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Anatis mali (Say), a coccinellid predator of spruce budworm egg masses

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ABSTRACT

The coccinellid, *Anatis mali* (Say), fed singly and in groups of three to four on egg masses of the spruce budworm, *Choristoneura fumiferana* (Clemens). The potential of this predator as a biological control agent was investigated by reviewing the literature and establishing laboratory and field experiments on host synchrony and feeding behavior. The predaceous stages of the *A. mali* life cycle coincide with the spruce budworm oviposition period. The predator's generalist feeding behavior may however limit its importance as a predator of the spruce budworm.

INTRODUCTION

Beetles of the family Coccinellidae are known for their predaceous habits (Hagen 1962). Few have been utilized in biological control programs of forest insects pests, except the exotic predator, *Aphidecta obliterata* (L.), released for control of the introduced balsam woolly aphid, *Chermes piceae* Ratzeburg (Amman 1966). *Anatis* spp. have been recorded feeding on various forest defoliators. Struble (1957) reported that *A. rathvoni* (LeConte) was a very common predator of white-fir sawfly (*Neodiprion abietis* complex) [sic] larvae during outbreaks in white fir [*Abies concolor* (Gord. & Glend.) Lindl.] in California. *A. ocellata* (L.) [sic] adults have been observed feeding on larvae of the jack pine budworm, *Choristoneura pinus* Freeman (Allen *et al*. 1970). Graham and Knight (1965) reported that *A. ocellata* [sic] was partly responsible for checking an outbreak of the jack pine budworm. Smith (1966) reported that *A. mali* found on white spruce, *Picea glauca* (Moench) Voss, and on balsam fir, *Abies balsamea* (L.) Mill., fed on spruce budworm, *C. fumiferana* (Clemens), larvae.

We report here our observations of *A. mali* feeding on spruce budworm egg masses. The potential of this predator to act as a biological control agent of spruce budworm egg mass populations is not known. We have investigated this potential with a review of pertinent literature, field observations of the synchrony of predaceous stages of *A. mali* with the spruce budworm's oviposition period, and field and laboratory observations of *A. mali* feeding behavior.

LITERATURE REVIEW

Taxonomy

Watson (1976) clarified the synonomy and species descriptions of the genus *Anatis* Mulsant. This genus has six species: *mali* (Say), *ocellata* (L.), *halonis* Lewis, *labiculata* (Say), *rathvoni* (LeConte) and *lecontei* Casey. Two species, *A. rathvoni* and *A. lecontei*, are distributed in western North America; whereas, *A. labiculata* and *A. mali* are predominately found in eastern and northern North America, respectively. The two remaining species, *A. halonis* and *A. ocellata*, are found in Japan and Eurasia, respectively. Individuals from North America previously described as *A. ocellata* (L.) or *A. ocellata mali* (Say), and which have each black spot on the elytra ocellated with white or ivory, are now recognized as *A. mali* (Say). *A. mali* is generally distributed in coniferous areas of the northern half of North America, from Nebraska and Virginia in the U.S. to southern Yukon and the MacKenzie District in Canada (Watson 1976).

Life History

General biologies of coccinellids were given by Hagen (1962) and Hodek (1973). Gagne and Martin (1968) described the life stages and habits of *A. mali* in Ontario. *A. mali* is a univoltine species; adults overwinter and become active in early May. Oviposition commences in early June and continues into mid-July. Larval development required 32.6 days in laboratory tests at 21°C. Pupation occurs characteristically on needles of the lowest foliated branches and is generally completed by late August. Adult emergence is generally completed by mid-September. Allen *et al.* (1970) reported a similar life history for *A. ocellata* [sic] in Michigan, and noted that larvae passed through four stadia and completed development in 5-6 weeks.

Habitat Associations

A. mali is predaceous on insects associated with conifer forests (Gagne and Martin 1968, Watson 1976). Smith (1966) collected *A. mali* from white spruce, balsam fir, red pine (*Pinus resinosa* Ait.), and Scots pine (*P. sylvestris* L.). Allen *et al*. (1970) reported that *A. ocellata* [sic] are frequently encountered on jack pine (*P. banksiana* Lamb.) in Michigan. Martin (1966) reported that coccinellids represented a major portion of the insect predator complex in the crowns of red pine in central Ontario plantations. Martin (1966) and Gagne and Martin (1968) demonstrated that coccinellid species composition was related to the age of red pine stands. Prey density and coccinellid species diversity decreased in older red pine plantations. *A. mali* and *Mulsantina picta* (Randall) were the dominant species in older red pine plantations.

Searching Behavior

Gagne and Martin (1968) noted that old-stand coccinellid larvae such as *A. mali* had greater searching capacity and mobility than did larvae of coccinellid species which predominated in young red pine stands. These searching characteristics are presumably required for survival in areas where prey density is low. Several authors have concluded that coccinellid larvae perceive their prey only by physical contact (Hagen 1962, Hodek 1973). Kesten (1969) reported that *A. ocellata* did not have adequate sensory organs to perceive food at a distance. Smith (1965a) reported that visual stimuli, such as prey movement, shape, size, color, and texture are of little importance for perception of food by ten species of coccinellids, including A. mali. Allen et al. (1970), however, indicated that visual stimuli seemed to play a role when A. ocellata [sic] adults were within 1/2 - 3/4 in (1.3 - 1.9 cm) of jack pine budworm larvae.

Feeding Behavior

Allen et al. (1970) reported that A. ocellata [sic] larvae in the first two stadia are small (3.0-7.0 mm long), slow moving, and not able to negotiate silk spun by jack pine budworm larvae. These young Anatis larvae probably rely on relatively immobile prey (e.g., aphids and mealybugs) for food. Newly hatched coccinellid larvae are also cannibalistic (Allen et al. 1970, Banks 1956, Gagne and Martin 1968). Larvae consume their egg shells and usually other unhatched eggs. A. mali adults have also been observed to cannibalize eggs, pupae, and teneral adults (Gagne and Martin 1968).

Feeding rates of Anatis have been reported by Grobler (1962) and Allen et al. (1970). A. ocellata [sic] adults consumed 0.4 fifth-and sixth-stadium jack pine budworm larvae per day over a 30-day feeding period in the laboratory (Allen et al. 1970). Third- and 4th-stadium A. ocellata [sic] larvae consumed two 4th-stadium budworm larvae per day for 20 days. Consumption of a budworm larva required 3-5 minutes. Grobler (1962) observed A. mali feeding on woolly pine needle aphids [Schizolachnus piniradiatae (Davidson)] on red pine in Ontario. Two A. mali adults in captivity each consumed more than 900 aphids in 23 days.

Smith (1965a) concluded that A. mali was the most generalized feeder of the primitive coccinellid species which he studied, and it would probably respond to dry supplemental foods in the field. Allen et al. (1970) reported that A. ocellata [sic] adults feed on pollen in the staminate flower heads of jack pine. Smith (1965b) determined in the laboratory that A. mali would eat foods not normally encountered in its natural habitat (e.g., aphids associated with alfalfa and corn). Previous feeding by larvae and adults did not affect the food preference of A. mali adults.

Smith (1965c) compared the responses of A. mali and Coleomegilla maculata lengi Timberlake to changes in quality and quantity of larval food and concluded that A. mali was better adapted to tolerate a shortage of food. Food quality significantly affected the larval growth rate of C. maculata, but had a negligible effect on A. mali growth. A. mali was also capable of converting a greater percentage of food into body weight when food was scarce than when food was abundant.

Parasites of Anatis

Parasitism of A. quindecimpunctata Oliver [sic] was reported by Kulman (1971). The encyrtid wasp, Homalotylus terminalis (Say), parasitized 26% of larvae collected in Virginia. Kulman postulated that this parasite may influence the biological control potential of Anatis. Gagne and Martin (1968) also reported parasitism of A. mali pupae by the pteromalid, Pachyneuron sp.

Effects of Insecticides

Responses of A. mali to chemicals used for insect population suppression have been variable. Smith and Berube (1966) reported that sex sterilants (N, N'-hexamethylene bisaziridinyl carboxamide and apholate) in the drinking water at concentrations of 1.0, 0.1 and 0.01%, interfered with the growth of A. mali and prevented it from reaching the adult stage. Conversely, Macdonald and Webb (1963) reported that Coccinellidae (suspected to be A. mali, personal communications with I.W. Varty) were found at higher densities in spruce-fir stands in New Brunswick sprayed with insecticides for spruce budworm suppression than in stands not sprayed. Hydorn[1] observed variable responses by sparse populations of Anatis sp. in spruce-fir stands in central Maine to applications of carbaryl and acephate for suppression of spruce budworm populations.

MATERIALS AND METHODS

Initial observations of A. mali predation on spruce budworm egg masses were made in 1978 and 1979 in spruce-fir stands of central Maine. In 1982, more intensive field studies of A. mali life history and feeding behavior were conducted at Alton and Old Town, Maine. The Alton site was composed of a stand of tamarack, Larix laricina (DuRoi) K. Koch, on the border between a large bog and mixed stands of spruce, balsam fir, and hardwoods. The Old Town site was composed of a Christmas tree plantation (balsam fir, white spruce and Scots pine) and a surrounding mixed stand of balsam fir, spruce, tamarack and hardwoods. Detailed observations of A. mali activity and life stages were made at each site once or twice per week from 8 June to 31 August 1982.

Studies of A. mali life history and feeding behavior were also conducted in the laboratory in 1982. A. mali eggs and larvae were collected at the study sites, caged individually in 30 ml plastic

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[1]Hydorn, S.B. 1979. The influence of pesticides sprayed for spruce budworm control on certain non-target terrestrial invertebrates in the forest. Report to the Maine Forest Service. 30 p.

creamer cups, and placed in an environmental chamber (ca. 25°C, 70-95% RH, and 24-hr light) for rearing. Beetle larvae and adults were provided eggs of the Angoumois grain moth, Sitotroga cerealella (Olivier), as food. Dates were recorded for A. mali egg hatch, larval ecdysis, pupation, and adult emergence.

For observations of A. mali feeding behavior, 14 laboratory-reared beetles were placed individually in 9 cm diameter petri plates, each containing a single balsam fir needle bearing a spruce budworm egg mass. Recently-emerged beetle adults (< 24 hrs.) were denied food for 24 hours prior to testing. Spruce budworm egg masses were collected from balsam fir at the Old Town study site. The number of eggs/egg mass was recorded prior to each test. Each beetle was tested for one to five hours. Each beetle activity (e.g., walking, feeding, stationary with no feeding, etc.) was timed and recorded.

RESULTS

On 12 July 1978, the authors observed adult A. mali feeding singly (Fig. 1) and in groups of three to four individuals on newly-deposited spruce budworm egg masses at Medford, Piscataquis County, Maine. Specimens of these beetles were sent to the USDA Insect Identification and Beneficial Insect Introduction Institute in Beltsville, Maryland and were identified as Anatis mali (Say) by R.D. Gordon. These identifications were confirmed by J. McNamara of Agriculture Canada, Biosystematics Research Institute at Ottawa, Ontario [Anatis ocellata mali (Say)].

Synchrony of Predator and Prey Life Histories

Mating of overwintered adults was observed as early as 9 May (1978) in the field. Uneclosed egg clusters were observed on balsam fir, spruce, tamarack, and eastern white pine (*Pinus strobus* L.) from mid-May to early July. Egg clusters collected from Alton and Old Town in 1982 ranged from 3 to 23 eggs/cluster ($\bar{x}$ = 12.1, n = 25). One adult female, collected 10 June 1982 and provided with *S. cerealella* eggs as prey, produced more than 159 eggs from 14 June to 26 July in the laboratory. Eggs hatched after 3-5 days under constant laboratory conditions (ca. 25^{o}C, 70-95% RH, 24-hr light).

Larvae of *A. mali* were observed in the field from early June to mid-July. Pupae were most abundant from late June to mid-July. The length of the development period (four larval stadia and the pupal stadium) ranged from 20 - 29 days (n = 42) for *A. mali* reared under constant laboratory conditions and provided with *S. cerealella* eggs as prey.

Emergence of current-year adults was first observed in the field in early July (1982) and peaked ca. 15 July. Although Gagne and Martin (1968) reported that *A. mali* pupation and adult emergence continued through late August and mid-September in Ontario red pine plantations, we observed no *A. mali* pupae or adults in the field after late July. There is considerable overlap between the predatory stages of *A. mali* and the oviposition period of spruce budworm. Egg masses of the spruce budworm are deposited over approximately a 27-day period beginning in late June or early July (Houseweart *et al*. 1982). The last two weeks of the coccinellid's larval period (3rd and 4th instars) coincide with the beginning of the spruce budworm egg mass period. Newly emerged *A. mali* adults are present for about three weeks of the spruce budworm egg mass period. Adults and 3rd and 4th stadum larvae are the life stages with the greatest mobility and the greatest consumptive capability. From our field and laboratory observations, we conclude that A. mali is well synchronized with the spruce budworm's egg mass period; hence this coccinellid has a potential predatory impact on the spruce budworm egg population.

A. mali Feeding Behavior

Visual stimuli did not appear to be important for prey perception by A. mali adults in laboratory feeding tests. Adults frequently walked within 2-3 mm of balsam fir needles which held spruce budworm egg masses, apparently without detecting the potential prey. When the path of a beetle intersected the balsam fir needle, the beetle usually searched the length of the needle until the egg mass was found.

The time A. mali adults (n = 9) spent feeding on a spruce budworm egg mass ranged from less than 15 minutes to more than 250 minutes in laboratory tests. This is equivalent to 2-15 min/egg, when egg mass size is considered. No obvious relationship between egg mass size and quantity of time spent feeding was detected during our tests. In field observations, one A. mali adult spent five hours feeding on a single egg mass; however, during this time, there were intermittent periods of non-feeding, when the beetle remained stationary on the same balsam fir branch within 10 mm of the egg mass. When not feeding, A. mali adults were most frequently observed in secluded places on coniferous trees (e.g., on the bole, on the under surface of branches).

Like Smith (1965a), our observations indicated the generalist feeding nature of A. mali. It was easily reared in the laboratory on a non-native prey (S. cerealella eggs) and was observed to readily feed on various species of aphids. We also observed cannibalism in the field as reported by Banks (1956) and Gagne and Martin (1968). Early instars of A. mali fed on late-hatching eggs and larvae. A. mali adults were observed to feed upon A. mali pupae.

Jennings and Houseweart (1983) reported spruce budworm egg masses were damaged by unknown predators or by physical breakage. Although not confirmed, we suspect that many of these egg masses may have been fed upon by coccinellid beetles such as A. mali. Damage on these "chewed" egg masses was similar to known feeding patterns of A. mali (Fig. 2). Jennings and Houseweart (1983) reported "chewed" egg masses collected in mid-winter were significantly more common among parasitized egg masses (75.6%), than among partially parasitized (29.9%) or normal, eclosed (43.8%) egg masses.

Cessation of egg development caused by the egg parasitoid, Trichogramma minutum Riley, may prolong the exposure of parasitized egg masses to predators such as A. mali. This factor seems to diminish the positive effect of A. mali in overall biological suppression of spruce budworm egg populations. It is not known, however, what portion of the parasitized egg population is affected by A. mali predation.

CONCLUSIONS

The life history of A. mali is well synchronized with the oviposition period of the spruce budworm. This predator feeds on both parasitized and unparasitized spruce budworm egg masses. The overall effects of A. mali predation on spruce budworm generation survival are not known. The apparent generalist feeding behavior of this predator, however, may limit its potential for use in biological control efforts for suppression of spruce budworm egg populations.

ACKNOWLEDGEMENTS

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S. cerealella eggs used as prey in *A. mali* rearing procedures were provided by Richard K. Morrison, USDA-SEA/ARS, Cotton Insects Research Laboratory, College Station, Texas.

FIGURE CAPTIONS

Figure 1. *Anatis mali* (Say) adult feeding on a spruce budworm egg mass.

Figure 2. Characteristic feeding pattern of *Anatis mali* (Say) on a parasitized spruce budworm egg mass.

REFERENCES CITED

Allen, Douglas C., Fred B. Knight and John L. Foltz. 1970. Invertebrate predators of the jack-pine budworm, Choristoneura pinus, in Michigan. Ann. Entomol. Soc. Amer. 63:59-64.

Amman, Gene D. 1966. Aphidecta obliterata (Coleoptera: Coccinellidae), an introduced predator of the balsam woolly aphid, Chermes piceae (Homoptera:Chermidae), established in North Carolina. J. Econ. Entomol. 59:506-508.

Banks, C.J. 1956. Observations on the behaviour and mortality in Coccinellidae before dispersal from the egg shells. Proc. Roy. Entomol. Soc. London. (A) 31:56-60.

Gagne, W.C. and J.L. Martin. 1968. The insect ecology of red pine plantations in central Ontario. V. The Coccinellidae (Coleoptera). Can. Entomol. 100:835-846.

Graham, Samuel A. and Fred B. Knight. 1965. Principles of forest entomology. McGraw-Hill Book Co., 417 p.

Grobler, Johan H. 1962. The life history and ecology of the woolly pine needle aphid, Schizolachnus pini-radiatae (Davidson) (Homopotera: Aphididae). Can. Entomol. 94:35-45.

Hagen, Kenneth S. 1962. Biology and ecology of predaceous Coccinellidae. Ann. Rev. Entomol. 7:289-326.

Hodek, Ivo. 1973. Biology of Coccinellidae. Academia Publishing House of the Czechoslovak Academy of Sciences. Prague. 260 p.

Houseweart, Mark W., Susan G. Southard, and Daniel T. Jennings. 1982. Availability and acceptability of spruce budworm eggs to parasitism by the egg parasitoid, Trichogramma minutum (Hymenoptera: Trichogrammatidae). Can. Entomol. 114:657-666.

Jennings, Daniel T. and Mark W. Houseweart. 1983. Parasitism of spruce budworm (Lepidoptera: Tortricidae) eggs by Trichogramma minutum and absence of overwintering parasitoids. Environ. Entomol. 12:535-540.

Kesten, Ursula. 1969. Zur morphologie und biologie von Anatis ocellata (L.)(Coleoptera, Coccinellidae). Z. Angew. Ent. 63:412-445.

Kulman, H.M. 1971. Parasitism of Anatis quindecimpunctata by Homalotylus terminalis. Ann. Entomol. Soc. Amer. 64:953-954.

Macdonald, D.R. and F.E. Webb. 1963. Insecticides and the spruce budworm. pp. 288-310. In: R.F. Morris (Ed.). The dynamics of epidemic spruce budworm populations. Mem. Entomol. Soc. Can. 31. 332 p.

Martin, J. Lynton. 1966. The insect ecology of red pine plantations in central Ontario. IV. The crown fauna. Can. Entomol. 98:10-27.

Smith, B.C. 1965a. Growth and development of coccinellid larvae on dry foods (Coleoptera: Coccinellidae) Can. Entomol. 97:760-768.

_________. 1965b. Effects of food on the longevity, fecundity, and development of adult coccinellids (Coleoptera: Coccinellidae). Can. Entomol. 97:910-919.

_________. 1965c. Differences in Anatis mali Auct. and Coleomegilla maculata lengi Timberlake to changes in the quality and quantity of the larval food (Coleoptera: Coccinellidae). Can. Entomol. 97:1159-1166.

_________. 1966. Variation in weight, size, and sex ratio of coccinellid adults (Coleoptera: Coccinellidae). Can. Entomol. 98:639-644.

Smith, B.C. and J.A.C. Berube. 1966. Effects of sex sterilants on the growth of coccinellid larvae (Coleoptera: Coccinellidae). Can. Entomol. 98:1005.

Struble, George R. 1957. Biology and control of the white-fir sawfly. For. Sci. 3:306-313.

Watson, W.Y. 1976. A review of the genus Anatis Mulsant (Coleoptera: Coccinellidae). Can. Entomol. 108:935-944.

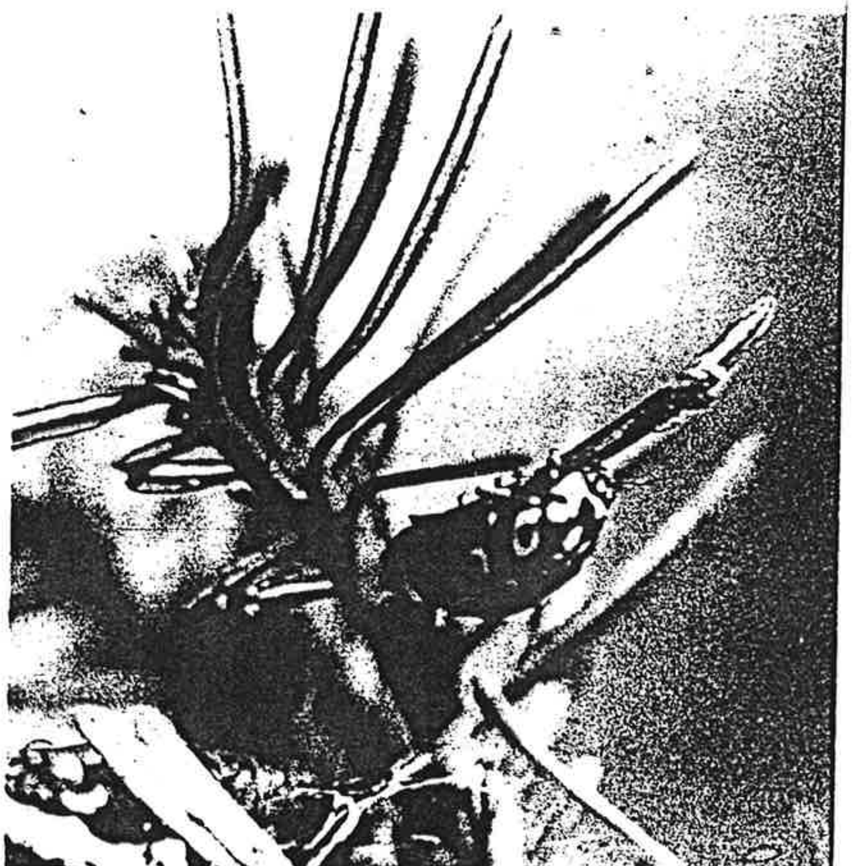

Fig. 1

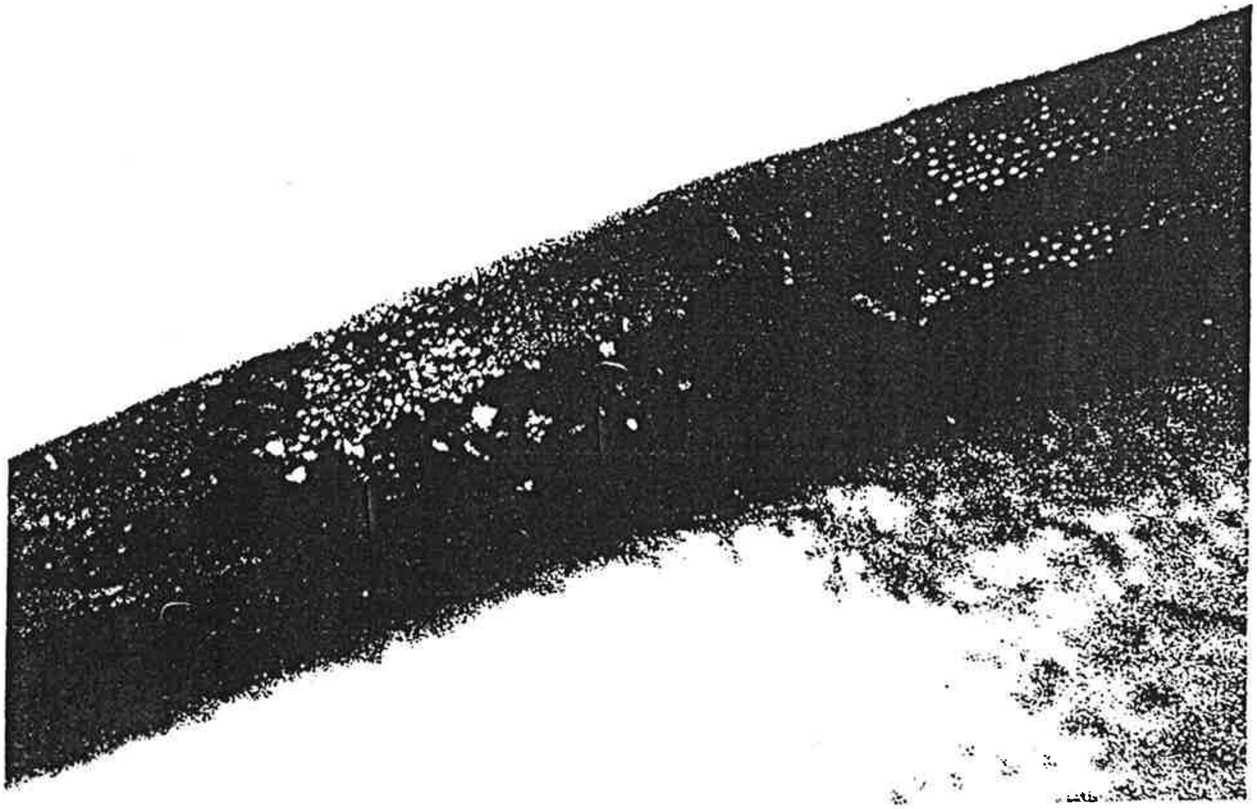

Fig. 2

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