base of the falling column, the vertical flow of the more dense aerosol is changed by the surface of the earth to a horizontal flow. The falling particles then must travel across streamlines of flow in order to be deposited on the earth's surface. Calculations of the "stopping distance" at which a particle will be brought to rest by viscous forces in still air show that an insignificant number of the particles will impact the earth while most of them will form a radially expanding base surge along the surface of the earth.

In the absence of an atmosphere, particles lofted by an explosive process will not entrain air. Even if the explosive process is of volcanic origin with enough gas emitted to form some sort of aerosol, a base surge will not form without a surrounding atmosphere to produce the two-fluid effect. The comparison is similar to that of a landslide, in which the density of the "moving fluid" is much greater than that of the surrounding fluid of the atmosphere, with an underwater landslide or turbidity current which may move for some hundreds of kilometers across a very nearly horizontal surface in the ocean. Base surges of the type described by Fisher and Waters cannot exist in the absence of an atmosphere and therefore cannot be considered a factor in lunar sedimentation at the present time. The base-surge mechanism could possibly have been of importance if in the past the moon had a significant atmosphere.

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According to Grine (*1*), who cites a paper by G. A. Young (*2*), a base surge develops when water droplets or dust particles within a vertical explosion column start to fall and entrain air on the way down; at the base of the falling column, the aerosol is changed by the surface of the earth to a horizontal flow. It was concluded by Young (*3*), in a later paper, however, that the base surge forms from the crest of a large solitary wave which develops by gases expanding from the center of explosion. The top of this wave breaks and feeds the base surge. In Young's (*3*) study of the base surge which developed during the 1946 Bikini underwater atomic explosion, he noted that the main base surge appeared before the outside of the central column had started to fall. Similar early appearance of the base surge has been photographed at Capelinhos Volcano (*4*), and at the Sedan nuclear explosion (*5*).

The pertinent point is whether a base surge could develop and flow in the absence of an atmosphere. We maintain that it is probable because large impacting meteorites could produce large quantities of vapor.

Upon impact, a large volume of particulate matter would be entrained in gas—a mass which doubtless would be highly turbulent. If a large solitary wave were formed, this mass would then move laterally. How far such a flow could move would depend upon its size, the pull of gravity, the internal forces of friction ("viscosity"), and other factors. The particles within the mass could move within the newly created and internal gaseous "atmosphere," and could be deposited and buried without ever experiencing the effects of travel within a vacuum. Additionally, the leading edge and outer surfaces of the flow, in the absence of an external atmosphere, would move without experiencing inhibiting frictional drag. Thus, it seems reasonable to assume that under 1/6 gravity, such a mass would not only move, but perhaps could move farther than a cloud of comparable size on earth.

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Bark Beetle Pheromones

Although we have attempted to clarify some issues related to research on bark beetle pheromones in other reviews (*1, 2*), Pitman's recent comment (*3*) deserves reply.

The methodology used by Pitman and his colleagues at the Boyce Thompson Institute is so different from ours that direct comparison of results is difficult. We have attempted systematically to isolate and identify the compounds in bark beetle frass that are attractants. Chemical fractionation of frass is monitored with an olfactometer where beetles exhibit an upwind taxis in response to attractants. After such sequential fractionation, the active compounds are isolated in pure form, identified, and synthesized. The synthetic compounds are then exposed in olfactometers under field conditions, in order to determine their effectiveness in attracting beetles in flight. The group at Boyce Thompson has been attempting to identify the major volatile compounds in hindguts and then to determine if they are attractants in the field. The compounds are tested alone or in combination with gross oleoresin from the host tree or with the major known host monoterpenes.

Their identification of pheromones has been derivative (*2*). We isolated and identified both *exo*- and *endo*-brevicomin from the frass of *Dendroctonus brevicomis* females (*4*). In the course of the isolation, we found that a hydrocarbon fraction strongly synergized the activity of brevicomin. One of these synergistic compounds was identified as myrcene (*5*). In the field *exo*-brevicomin was attractive, and, as in the laboratory, the mixture of it and myrcene was the most attractive (*6*). After our announcement of brevicomin (*7*), Kinzer, working with the group from Boyce Thompson, isolated a very close analog of brevicomin from the hindgut of *D. brevicomis* males (*8*). (Brevicomin is a bicyclic ketal with a methyl and an ethyl substituent; Kinzer's compound is a bicyclic ketal with two methyl substituents.) No biological significance relative to *D. brevicomis* was ascribed to this compound by Kinzer, and no acknowledgment was made of the close chemical relationship between it and brevicomin. The fact is that both bicyclic ketals are important components of the *D. brevicomis* pheromone. (We acknowledge this significant contribution of frontalin by the Boyce Thompson group.) In view of this, it seems most unfortunate and totally incomprehensible that an analog of a known pheromone of *D. brevicomis* that was also isolated and identified from the same insect should be named "frontalin." The rationale seems to be based on the coincidence in chromatographic properties of the compound isolated from male *D. brevicomis* and those properties of a compound isolated from *D. frontalis* (*2*). Now, after we reported myrcene as a specific host-produced terpene that synergized a pheromone, they develop a "logical assumption" and proffer 3-carene.

We respond to the following statements in Pitman's comment (*3*):

1) "This effect [activation] on *trans*-verbenol was traced to resin of *P. monticola* and particularly to alpha-pinene, a major component (32 to 60 percent) of the oleoresins . . ." and ". . . it was demonstrated that it [frontalin] was active alone but alpha-pinene and *trans*-verbenol would accentuate the pheromone activity of the synthetic compound." These claims to "activation" or "accentuation" by alpha-pinene are not documented in the published literature.

2) "The failure of brevicomin alone to compete with natural sources of attractants in the forest is distinctly different from the results recently reported by Bedard *et al.*" This statement contradicts their own results. Vité and Pitman (*9*) show that brevicomin "within 5 meters of a natural source of attraction" (female-infested bolt) attracted an average of 5.4 beetles per 30-minute test period. We are gratified by this support of our finding that brevicomin alone attracted *D. brevicomis* in competition with natural sources. These results can hardly be considered "indifferent," nor can brevicomin be considered "totally ineffective."

3) "The brevicomin released from a tree in their experiments was probably associated with some natural component of the host." This criticism can be made of any tests in the forest. However, many other explanations apply; for example, the tree is a more natural visual image to the bark beetle in flight than their canvas sleeve olfactometer.

4) "Their data show that myrcene might serve in this capacity but it would be more logical to assume that 3-carene was responsible [as a host synergist for brevicomin] since it is a predominant component of oleoresin in ponderosa pine . . . as compared to myrcene." We cannot understand how Pitman can say myrcene "might serve in this capacity" when we present evidence (*6*) that it does serve in this capacity (also see Table 1). There is no logic whatever in the a priori assumption favoring a "predominant" component over a minor one. Is Pitman unaware of the literature that denies this as a reasonable hypothesis? Some hosts of *D. brevicomis* lack 3-carene; Coulter pine had 3-carene in only half of the trees examined (*10*). Ponderosa pine had less than 0.1 of 1 percent 3-carene in some instances (*11*). And ponderosa pines lacking 3-carene were even killed by *D. brevicomis* (*12*). In an unpublished study the resin of ponderosa pines in southern California was characterized by a lack of 3-carene (*13*). Pitman's statement that the oleoresin of ponderosa pine contains an average of 38 percent 3-carene and 15 percent myrcene is in error, because only 20 to 25 percent of ponderosa pine oleoresin is volatile (*14*). These terpene hydrocarbons are in the volatile fraction.

5) "It is not clear whether brevicomin will be an essential component in the mixture. . . ." We believe brevicomin is essential to the *D. brevicomis* pheromone. Results were obtained during the summer of 1969, using methods established by Wood *et al.* (*15*) (Table 1). The mixture of frontalin plus 3-carene is much less attractive than the mixture of *exo*-brevicomin, frontalin, and 3-carene. Also, 3-carene does not improve the attractiveness of the mixture of *exo*-brevicomin and frontalin. Clearly, the most attractive combination was *exo*-brevicomin, frontalin, and myrcene. Until Pitman publishes his data along with a full description of his methods we cannot identify the source of our differences.

Table 1. *Dendroctonus brevicomis* caught in response to synthetic attractants. Two replications (a and b) of all combinations were offered simultaneously for 6 hours each day for 3 days of field tests. The traps were at least 50 m apart.

Synthetic mixture	Number of *Dentroctonus brevicomis* caught						
	Day 1		Day 2		Day 3		Mean
	a	b	a	b	a	b	
exo-Brevicomin + frontalin	60	3	1	10	40	41	25.8
exo-Brevicomin + frontalin + myrcene	22	27	74	40	156	39	59.7
exo-Brevicomin + frontalin + 3-carene	10	22	10	9	13	92	26.0
Frontalin + 3-carene	5	0	13	2	14	0	5.7

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