AB (Table 4; Figs. 1-3).

Reticulitermes virginicus

Twenty samples from three of the four soil provinces sampled key to *R. virginicus* on the basis of soldiers. All of these samples correspond to hydrocarbon phenotype C. This phenotype is the only one to have 11-meC31 and 11,15-dimeC31 in great quantities (Tables 6 and 7; Fig. 4). These hydrocarbons are part of a homologous series of 11-methyl- and 11,15-dimethylalkanes (C25-C37). Most of the phenotypes that have this homologous series of mono- and dimethylalkane make hydrocarbons with a longer parent chain (C33-41)(Figs. 1, 2, 3, and 11). No 5-methylalkanes, 5,17-dimethylalkanes or trimethylalkanes were detected (Tables 5, 7, & 8).

Reticulitermes hageni

Phenotypes D, E, F, G, H, I, and J all key to *R. hageni* based on soldiers (Table 9). Only collections of hydrocarbon phenotype D had alates that key to *R. hageni*. Samples from colonies with hydrocarbon

Table 6. Internally branched monomethylalkanes found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]										
Hydrocarbon[a]	A	AB	B	C	D	E	F	G	H	I	J
11-meC21				tr							
9-; 11-meC23	++	++	+	++	tr	tr	tr	tr	tr	tr	+
7-meC23			tr								
11-; 12-meC24	++	++	+	++							++
9-; 11- 13-meC25	+++	+++	+++	+++	++	+	+	+	+	+	+++
11-; 12-; 13-meC26	++	+		+			+				+++
11-; 13-meC27	+			++	tr	+	+++	++	+	++	+++
10-; 11-; 12-; 13-;14-meC28				tr			tr	tr			+
11-; 13-; 15-meC29				+				++	++	++	tr
11-; 14-; 15-meC30				+							
11-; 13-; 15-meC31				+++					+	+	
11-; 12-; 13-; 14-;15-meC32				+							
11-; 13-; 15-; 17-meC33	++	tr		+++	++	++	+	tr	++	++	
11-; 12-; 13-; 14-meC34	+	+	tr	+	+						
11-; 13-; 15-; 17-meC35	+++	+++	++	+++	+++	++	++	++	++	++	tr
12-; 14-meC36	+	+	+	tr							tr
11-; 13-; 15-; 17-meC37	++	++	++	++	+	++	tr	+	+	+	+++
12-; 13-; 14-meC38	tr		tr								+
11-; 13-; 15-; 17-;19-meC39	+	+	+	tr			+	+			++
11-; 13-; 15-; 17-meC40											tr
11-;13-; 15-; 17-meC41	+							tr			++

[a]Presented in order of elution.
[b]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

Table 7. Dimethylalkanes found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]										
Hydrocarbon[a]	A	AB	B	C	D	E	F	G	H	I	J
9,13-; 11,15-dimeC25	++	tr	tr	++							++
5,15-dimeC25											tr
3,7-dimeC25				tr							tr
11,13-; 12,14-dimeC26											tr
11,15-dimeC26											+
11,13-dimeC27				tr							
11,15-; 11,17-dimeC27				tr			tr				+++
5,17-dimeC27											+
11,15-dimeC28				tr							
13,15-dimeC29				tr							
11,15-dimeC29				++							
3,7-dimeC29				tr							
11,15-dimeC30				+							
11,15-dimeC31				+++							
12,16-dimeC32				+							
11,13-dimeC33				tr							
11,15-dimeC33	++	tr	tr	++							
7,11-dimeC33		tr	tr								
11,15-dimeC34	tr	tr	tr	tr							
11,13-dimeC35									+	+	
11,15-; 13,17-dimeC35	++	+++	+++	++			tr	+	+	+	
9,13-dimeC35			+								
7,11-dimeC35		+	+								
5,17-dimeC35			+++		tr	+					
11,15-; 12,16-dimeC36	tr	+	+	tr							
6,18-dimeC36			+								
5,17-dimeC36			+								
11,15-; 13,17-dimeC37	+++	+++	+++	+			+	+	++	++	+++

Table 7 (continued). Dimethylalkanes found in the cuticular hydrocarbons of each of 11 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]										
Hydrocarbon[a]	A	AB	B	C	D	E	F	G	H	I	J
7,X-dimeC37			tr								tr
5,17-; 5,15-dimeC37			+++			+	++				
11,15-; 12,16-dimeC38	tr	tr	tr								+
6,18-; 6,16-dimeC38			+								
5,17-dimeC38			tr								
11,15-; 13,17-dimeC39	++	++	+	tr			++	++			+++
7,X-dimeC39			tr								
5,17-dimeC39			++								+
12,16-; 14,18-dimeC40											+
15,17-dimeC41											++
11,15-; 13,17-dimeC41	++	++	tr				++	++			++
5,17-dimeC41			++								
11,15-; 13,17-;15,19-dimeC43							+				+
5,17-dimeC43				tr							

[a]Presented in order of elution.

[b]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

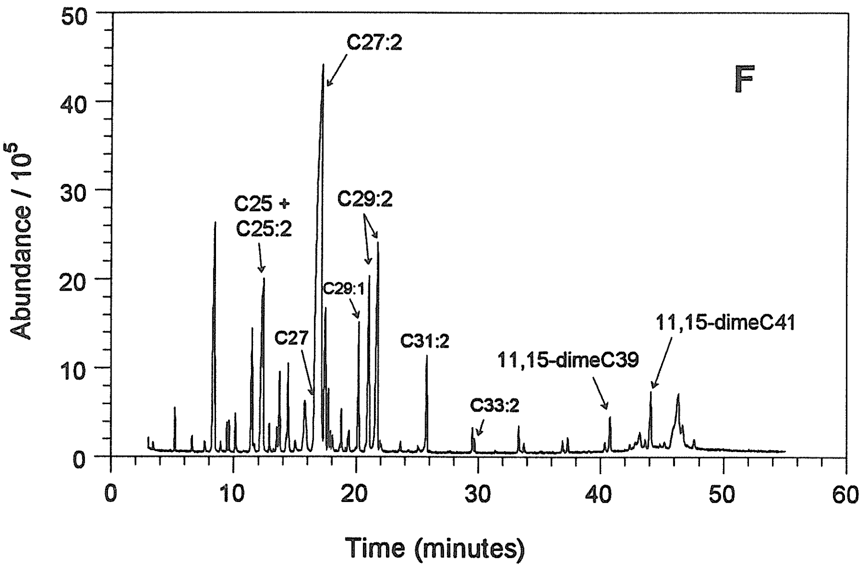

Fig. 7. Total ion chromatogram of cuticular hydrocarbons from Phenotype F specimens from Sapelo Island, McIntosh County, Georgia, identified *Reticulitermes hageni* from soldiers and as *R. virginicus* from alates.

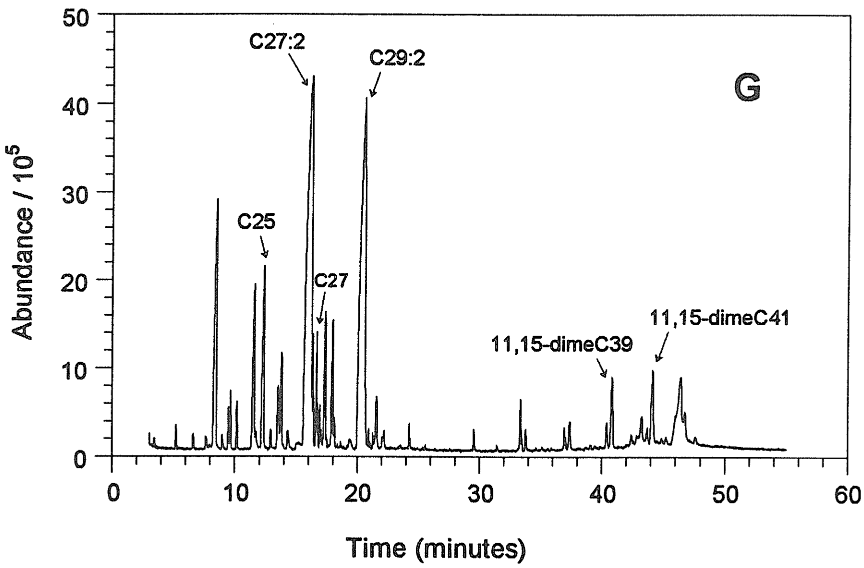

Fig. 8. Total ion chromatogram of cuticular hydrocarbons from Phenotype G specimens from Sapelo Island, McIntosh County, Georgia, identified as *Reticulitermes hageni* from soldiers.

phenotypes E and F contain alates that key to *R. virginicus* and very likely represent different taxa. The samples that comprise hydrocarbon phenotypes G, H, I, and J did not have alate specimens to allow us to state, without reservation, that they are or are not *R. hageni*.

All of these hydrocarbon phenotypes, except phenotype J, have an abundance of unsaturated compounds. In phenotype D, singleisomers of C27:2, C27:1, C37:3, and C37:2 are predominant with minor amounts of other olefins (Table 4; Fig. 5). In phenotypes E and I, C27:1 and C29:1 comprise the predominant hydrocarbons with no detectable C27:2 (Figs. 6 & 10). However, other significant differences can be found to separate phenotypes E and I. The late-eluting dimethylalkanes are 5,17-dimeC35 and 5,17-dimeC37 in phenotype E, whereas 11,15-dimeC35 and 11,15-dimeC37 are found in phenotype I (Table 7; Figs. 6 & 10). The abundant late-eluting olefins are C35:1, C37:2, and C39:2 in phenotype E, whereas C33:2 and C35:2 are the abundant olefins in phenotype I (Table 4; Figs. 6 & 10).

Phenotypes F and G both have abundant quantities of C27:2, but their relative elution times (ECL=27.00 and 26.75, respectively) indicate that these are different isomers of the same diene (Table 4; Figs 7 & 8). These phenotypes also have abundant amounts of C29:2, but again their relative elution times (ECLs of 29.01 and 29.27 for F and 28.75 for G) would indicate that these are different isomers of the same diene (Table 4). Phenotype F has several dienes (C23:2, C25:2, and C26:2) that co-elute with *n*-alkanes of the same carbon number (Table 4) as well as later-eluting dienes not found in phenotype G. The late-eluting homologous series of mono- and dimethylalkanes from C35 to C41 are the same for phenotypes F and G (Tables 6 & 7; Figs. 7 & 8). Phenotype H has abundant quantities of C27:2 (two isomers), C29:2, and several other olefins (Table 4; Fig. 9), but lacks the homologous series of mono- and dimethylalkanes from C39-41 present in phenotypes F and G (Tables 6 & 7; Figs. 7, 8, & 9).

The most unique of all of the hydrocarbon phenotypes of *Reticulitermes* from Georgia is phenotype J. This is the only hydrocarbon phenotype that has no unsaturated compounds in its hydrocarbon mixture (Table 4; Fig. 11). The predominant early eluting compounds are internally branched monomethylalkanes; the late-eluting hydrocarbons are a homologous series of internally branched mono- and dimethylalkanes (Fig. 11). Internally branched dimethylalkanes with one methylene unit separating the methyl branches co-elute with the monomethylalkanes at C25, C26, C27, C39, and C41 (Table 7; Fig. 11).

Table 8. Trimethylalkanes found in the cuticular hydrocarbons of 6 hydrocarbon phenotypes of *Reticulitermes* collected in Georgia, U.S.A.

	Reticulitermes Hydrocarbon Phenotype[b]			
Hydrocarbon[a]	A	AB	B	C-J
5,9,15-trimeC25			+	
7,11,15-trimeC33			tr	
7,11,15-trimeC35		tr	+	
5,9,17-trimeC35			+	
5,9,17-trimeC37			tr	

[a]Presented in order of elution.
[b]+++ = > 3%, ++ = 1 to 3%, + = 0.3 to 1.0% of total hydrocarbon. tr = trace.

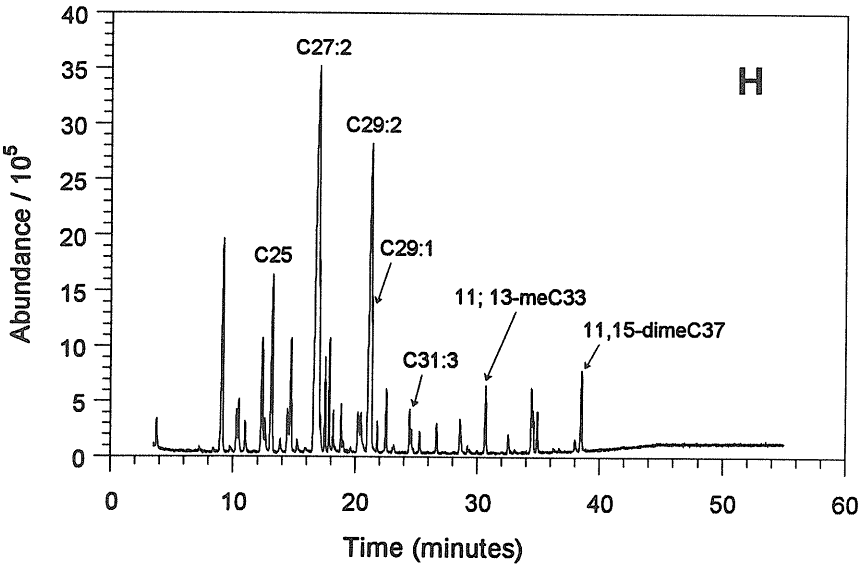

Fig. 9. Total ion chromatogram of cuticular hydrocarbons from Phenotype H specimens from Plains, Sumter County, Georgia, identified as *Reticulitermes hageni* from soldiers.

DISCUSSION

Early characterizations of the cuticular hydrocarbons of *R. flavipes* by Howard *et al.* (1978) and Bagnères *et al.* (1990) did not include identification of components that would elute after *n*-C26. These late-eluting compounds were probably missed, at least in the case of Howard *et al.* (1978), because they used packed columns, rather than capillary columns which provide superior sensitivity and resolution of cuticular hydrocarbons. Haverty *et al.* (1991a) characterized *R. flavipes* from

Table 9. Species diagnoses and cuticular hydrocarbon phenotypes for colonies of *Reticulitermes* collected in Georgia, U.S.A.

Colony	Species	Determination[a]	Hydrocarbon Phenotype
Bamboo 2	*R. flavipes*		A
Bledsoe W.S.	*R. flavipes*		A
Chris 8	*R. flavipes*	alate	A
Clark	*R. flavipes*	alate	A
France 2	*R. flavipes*	alate	A
Hell Hole 9	*R. flavipes*		A
Peach 2	*R. flavipes*		A
Plains 9	*R. flavipes*		A
Stowe	*R. flavipes*		A
Tyler	*R. flavipes*		A
GA 5	*R. flavipes*		A
GA 6	*R. flavipes*		A
N GA 1	*R. flavipes*		A
N GA 2	*R. flavipes*		A
N GA 3	*R. flavipes*		A
N GA 4	*R. flavipes*		A
N GA 6	*R. flavipes*		A
N GA 7	*R. flavipes*	alate	A
N GA 8	*R. flavipes*		A
24	*R. flavipes*	alate	A
25	*R. flavipes*		A
42	*R. flavipes*		A
43	*R. flavipes*	alate	A
56	*R. flavipes*	alate	A
101	*R. flavipes*	alate	A
GA 1	*R. flavipes*		B
2	*R. flavipes*	alate	B
28	*R. flavipes*		B
31	*R. flavipes*		B
35	*R. flavipes*	alate	B
Big House 1	*R. flavipes*	alate	AB
Stowe 2	*R. flavipes*	alate	AB
Big House 13	*R. virginicus*	alate	C
Mac 1	*R. virginicus*		C
Nina 4	*R. virginicus*		C
GA 2	*R. virginicus*		C
GA 3	*R. virginicus*		C
GA 8	*R. virginicus*		C
GA 9	*R. virginicus*		C
GA 10	*R. virginicus*		C
8	*R. virginicus*		C
18	*R. virginicus*		C
21	*R. virginicus*		C
29	*R. virginicus*		C
34	*R. virginicus*		C
38	*R. virginicus*		C

Table 9 (continued). Species diagnoses and cuticular hydrocarbon phenotypes for colonies of *Reticulitermes* collected in Georgia, U.S.A.

Colony	Species	Determination[a]	Hydrocarbon Phenotype
40	*R. virginicus*		C
85	*R. virginicus*		C
93	*R. virginicus*	alate	C
94	*R. virginicus*	alate	C
95	*R. virginicus*	alate	C
97	*R. virginicus*	alate	C
Andy	*R. hageni*	alate	D
Barn	*R. hageni*	alate	D
France 1	*R. hageni*	alate	D
House 19/2	*R. hageni*	alate	D
House 26/1	*R. hageni*		D
Ryan 3	*R. hageni*		E
GA 7	Unknown	soldier/alate	E
N GA 5	*R. hageni*		E
N GA 9	Unknown	soldier/alate	E
60	*R. hageni*		E
63	*R. hageni*		E
87	*R. hageni*		E
Big House 6	*R. hageni*		F
Big House 9	*R. hageni*		F
Mary 3	Unknown	soldier/alate	F
Pine 6	*R. hageni*		G
GA 4	*R. hageni*		G
Hell Hole 7	*R. hageni*		H
Plains 16	*R. hageni*		I
Davis 1	*R. hageni*		J
Davis 2	*R. hageni*		J

[a]All colonies were identified with a morphological key for soldiers (Scheffrahn and Su 1994). If alates were available, species identification was confirmed with a morphological key for alates (Weesner 1965). These colonies are so noted. Colonies diagnosed as unknown keyed to *R. hageni* based on soldier morphology and *R. virginicus* based on alate morphology and are marked as soldier/alate.

locations in Massachusetts, Florida, and Mississippi. They found hydrocarbons ranging from *n*-C23 to 5,17-dimeC41. By re-examining the data presented in Table 6 of Haverty *et al.* (1991a) it appears that they may have reported hydrocarbon mixtures from what we now consider to be two separate phenotypes, AB and B. Only one of their samples, LSU2 from Mississippi, had measurable quantities of 7,17- and 5,17-dimethylalkanes which are characteristic of phenotype B. The other samples from Massachusetts and Florida more closely resembled phenotype AB because they lacked the trienes common to phenotypes A and B, and they did not have any 5,17-dimethylalkanes. However, the

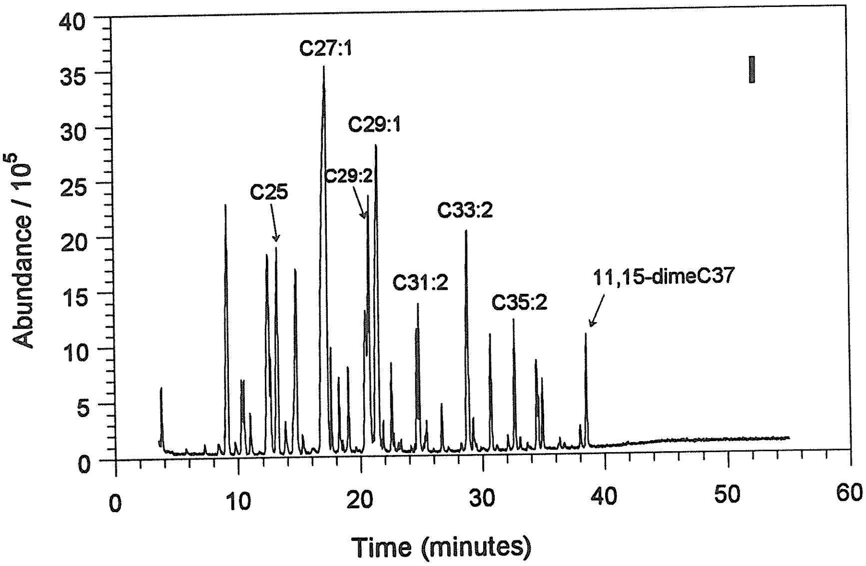

Fig. 10. Total ion chromatogram of cuticular hydrocarbons from Phenotype I specimens from Plains, Sumter County, Georgia, identified as *Reticulitermes hageni* from soldiers.

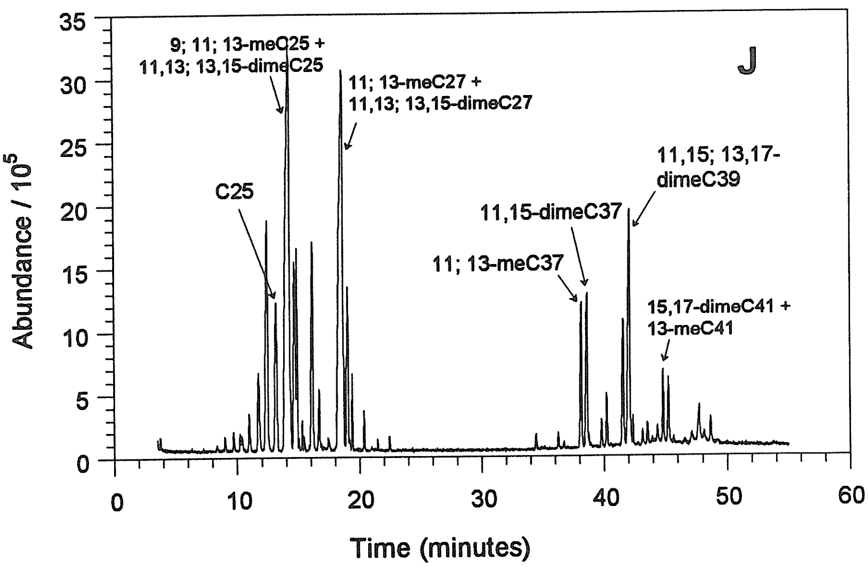

Fig. 11. Total ion chromatogram of cuticular hydrocarbons from Phenotype J specimens from Sapelo Island, McIntosh County, Georgia, identified as *Reticulitermes hageni* from soldiers.

7,11-dimethylalkanes and 7,11,15-trimeC35 seen in phenotype AB were not detected in these samples.

The Mississippi sample of *R. flavipes* reported in Haverty *et al.* (1991a) lacks the two isomers of C25:3 which are characteristic of phenotype B. After examining sample records, we found that this sample was a combination of three extracts previously characterized with a flame ionization detector, not an extract of dried or fresh specimens. Olefins within the cuticleof frozen or dried specimens do not degrade and remain stable fordecades (Page*et al.* 1990). However, once extracted the olefins in the extract, particularly those with more than two double bonds, quickly degrade if the solvent evaporates and are no longer identifiable after only a few days. Hydrocarbons from allsamples of *Reticulitermes* used in our present study were characterized within 8 hours of extraction.

The results of this present study indicate two possibilities to account for the three distinct hydrocarbon phenotypes among specimens that key to *R. flavipes*. Phenotypes A, AB, and B could be chemical variants of one species or they could represent separate, related taxa (races, subspecies, or species).

The cuticular hydrocarbon mixtures reported for samples of *R. virginicus* appear to be quite consistent among the studies of Howard *et al.* (1982), Haverty *et al.* (1991a), and the present study. This is especially convincing because of the geographic range of specimens examined in these studies (from Louisiana, Mississippi, and Georgia). Although Howard *et al.* (1982) did not quantify individual hydrocarbons, all studies appear to agree on the hydrocarbons present except for a few that we recently found in relatively low quantities. The minor differences could very well just be due to sample concentration and degradation of the trienes in the combined extract reported in Haverty *et al.* (1991a). On this basis, we conclude that *R. virginicus* is represented by a single hydrocarbon phenotype with little qualitative or quantitative variation.

The cuticular hydrocarbon mixture of *R. hageni* was not previously reported in the literature. We have only one hydrocarbon phenotype that keys as *R. hageni* based on soldiers and alates, yet have 6 that key to *R. hageni* based on soldiers alone. Preliminary investigations of soldier defense secretions (unpublished data) and alate characteristics (hydrocarbon phenotypes D and F) indicate that these hydrocarbon phenotypes are indeed different and probably represent 7 distinct taxa. Phenotypes F and J were only collected from Sapelo Island, Georgia, and phenotypes H and I only from the Coastal Plains. Morphological measurements of soldiers and characterization of the soldier defense secretions (unpublished data) support aconclusion that these phenotypes represent separate taxa.

It is generally agreed that the genus *Reticulitermes* is in need of revision (Weesner 1970, Nutting 1990, Scheffrahn & Su 1994). Our results demonstrate 11 distinct hydrocarbon phenotypes among *Reticulitermes* collected from Georgia. Studies are in progress to evaluate these phenotypes in light of species groupings. We hope to compile sample series that contain soldiers, alates, and workers for morphological studies, coupled with cuticular hydrocarbon and soldier defense secretion profile for the same samples. These data, in conjunction with biological and biogeographic observations, will help us to align hydrocarbon phenotypes with described species, and to identify and describe new taxa if warranted.

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