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SOME ASPECTS OF SOIL CONDITIONS AND ARTHROPOD DISTRIBUTION IN ANTARCTICA

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Abstract: Various aspects of Antarctic soils are discussed in relation to their biology. Analyses conducted at McMurdo Station, Antarctica, show that certain soil salts are higher in areas where no arthropods are present. These coincide with areas of low available water and it is concluded that soil dwelling Arthropoda in the parts of South Victoria Land studied are probably excluded from colonizing certain areas because of a lack of sufficient available water.

During the summer season of 1963/64 a series of studies was made on Antarctic soils. The aim of these studies was to try to discover if any relationships existed between selected soil conditions and arthropod distribution. These studies were conducted in conjunction with ecological and distributional investigations on the Insecta and Acari occurring in the South Victoria Land area. These have already been reported on (Wise & Spain 1967).

The present study is based on work done in South Victoria Land and soil samples from the Ellsworth Mountains which were supplied by Mr K. Rennell of the Bishop Museum team.

Physical Characteristics of Antarctic Soils

Antarctic soils are stony and coarse in texture (McCraw 1960) although small particles occur, even down to clay size (Blakemore & Swindale 1958). Jensen (1916) in a mechanical analysis of a soil derived chiefly from kenyite, gives the proportion of "impalpable matter, chiefly clay" as 36.7 percent. This is a high clay percentage for Antarctic soils and Blakemore & Swindale (1958) report that the clay content of a soil sample from the Scott Base area was less than 1%. It is considered that this is probably a more representative figure than that of Jensen (1916). It would appear, though, that sand-sized particles predominate in many situations below the surface layer of stones.

Desert pavements are present over a large part of the ice free areas of Antarctica and normally constitute the surface layer of the soil. They are formed by wind which removes the smaller, lighter soil particles from the surface layer. This leaves a protective layer of larger stones which acts as a "wind break" effectively retarding further erosion (Tedrow & Ugolini 1966).

Antarctic soils are structureless in the normal sense of the word although "mudball structure" has been observed in a few limited areas (Claridge & Campbell 1965).

Patterned ground is a common feature of the Antarctic landscape in the ice free areas. This patterning usually takes the form of frost polygons which are outlined by troughs that often fill with ice or snow. This latter phenomenon has given rise to conditions moist enough to support arthropods. Examples of this situation have been seen by me at an area to the south of Cape Crozier on Ross Island.

Chemical Characteristics of Antarctic Soils

Antarctic soils are usually alkaline in reaction, some strongly so. Jensen (1916) recorded this for soils from South Victoria Land and since then a number of other authors have confirmed this

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(Llano 1962; Wise, Fearon & Wilkes 1964; Rudolph 1966; Boyd, Staley & Boyd 1966; Tedrow & Ugolini 1966).

The salt content of the soils of this region is usually high. Many soils are also saline as soluble sodium and potassium are often present in measurable quantities (Tedrow & Ugolini 1966). The reason for this high salt concentration in the soil is probably associated with the dryness of the environment. Effective precipitation is so low that in many areas the salts liberated by rock weathering form deposits on the rock and soil surfaces.

With the notable exception of ornithogenetic soils (Tedrow & Ugolini 1966) soil organic matter is very low in many Antarctic areas. Tedrow & Ugolini (1966) state that these soils are, for all practical purposes, ahumic. They emphasize, however, that they are not abiotic as organisms of some type occur in most areas.

The Biology of Antarctic Soils

Plant Life

With the exception of a small area on the northern end of the Antarctic Peninsula no flowering plants occur on the Antarctic continent, thus the vegetation is composed almost entirely of cryptogams (Rudolph 1966).

Algae, mosses, fungi and bacteria have been found to occur widely in the soils of the ice free areas of the continent (Rudolph 1966; Boyd, Staley & Boyd 1966). All of these, with the possible exception of the bacteria, have some significance as arthropod food sources (Pryor 1962; Janetschek 1963).

Algae of various types are present in the soils of South Victoria Land and occur where no macroscopic vegetation is visible (Wise, Fearon & Wilkes 1964). Flint & Stout (1960) have shown that a number of genera typical of temperate zone soils, such as *Chlorella* and *Chlamydomonas*, occur. Their significance as arthropod food material has been demonstrated by Wise, Fearon & Wilkes (1964) in feeding experiments conducted at McMurdo Station. These authors showed that the collembolan *Gomphiocephalus hodgsoni* Carpenter feeds to some extent, at least under laboratory conditions, on green algae. Pryor (1962), in discussing the food habits of the collembolan *Isotoma klovstadi* Carpenter, states that one of its primary food sources is algae.

Mosses occur generally in the ice free areas of the Antarctic continent and are found as far south as 84° 42′ (Wise & Gressitt 1965). They are probably an important food material for a variety of terrestrial arthropods and have been demonstrated to be the primary food of both *Isotoma klovstadi* and *Gomphiocephalus hodgsoni* (Pryor 1962; Wise, Fearon and Wilkes 1964).

Fungi are probably of some importance as an arthropod food especially in chalikosystem soils (Janetschek 1963). The feeding experiments of Wise, Fearon & Wilkes (1964) have shown that both mites and Collembola feed on fungi (*Penicillium* sp.) and that, for *Gomphiocephalus hodgsoni* at least, fungi are one of the most preferred articles of diet.

A wide range of bacterial types occur in Antarctic soils and are present both naturally and due to the presence of man and his domestic animals (Boyd, Staley & Boyd 1966). They appear to be of little direct significance in the ecology of terrestrial arthropods, although they may well be important to some of the lower forms of animal life.

Lichens would appear to be only a minor food source for terrestrial arthropods. A few records of arthropods feeding on lichens are in the literature. Pryor (1962) states that *Isotoma klovstadi* fed on lichens for short periods in the laboratory. The cryptostigmatic mite *Maudheimia wilsoni* Dalenius, and some others, have been recorded as feeding on arborescent lichens (Gressitt 1965a).

Animal Life

The highest forms of terrestrial life in Antarctica are the acarine and insect members of the phylum Arthropoda. Various other soil inhabiting animal groups are present and include the Protozoa, Rotifera, Nematoda and Tardigrada.

Two orders of free living insects occur on continental Antarctica: the Diptera and the Collembola. The Diptera are represented by the chironomid *Belgica antarctica* Jacobs which occurs only in a limited area on the west side of the Antarctic Peninsula, and breeds mainly in rock cavities filled with snow melt and often near penguin rookeries (Gressitt 1965a). The Collembola, or springtails, have a somewhat more diverse representation with more than a dozen species having been recorded. They have a wide latitudinal range throughout the continent and *Anurophorus subpolaris* Salmon has been taken from as far south as 84° 47′ (Wise & Gressitt 1965).

Free living Acarina of the suborders Mesostigmata, Prostigmata, and Cryptostigmata occur on continental Antarctica, and Gressitt (1965a) considers that the Acarina are probably one of the most widespread groups. Their climatic tolerances are probably wider than those of the Collembola as they have been taken further south and further inland than any other arthropods (Wise & Gressitt 1965; Gressitt 1965a).

Antarctica has a scanty soil and plant biota which is composed of simple organisms that have been able to adapt themselves to the rigors of the environment. Interrelationships between the various groups of organisms are presumably complex and largely unknown. A generalized food chain is given by Boyd, Staley & Boyd (1966) which gives an overall picture of the relationships between the major groups.

Soil Conditions and Arthropod Distribution

A number of authors have measured physical and chemical properties of Antarctic soils but few have attempted to correlate chemical factors with the distribution of the biota of the area.

Wise, Fearon & Wilkes (1964) measured a number of characteristics of soils in South Victoria Land in an attempt to explain the occurrence, or non-occurrence, of arthropods at various localities. These workers found a positive correlation between the water content of the soil and the presence or absence of arthropods. In the case of *Gomphiocephalus hodgsoni* the tolerance levels were between 3 and 12 percent of soil moisture (Wise, Fearon & Wilkes 1964), but *Isotoma klovstadi* was shown by Pryor (1962) to be capable of withstanding prolonged immersion in water without suffering any obvious damage. It would appear that the most important factor is the relative humidity of the soil air as these Collembola are cutaneously respiring types and require a moist cuticle in order to attain a satisfactory level of gas exchange.

Studies have shown that the distribution of Antarctic soil dwelling arthropods is largely unaffected by the acidity or alkalinity of the soil. This has been brought out by the studies of Wise, Fearon & Wilkes (1964) and also those of Wise & Spain (1967). Food supply in the form of microorganisms also seems to be independent of soil pH. This has been demonstrated by the studies of Boyd, Staley & Boyd (1966) in the Dry Valleys of South Victoria Land.

As would perhaps be expected, arthropod distribution shows some correlation with the level of water soluble salts in the soil. Wise, Fearon & Wilkes (1964) found that in South Victoria Land arthropods occurred in soils that had soil water soluble salt levels ranging from 0.12 to 1.8 percent. Wise & Spain (1967) working in the same area, found arthropods occurring in soils that had soluble salt levels as low as 0.002 per cent. This would suggest that these arthropods are not limited in their distribution by low levels of water soluble salts, as was suggested by Wise, Fearon & Wilkes (1964).

The only work that has been done to try to correlate the levels of individual salts with distribution is that of Boyd, Staley & Boyd (1966). They found that high levels of chloride and/or sulphate severely limited microbial growth but that these high salt levels only occurred in combination with moisture levels.

METHODS OF STUDY

Sampling. Soil sampling was carried out at a number of localities in South Victoria Land and a few samples were obtained from the Ellsworth Mountains. Individual samples were collected from the actual sites that arthropods occupied. Where none were present samples were taken from corresponding sites.

Analysis. The analytical work on which this study is based was carried out at the Biological Laboratory, McMurdo Station, Antarctica. Soil tests were made using a "Hellige-Truog Combination Soil Tester" manufactured by Hellige Incorporated, of Garden City, New York.

RESULTS

The sites that soil samples were collected from, and the arthropods occurring at each, are presented in Table 1.

Table 2 presents the results of a series of analyses carried out on the soil samples collected in South Victoria Land. Table 3 presents similar results for the samples obtained from the Ellsworth Mountains.

DISCUSSION

The data presented in Table 2 shows that, for most salts, there is little difference between the 3 classes of locality as far as the individual levels are concerned. The exceptions to this are the levels of magnesium, chloride and sulphate which are all somewhat higher in areas where no arthropods were found than in the others.

The results of the analyses given in Table 3 show a uniformly high level of pH values which is

Table 1. Arthropoda occurring at soil sampling sites.

Site	Collembola	Acari
Observation Hill	absent	present
Lake Penny	present	present
Lake Péwé	present	present
Lake Bonney	absent	absent
Marble Point	present	present
Granite Harbor	present	present
Springtail Point	present	present
Darwin Glacier	absent	absent
Lake Chad	absent	present
Cliff Nunatak	present	present
Terra Nova Bay	present	present
Ellsworth Mountains	absent	absent

Note: The common species of Collembola in South Victoria Land is *Gomphiocephalus hodgsoni* Carpenter; the common species of Acari in South Victoria Land are *Stereotydeus mollis* Womersley & Strandtmann and *Nanorchestes antarcticus* Strandtmann. Other species of both Collembola and Acarina occur at some of the localities mentioned in the table.

Table 2. Concentration of salts in some South Victoria land soils.

Situation	Parts per Million								No. of Samples
	P	K	Ca	Mg	NO_3'	NH_4^+	Cl′	SO_4''	
(a) Areas where only Acari were found.									
Lake Chad	80	128	2000	100	6	8	1000	150	1
Observation Hill	123	337	1600	100	0	20	433	113	3
Mean	101	132	1800	100	3	14	716	131	
Range	80–123	128–337	1600–2000	100–100	0–6	8–20	433–1000	113–150	
(b) Areas where Acari and Collembola were found.									
Lake Penny	36	136	2320	110	0	20	720	106	5
Lake Péwé	<10	120	3600	400	2	40+	675	50	2
Marble Point	33	171	3200	133	0	14	367	98	3
Granite Harbor	87	151	567	100	2	10	533	120	3
Springtail Point	40	128	2000	125	16	10	800	250	2
Cliff Nunatak	40	40	300	100	0	?	150	900	1
Terra Nova Bay	32	80	300	100	0	10	150	80	1
Mean	40	118	1755	153	3	15	488	229	
Range	10–87	40–171	300–3600	100–400	0–16	10–40+	150–800	50–900	
(c) Areas where no Arthropoda were found.									
Lake Bonney	40	141	1867	1067	2	12	2000	200	3
Darwin Glacier	45	128	1093	466	2	11	666	133	3
Mean	63	134	1480	766	2	11	1333	166	
Range	45–80	128–141	1093–1867	466–1067	2–2	11–12	666–2000	133–200	

Note: The values for each locality are means of a variable number of tests. The number of tests made from soils of each locality are indicated in the column headed "No. of Samples".

Table 3. Analysis of some soil samples from the Ellsworth Mountains.

Situation	Parts per Million								pH
	P	K	Ca	Mg	NO_3'	NH_4^+	Cl′	SO_4''	
Inferno Camp Area	10	48	2400+	100	0	?	150	900	8.25
Meyer Hills (a)	160	48	800	100	2.5	?	600	<100	8.25
Meyer Hills (b)	80	80	2000	100	0	15	200	150	8.25
Collier Hills (a)	10	128	2400	200	0	40?	1200	2000	8.25
Collier Hills (b)	80+	80	2400	100		20	1200	150	8.25

Note: The sample described as Meyer Hills (a) was collected from a lake outlet area; (b) was collected from the edge of the lake mentioned in connection with Meyer Hills (a).
The samples described as Collier Hills (a) and (b) were from two different localities in this area.

in the upper part of the range of values given by Wise, Fearon & Wilkes (1964) and Wise & Spain (1967) for the South Victoria Land area. Most salt levels are similar to those presented in Table 2 except for chloride and sulphate which correspond more to the values given for Area C of Table 3.

If the totals of the mean levels of the potassium, magnesium, chloride and sulphate salts are considered for each class of arthropod distribution mentioned in Table 2, it will be seen that soils which do not support arthropods have a considerably higher soluble salt content than those that do. It would also appear that Acari have a somewhat greater tolerance of high soil water soluble salts than do Collembola.

This may mean that high concentrations of these salts could exert some inimical effect on the osmotic balance of the arthropods that might otherwise occur in these areas. Another possibility is that high concentrations of these salts exert their effects through their restriction of a potential microbial food supply.

It is considered that lack of available water is the principal factor limiting arthropod distribution in the areas examined. If available water levels were higher, then soil water soluble salt concentrations would be lower. Thus, regions of high soil water soluble salts are probably too dry for soil inhabiting Arthropoda, especially the cutaneously respiring Collembola.

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