Pacific Insects Monograph 25: 167–178 **20 March 1971**

ANTARCTIC ENTOMOLOGY WITH EMPHASIS ON BIOGEOGRAPHICAL ASPECTS[1]

By **J. Linsley Gressitt**[2]

Abstract: During the past 3 years or so the known land arthropod fauna of Antarctica proper has been increased from about 130 to about 136 species, and the published fossil species of insects have increased from 3 to 6. Recent further evidence for the existence of Gondwanaland and continental drift helps to strengthen reliance on the apparent indications that the antarctic land fauna is related to those of the several southern continents and that the apparent endemic genera may have survived the Pleistocene on the Antarctic continent and that their relatives may be found on any of the southern continents.

In 1967 the American Geophysical Union published "Entomology of Antarctica" as volume 10 of the Antarctic Research Series (Gressitt, ed., 1967). At the time that volume was in press, some field work in Antarctica was just being completed or was then in the process of being written up, and the results were not available in time for publication in that volume. Some of the results of those projects form the bulk of this volume, to which are added some pertinent reports from other sources.

Recent discoveries of fossil vertebrates and fossil insects in the interior of Antarctica and various lines of new evidence on the history of the Antarctic continent stimulate new attempts to determine the role of Antarctica in the history of evolution and spread of Southern Hemisphere insects. Though the data available are still too meagre for many conclusions, it may be appropriate to evaluate our present knowledge in this brief review. With the prospect of many more fossil discoveries of interest, and the probability of discovery of some more living arthropods in inadequately explored portions of the continent, more of the outstanding questions may be resolved in the near future. At the same time, as the primitive groups existing in Antarctica become better known generally in the Southern Hemisphere, better interpretation of history and relationships can be made in the future.

Although the collection of the present living land arthropod fauna of Antarctica is probably not yet complete, recent efforts have increasingly concerned phases of entomology other than merely collection and classification. One-half of the above-mentioned "Entomology of Antarctica" concerned ecology or aspects other than systematics, and most of the present volume reflects this trend. As pointed out by Holdgate (1970), much of the study of antarctic biology until just a few years ago concerned the making known of the biota, whereas recently emphasis has turned to ecology, and particularly to the clarification of how the biota relates to the factors of the rigorous antarctic environment.

Recent entomological studies in Antarctica have involved several of the 12 SCAR (Special Committee for Antarctic Research, of ICSU = International Council of Scientific Unions) member nations. The British Antarctic Survey (principally P. J. Tilbrook 1967, 1970) has carried on ecological studies at Signy Island of the S. Orkneys and in the Antarctic Peninsula—S. Shetland Is. area. The Chilean Antarctic Research Program (F. Saiz, F. de Castri, R. Covarrubias and others) has done field work principally in the S. Shetland Is. The New Zealand Antarctic Research Program has done some ecological work on Collembola (Peterson, this vol.) and skua lice (Spellerberg, this vol.). Studies on the Australian National Antarctic Research Expeditions have largely been limited to the

1. Contribution from Bishop Museum, Honolulu; in part bearing on results of grants to Bishop Museum from the Office of Antarctic Programs (now Office of Polar Programs), National Science Foundation.
2. Bishop Museum, P. O. Box 6037, Honolulu, Hawaii 96818.

subantarctic (Murray 1967). Little has been noted in entomology from the USSR program (Rogacheva 1969). On the United States Antarctic Research Program a number of investigators representing Bishop Museum have made primary surveys, including Wise (Wise & Spain 1967, Wise & Shoup, 1967, this vol), Gressitt (1967a, b), Gressitt & Shoup (1967), Strandtmann and others (Strandtmann & Pittard 1968; Pittard, this vol.); and also ecological studies (Janetschek 1967, 1970; Strong 1967; Fitzsimons, this vol.; Peckham, this vol.; Gless 1967; and others).

Definition of Antarctic: In terms of terrestrial biology, the term antarctic encompasses areas where mean air temperatures do not exceed $+1.5\,^{\circ}C$ in any month of the year. This classification includes all of the antarctic continent, the nearby islands, the South Shetland Is., South Orkney Is., South Sandwich Is., Bouvetøya and Peter I øy. In the sense of this classification (Holdgate 1964: 182) the term "subantarctic" applies to areas with mean monthly temperatures ranging from $-3\,^{\circ}C$ to just over $+8\,^{\circ}C$, which is below the level permitting the existence of trees. The areas in this category are all islands: South Georgia, Marion & Prince Edward, the Crozet Is., Kerguelen, Heard I. and Macquarie (Gressitt 1970). Other islands which have been called subantarctic (Tierra del Fuego, Falkland Is., Tristan da Cunha, Gough, St Paul, New Amsterdam, Campbell, Auckland Is., Bounty, Snares, Antipodes) are in this classification termed Southern Cold Temperate.

The land arthropod fauna of Antarctica

In "Entomology of Antarctica" (Gressitt 1967a) 130 species (plus 2 or 3 questionable ones) were listed from Antarctica. These did not include the strictly marine mites, but included 56 parasitic species (mites, ticks, lice, flea). Thus about 77 free-living kinds were recorded. Of these, 56 are mites, 19 are Collembola and 2 are midges. One of the mites is wet-intertidal and one of the springtails is dry-intertidal. Since the publication of that volume, a few more records have been published:

Strandtmann & Tilbrook (1968) described 2 new species and added a new record:

Eupodidae

Cocceupodes australis S. & T. from Deception I., S. Shetlands.

Halotydeus signiensis S. & T. from Signy I., S. Orkneys.

Ereynetidae

Ereynetes macquariensis Fain, 1962, recorded from Signy I., S. Orkneys.

In Covarrubias (1968) 3 new kinds, a species and 2 subspecies, were described:

Brachychthoniidae

Liochthonius australis Covarrubias, Deception I., S. Shetlands.

Oppiidae

Oppia loxolineata ssp. *longipilosa* Cov., S. Shetlands & Antarctic Peninsula.

O. pepitensis ssp. *brevipectinata* Cov., Greenwich I., S. Shetlands.

Sitnikova (1968) described an oribatid mite of the Podacaridae from Molodezhnaya, *Petrozetes oblongus*, which may be a synonym of *Antarcticola meyeri* Wallwork, 1967, *Antarc. Res. Ser.* 10: 113.

Hughes & Goodman (1969) described a new astigmatic mite from Signy Island:

Hyadesiidae

Neohyadesia signyi H. & G., Signy I., S. Orkneys.

Some free-living mites are proving to have very wide distributions. Shiba (1969) records *Eupodes longisetatus* Strandtmann of Campbell I. and *Nanorchestes antarcticus* Str. from a subalpine forest in Japan.

Additional and questionable records: A young psocopteran (Bishop Museum) was taken from a pond NW of Blue Lake, near Cape Royds, 29 Jan. 1960. This was overlooked in earlier examination of collections. It might have been blown into the lake from supplies or from a ship entering McMurdo Sound. Some psocopterans are associated with dried foods, starch, paper and similar materials.

A dead aphid was found on snow at Brockton Station, 320 km E of McMurdo Sound; grid 270, lat. 79°S; long. 175°W; 1964. This might have come out of food supplies from New Zealand.

Saiz, Hajek & Hermosilla (1970) give records of unidentified species of several groups of land arthropods from the S. Shetland Is., some of which have not been previously recorded. Because of the nature of the experimentation they were carrying out with introduced materials, it may be suspected that some of these species were accidentally introduced by them, or by earlier visitors to the islands. The groups reported are:

Araneida. A young spider in control moss at 5–10 cm depth. Another spider was recorded from humus-rich sandy soil (Covarrubias 1966a). Spiders have not yet been proven to occur in Antarctica.

Psocoptera. Specimens in 3 control moss samples. Covarrubias (1966a) recorded a single specimen in lichens. Identification should demonstrate whether these represent native or widespread species.

Thysanoptera. Winged specimens (9) were taken in a surface moss control sample. Results of identification should be interesting. For instance, it might be the same as the species in South Georgia, which has a wide erratic distribution suggesting introduction by man.

Coleoptera: Lathridiidae. Larvae (12 + 1) probably of this family were found in 2 control moss samples. Previous records were by Balfour-Browne & Tilbrook, and by Schlatter et al. (1968).

Relationships of the antarctic fauna: Not a great deal can be stated of the relationships of the present antarctic land fauna because of the imperfect knowledge of the existing groups on nearby continents or islands. In general, there appears to be high generic endemism for inner Antarctica among the Collembola, and circum-antarctic relationships for most of those on the antarctic fringe. Among the free-living Acarina, also poorly known, quite a few of the genera are widespread on southern continents and some are even bipolar or nearly cosmopolitan. Some species appear to be quite localized and some widely distributed. As far as present studies go, endemic genera (2) have only been recorded for the Cryptostigmata (oribatid mites).

In general the subantarctic fauna is an extention of that of Antarctica, with a few more orders and families represented. There is at least considerable superficial similarity between the antarctic-subantarctic fauna and that on high mountain areas in S. Africa, New Guinea and New Zealand. These indications are in keeping with the facts of the break-up of Gondwanaland as now understood (see below).

As far as the antarctic fauna is known, it has relationships with all the major southern land masses. Probably more common elements will come to light as studies progress. The apparent high endemicity of Collembola genera (5 out of 13) may be reduced with more widespread investigation. However, this apparent evidence of divergence in isolation may prove factual and may prove that these elements survived the coldest periods of the Pleistocene in Antarctica. Other elements suggest that they might have recolonized Antarctica with aid of air currents after maximum glaciation. Some of the oribatid mites are salt-tolerant and might have floated to shores in the Peninsular area on driftwood.

Historical Biogeography

Much recent data has proven that Gondwanaland and continental drift were realities. Craddock (1970) has presented antarctic evidence on Gondwanaland stressing the following points:

1. Basement rocks of coastal E. Antarctica are similar to those of matching coasts of other continents.

2. Rocks of the Beacon Group in Antarctica are similar to Paleo- and Mesozoic Gondwana sedimentary successions on the other southern continents and continental islands—as old as Devonian. *Glossopteris* in Permian over glacial tillites. Succession matched in Australia, India, Madagascar, Africa, Falklands, South America.

3. Paleo- and Mesozoic fossil record in Antarctica similar to those of other southern continents for shallow sea forms and land forms. Common Triassic reptiles and amphibians significant. *Glossopteris* floras similar. Thus Antarctica could not have been isolated in Mesozoic.

4. Ellsworth Mts resemble the African Cape fold belt (both part of Samfrau Geosyncline— to fold mountains of E. Argentina).

5. Jurassic igneous rocks (abundant) similar to those in Brazil, S. Africa and Tasmania—a single igneous province—perhaps related to initial fragmentation of the protocontinent. More varied rocks with counterparts in Argentina and Australia may be products of activity in a mobile belt along the margin of Gondwanaland.

6. Late Cretaceous to early Tertiary igneous plutons, widespread in Antarctic Peninsula and along coast of W. Antarctica, are similar to intrusive rocks along west margin of America—Canada to Tierra del Fuego—and suggest that W. Antarctica is part of Mesozoic-Cenozoic circum-Pacific mobile belt—related to breakup of Gondwanaland. But few earthquakes in Antarctica in contrast to rest of Pacific fringe.

7. Sea-floor spreading and continental drift indicated by magnetic-anomaly belts parallel to and symmetrical about the mid-ocean ridges. Alternating belts ascribed to reversing of poles. When fully proven, chronology should become evident.

8. Antarctic Ice Sheet at least 7 million years old—suggesting Antarctica a separate polar continent by then. Some variation in climate, but essentially cold to temperate in the Tertiary.

Craddock indicated that du Toit's 1937 predictions apparently are all correct, making a strong case for Gondwanaland.

Colbert (1970) has presented an interesting preliminary report on the discovery of the exciting fossil land amphibians and land reptiles in Antarctica, at Coalsack Bluff. He indicated that earlier, continental drift had not been essential to explain the present distribution of fossil vertebrates. Recently, the similarity between Triassic S. African and South American reptiles indicated relationships and suggested evidence for Gondwanaland. Even then, some vertebrate paleontologists still held the earlier view that the distribution of fossils might have been the result of migration over the Bering Bridge. Now, however, with the discovery of fossil land vertebrates in Antarctica, continental drift had to be accepted.

The fossil land vertebrates found in the last 2 seasons at Coalsack Bluff, near the Beardmore Glacier in the Transantarctic Mountains, and now being studied, represent the following groups:

Amphibia: Labyrinthodontia. Large ancestral amphibians which probably lived in freshwater swamps; abundant and widespread in late Paleozoic and Triassic.

Reptilia: Archosauria: Thecodontia. Triassic ancestors of dinosaurs, birds and others. In particular, the genus *Lystrosaurus* was recognized. This land reptile also occurs as fossils in Africa, India and China, and proves that dry land connections existed between these continents.

Reptilia: Synapsida: Therapsida. These were mammal-like reptiles, characteristic of the Triassic of S. Africa, South America and India.

The Gondwanaland paleobotany is also of the greatest significance. Schopf (1970) indicated that Permian plants suggest that Antarctica was north of the Antarctic Circle at that time. The 4 genera *Glossopteris*, *Gangamopteris*, *Noeggerathiopsis* and *Paracalamites* have antarctic species very similar to those of other southern continents, showing lack of isolation in the Permian. The *Glossopteris* flora is fairly uniform on the different continents, with the dominant species of *Glossopteris* mostly the same in different areas. This clearly indicates intermigration between the present continents. *Glossopteris* commonly occurred in freshwater swamps and is an important constituent of Permian coal. Deposits of this sort would not be expected on isthmian links. *Glossopteris* was a gymnosperm and was not adapted to seed flotation or air transport. Nor were there any bird vectors in the Permian. The antarctic Permian flora is very similar to those of Brazil, Transvaal and India. Sea-floor spreading proves to be the most supportable process for separating of former parts of Gondwanaland. It may also account for displacement of the Ellsworth Mts in Antarctica (Schopf 1969). West Antarctica may not have been part of Permian Antarctica. The break-up of Gondwanaland probably took place before the Cretaceous.

Further geological evidence for the place of Antarctica in Gondwanaland, given by Frakes & Crowell (1970), stresses 3 points:

1. Shapes of the coastlines; comparative geology in the respectively fitting edges.
2. Paleomagnetic data—assembled over the past 25 years.
3. Sea-floor spreading—data accumulated in past 10 years.

The 1000 meter isobath has proved satisfactory for fitting Antarctica to the other southern continents. Among the matching areas are Tasmania and the Ross Sea; and the Adelaide Geosyncline and the Ross Geosyncline. Also S. Africa and the Weddell Sea and South America. There is a distinctive type of glacial deposit in S. Africa and the Weddell Sea area. Ice flowed onto S. Africa and Australia from Antarctica.

McElhinny & Luck (1970) showed that in studying lower Paleozoic data, Gondwanaland could be reconstructed from paleomagnetic measurements alone, and that the reconstruction is corroborated by the computerized fit of the continental shelves and the matching of geological age provinces.

As to the actual mechanism for the isolation of the former parts of Gondwanaland, sea-floor spreading now appears to be the answer to the question. At the same time it is answering many other earlier questions (Hayes & Pitman 1970). All oceans have a mid-oceanic ridge—2000–2500 meters above adjacent basins. Narrow trenches are mostly near borders of continents. The sedimentary layer may be 0–2000 m thick, but always is thin near the mid-oceanic ridges. Relevant data is provided by studies of magnetic field strength—magnetic anomalies where magnetic alignment differs from earth's field of magnetism; also, measurements of strength of earth's gravitational field indicates distribution of density in crust and upper mantle. The spreading consists of splitting of sea-floor at mid-oceanic ridges with new magma coming up. With the occasional reversing of earth's polarity, magnetism reverses, and studies of this proved the theory, through following points:

1. Magnetic anomaly lines parallel to ridge axis.
2. Anomalies symmetrical.
3. Magnetic model consistent with observations (S. Pacific).
4. Similar model applicable to other ridges.

There are also discontinuities consisting of fracture zones. Shallow-based earthquakes occur along the mid-oceanic ridges and young mountain ranges, whereas those near the ocean trenches are deep-based. In summary, sea-floor spreading explains:

1. Presence of mid-oceanic ridges with offsets.
2. Presence of oceanic trenches.
3. Distribution, amount and age of sediments.
4. Similarity of continental outlines.
5. Geologic fit of continents and other indications of polar wandering and/or continental drift.
6. Presence of long, linear magnetic stripes parallel to mid-oceanic ridges.
7. Symmetry in magnetic lineation pattern.
8. Distribution and nature of earthquakes associated with trenches, ridges and transform faults.

Earthquakes occur around Antarctica but not on the continent. This suggests that the crustal plates surrounding Antarctica are moving away from the antarctic plate, and probably have been for 35–40 million years, according to Hayes & Pitman.

Fossil insects

Unfortunately only a few fossil insects are known from Antarctica so not a great deal can be deduced on the basis of the existing data. However the fact that half the material came to light in just the last few years suggests that much further material may be forthcoming in the future.

Two beetles, *Grahamelytron crofti* Zeuner, 1959, and *Ademosynoides antarctica* Zeuner, 1959, were described from a mid-Jurassic deposit on Mt Flora, Hope Bay, at the northern tip of the Antarctic Peninsula. These species, known only from isolated elytra, are of obscure family relationships. The latter genus is known also from the mid-Jurassic of Chaliabinsk.

The wing of an insect was illustrated by Plumstead (1962) from the *Glossopteris* beds of the Theron Mts, Antarctica, but the specimen was lost. Carpenter (1970: 418) indicates that the illustration represents a homopteran.

Another specimen, a Permian wing attributed to the Homoptera (Fig. 1), was reported by Tasch & Riek (1969) from micaceous graywacke from the Polarstar Formation, Sentinel Mts. Carpenter (1970) studied this same specimen further, and stated that it has 2 additional longitudinal

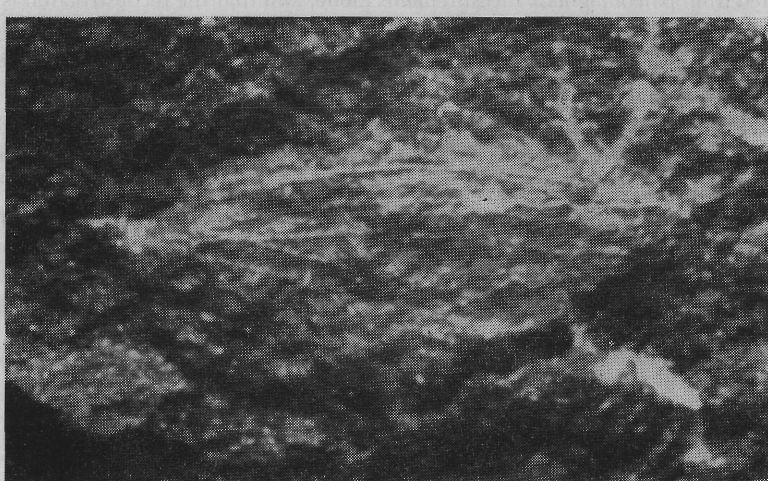

Fig. 1. Presumed homopteran wing from Polarstar Formation, Sentinel Mts (Tasch & Riek 1969), from photograph supplied by E. F. Riek. Kindness of authors, and *Science* (164: 1529): Copyright 1969 by the American Association for the Advancement of Science.

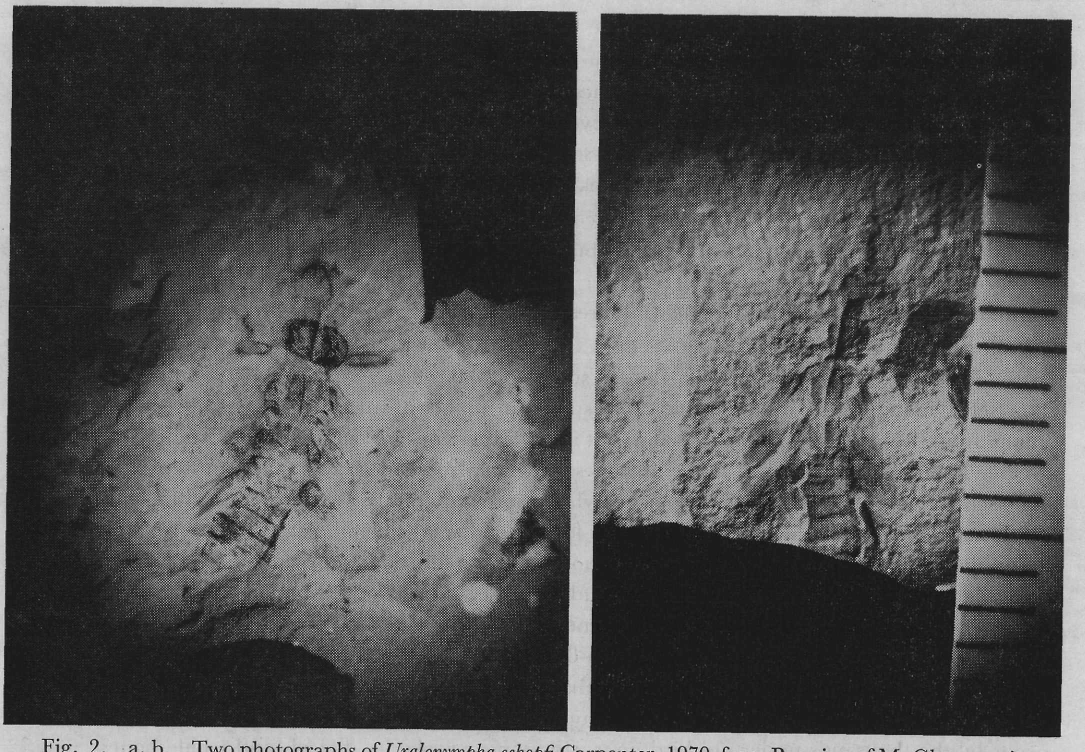

Fig. 2. a, b. Two photographs of *Uralonympha schopfi* Carpenter, 1970, from Permian of Mt Glossopteris Formation, Ohio Range. Prints supplied by J. M. Schopf.

veins and numerous cross veins, as well as a coarse rogosity of the wing membrane. However, its affinities are unclear.

Two better preserved antarctic fossil insects were described by Carpenter (1970). One of these, *Uralonympha schopfi* Carpenter (Fig. 2a, b) is Permian, from conchostracan-bearing beds of the Mt Glossopteris Formation, Ohio Range. Carpenter indicated that this nymph probably represents a plecopteran, but might be a protorthopteran.

The other species is *Caraphlebia antarctica* Carpenter, an odonatan of the suborder Anisozygoptera. It is from the Jurassic, from a pond deposit of the Mawson Tillite on Carapace Nunatak, S. Victoria Land. It belongs to the Liassophlebiidae (including Turanothermistidae), known also from the Jurassic of England and Siberia.

Additional Jurassic fossil insect specimens have been collected recently and are now being studied.

Ecology

Dunbar (1968) and Janetschek (1967, 1970) have shown that temperature is one of the least important factors limiting the occurrence of arthropods. Climatic change at the poles has been related to shift in position of the poles from that of open oceanic circulation to contained marine (Arctic) or continental (Antarctic) areas. High marine production characterizes the Antarctic.

The critical factor for supporting life is the availability of water as liquid or as moisture, requiring the local temperature to rise above 0 °C at times (Janetschek 1967, 1970). There is a diurnal cycle of activity corresponding with the temperature cycle. Areas which do not attain 0 °C on days with pronounced radiation remain devoid of life. Soil water content of at least 2% appears necessary to support arthropods, according to Janetschek.

The Bryosystem supports a moss-water community of protozoans, rotifers, nematodes and tardigrades. The Chalikosystem appears dry but includes some microphytes, and can support some microzoa, mites and Collembola. The latter are mostly represented by endemic genera in the far south, but there is usually just a single widespread prostigmatic mite species (*Nanorchestes*).

Population densities and biomasses are extremely small—up to 15 mg/l for Chalikosystem and in the Bryosystem from 100/sq.m in the far south to 10,000/sq.m or more on the antarctic fringe. Janetschek found higher numbers and more species at higher altitudes (around 1,000 m) somewhat inland from the coast in S. Victoria Land, but in my experience in several parts of Antarctica I found greater numbers in general at lower altitudes and often near the coasts or on quite small islands. Janetschek related his observations to areas which were apparently above the maximum Pleistocene glaciation, which may have served as refugia for the endemic Collembola. He did note that populations became reduced with progression to more southern latitudes. Covarrubias (1966b) reported similar diversity of species at different altitudes. There is a distinct tendency for populations to reach a peak near the middle of the short summer in the far south. Populations of the collembolan *Gomphiocephalus hodgsoni* Carpenter may reach 80 to 800 under one stone (Wise & Spain 1967). Janetschek (1970) quoted Törne as indicating that aggregations in Collembola may serve the purpose of combatting microbial influence on food supply. In the maritime antarctic, collembolans may occur by the thousands under old bird nests, stones near rookeries, boards and whale bones.

Janetschek indicated relative decrease of Collembola and increase of mites with increasing total biomass, perhaps related to denser vegetation. This is not always apparent, and my figures for the maritime antarctic (Gressitt 1967b) show collembolans still averaging higher numbers, while also averaging much larger body size. The abundant *Belgica*, where it occurs, also does not fit that pattern. In parts of N. Victoria Land, however, such as on Possession I. (Gressitt & Shoup 1967), very large numbers of mites were found with collembolans nearly absent. In S. Victoria Land the only free-living mites are Prostigmata, whereas in the Maritime Antarctic oribatid mites may occur in large numbers. The latter are mostly larger in size than the prostigmatic mites and are much less active.

As pointed out by Janetschek, the non-predatory Prostigmata are pioneers in inner Antarctica, starting with Pachygnathidae, Tydeidae and Eupodidae. The predaceous Rhagidiidae appear farther north and the Cryptostigmata (oribatids) only in N. Victoria Land in the Ross Sea sector. There is a general trend of increase in body size in these mites from south to north in this sector. The more southern Collembola also belong to families which include pioneers elsewhere (Onychiuridae, Hypogastruridae, Isotomidae), as noted by Janetschek.

Toward inner Antarctica the active season is short and the mode of overwintering is of particular interest. Janetschek (1967, 1970) estimated 90 days activity at 130 m at Cape Crozier and 57 days at 1200 m on Mt England, at similar latitude, both for the springtail *Gomphiocephalus hodgsoni*. Wise & Spain (1967) counted 96 days activity for the same species near sea lavel at same latitude. Hibernation appears to take place wherever the springtail is arrested by falling temperature, but only a fraction of the population survives the winter. Important factors determining successful establishment include the question of thawing of soil and possible duration of active period permitted by weather, in relation to life cycle.

Great opportunities for worthwhile research remain, in studying physiology and other aspects of biology, to answer many questions regarding the existence of life at, and near, its extreme limits of tolerance.

Acknowledgements: I am very grateful to F.M. Carpenter, E.F. Riek, J.M. Schopf and Paul Tasch for information, copies of reports and illustrations of fossil insects, and to Heinz Janetschek for his stimulus to Bishop Museum's participation in the U. S. Antarctic Research Program and his insight into the problems and significance of arthropod life in inner Antarctica.

Note: In a recent publication some of the data on the flora of South Georgia (Gressitt & Clagg, 1970, Pacif. Ins. Monogr. 23: 1–15) may be corrected (S. W. Greene, personal communication), as follows:

	As printed	Corrected
page 8, line 2 from bottom:	*Dicranum*	*Chorisodontium*
" 9, " 12:	*A. adscendens*	*A. decumbens*
" 9, " 22:	ferns are rare.	ferns are rare or absent.
" 9, " 2 from bottom:	*Rhacomitrium*	*Racomitrium*
" 10, " 20:	*Ophioglossum opacum*	*Ophioglossum crotalophoroides* Wait.
" 10, " 25:	**Cerastium holosteoides*	**Cerastium fontanum* Baumg.
" 10, " 26:	*Colobanthus crassifolius*	*Colobanthus quitensis* (Kunth.)
" 10, " 30:	*Acaena adscendens* ssp.	*A. decumbens* (Gaertn.) D.W. Walt.

In the same monograph, on pages 316, 330 and 342 I mistakenly synonymized *Neocanonopsis dreuxi* Hoffmann with *Christensenia antarctica* Brinck, according to G. Kuschel (personal communication).

BIBLIOGRAPHY

This bibliography includes literature cited in this brief review as well as recent antarctic entomological papers not cited in the introduction to "Entomology of Antarctica" (Gressitt 1967a).

Adie, Raymond J. 1970. Past environments and climates of Antarctica. *In:* Holdgate, Antarctic ecology, Academic Press, London, 7–14.

Boyd, William L. 1967. Ecology and physiology of soil micro-organisms in polar regions. Proc. Symp. Pacif.-Ant. Sci., Univ. of Tokyo, 1966; Nat. Sci. Mus., 265–75.

British Antarctic Survey, Annual Report, 1967–68 (Anon.). 1969. *Brit. Antarc. Surv. Bull.* **20:** 69–92 (Zool.: 74–77; Ent., 76, fig: electr. micr. photo of head of *Cryptopygus antarcticus*).

Brundin, Lars. 1970. Antarctic land faunas and their history. *In:* Holdgate, Antarctic ecology, Academic Press, London, 41–53.

Carpenter, Frank M. 1970. Fossil insects from Antarctica. *Psyche* **76:** 418–25, 6 fig.

Castri, F. di, R. Covarrubias & E. Hajek. 1967. Soil ecosystems in subantarctic regions. Symposium on ecology of sub-arctic regions. UNESCO, Helsinki.

Colbert, Edwin H. 1970. The fossil tetrapods of Coalsack Bluff. *Antarctic J. U.S.* **5**(3): 57–61, 5 fig. Paleontological investigations at Coalsack Bluff. op. cit. **5**(4): 86.

Covarrubias, R. 1966a. Observaciones cuantitativas sobre invertebrados terrestres antarticos y preantarticos. *Inst. Antart. Chile, Publ.* **9:** 1–53.

1966b. Estructura de las zoocenosis terrestres antarticas. *In:* Progresos en Biologia del Suelo. Monografias I, UNESCO, Montevideo, 343–47.

1968. Some observations on antarctic Oribatei (Acarina) *Liochthonius australis* sp. n. and two *Oppia* ssp. n. *Acarologia* **10**(2): 313–56, ill.

Craddock, Campbell. 1970. Antarctic geology and Gondwanaland. *Antarctic J. U.S.* **5**(3): 53–56, 3 fig.

Dunbar, M. J. 1968. Ecological development in polar regions. A study in evolution. Prentice-Hall, 119 p.

du Toit, Alexander L. 1937. Our wandering continents. Oliver & Boyd, Edinburgh, 366 p.

Forster, R. R. 1970. Appendix: Record from Antarctica—Family Micryphantidae. *Pacif. Ins. Monogr.* **23:** 42, fig. 27.

Frakes, Lawrence A. & John C. Crowell. 1970. Geologic evidence for the place of Antarctica in Gondwanaland. *Antarctic J. U.S.* **5**(3): 67–69, 2 fig.

Gless, Elmer E. 1967a. Entomological studies at Hallett Station. *Antarc. J. U.S.* **2**(4): 99.

1967b. Notes on the biology of *Coccorhagidia gressitti* Womersley and Strandtmann. *Antarc. Res. Ser.* **10:** 321–23, 1 fig.

Gless, Elmer E. & J. L. Gressitt. 1966. Entomological studies. *Antarc. J. U.S.* **1**(4): 145–46.

Gless, Elmer E. & Ellis A. Hicks. 1968. Entomological studies at Hallett Station. *Antarc. J. U.S.* **3**(4): 123.

Greene, S. W. 1967. The changing pattern of antarctic botanical studies. Proc. Symp. Pacif.-Ant. Sci., Univ. of Tokyo, 1966; Nat. Sci. Mus., 236–44.

Gressitt, J. L. (Editor) 1967. Entomology of Antarctica. Amer. Geophys. Union, *Antarc. Res. Ser.* **10:** xii, 395 p., ill.

Gressitt, J. L. 1967a. Introduction, Entomology of Antarctica. *Antarc. Res. Ser.* **10:** 1–33, ill.

1967b. Notes on arthropod populations in the Antarctic Peninsula—South Shetland Islands—South Orkney Islands area. *Antarc. Res. Ser.* **10:** 373–91, ill.

1967c. The fauna. *In:* Terrestrial life in Antarctica. *Antarc. Map Folio Ser.* (Am. Geogr. Soc., N.Y.) **5:** 17–21 (+21–24), pl. 1, 9, 10, 11 (fig. 1).

1968. Insects and their relatives [in Antarctica]. *Austral. Nat. Hist.* **16**(4): 124–28, ill.

1970. Subantarctic entomology and biogeography. *Pacif. Ins. Monogr.* **23:** 295–374, ill.

Gressitt, J. L. & Oliver S. Flint, Jr. 1966. Entomological collections. *Antarc. J. U.S.* **1**(4): 128.

Gressitt, J. L. & J. Shoup. 1967. Ecological notes on free-living mites in North Victoria Land. *Antarc. Res. Ser.* **10:** 307–20, ill.

Harrington, H. J. 1969. Fossiliferous rocks in moraines at Minna Bluff, McMurdo Sound. *Antarc. J. U.S.* **4**(4): 134–35.

Hayes, Dennis E. & Walter C. Pitman III. 1970. Marine geophysics and seafloor spreading in the Pacific-Antarctic area: A review. *Antarc. J. U.S.* **5**(3): 70–77, 11 fig.

Hermosilla, W., R. Covarrubias & F. di Castri. 1967. Estudio comparativo sobre la estructura de los zoocenosis edaficas en el tropico y en la Antartixa. IX Reunión Anual de Soc. de Biologia de Chile, Valparaíso.

Holdgate, M. W. 1964. Terrestrial ecology in the maritime Antarctic. Biologie Antarctique. Hermann, Paris, 181–94.

1967. The antarctic ecosystem. *Phil. Trans. Roy. Soc. Lond.* B **252**(777): 363–83.

Holdgate, M. W. (Editor) 1970. Antarctic Ecology. Academic Press, London, 2 vols.

Holdgate, M. W., P. J. Tilbrook & R. W. Vaughan. 1968. The biology of Bouvetøya. *Brit. Antarc. Surv. Bull.* **15:** 1–7, maps.

Hughes, A. M. & B. J. A. Goodman. 1969. *Neohyadesia signyi* (Hyadesidae: Acarina); a new genus and species from Signy Island, South Orkney Islands. *Brit. Antarc. Surv. Bull.* **22:** 39–48, ill.

Hunter, Preston E. 1967a. Mesostigmata: Rhodacaridae, Laelapidae (Mesostigmatic mites). *Antarc. Res. Ser.* **10:** 35–39, ill.

1967b. Rhodacaridae and Parasitidae mites (Acarina: Mesostigmata) collected by the British Antarctic Survey, 1961–64. *Brit. Antarc. Surv. Bull.* **13:** 31–39, ill.

Janetschek, Heinz. 1967. Arthropod ecology of South Victoria Land. *Antarc. Res. Ser.* **10:** 205–93, ill.

1970. Environments and ecology of terrestrial arthropods in the high Antarctic. *In:* Holdgate, Antarctic ecology, Academic Press, London, 871–85, 6 fig.

McElhinny, M. W. & G. R. Luck. 1970. Paleomagnetism and Gondwanaland. *Science* **168:** 830–32, 1 fig.

Mani, M. S. 1968. Ecology and biogeography of high altitude insects. *Ser. Ent.* 4. (see p. 396–407).

Mauri, Ricardo A. 1965. Acarina del sector Antartico Argentino. *Rev. Soc. Ent. Argent.* 27(1/4): 61–62.

Muller, D. B., F. R. Schoeman & E. M. van Zinderen Bakker. 1967. Some notes on a biological reconnaissance of Bouvetøya (Antarctic). *S. Afr. J. Sci.* **63**(6): 260–63, map.

Murray, M. D. 1967. Ectoparasites of antarctic seals and birds. Proc. Symp. Pacif.-Ant. Sci., Univ. of Tokyo, 1966; Nat. Sci. Mus., 185–91.

Murray, M. D., M. S. R. Smith & Z. Soucek. 1965. Studies on the ectoparasites of seals and penguins. II. *Austral. J. Zool.* **13**(5): 761–71, ill.

Peckham, Verne. 1967. Studies of the mite *Alaskozetes antarcticus* (Michael). *Antarc. J. U.S.* **2**(5): 196–97, ill.

Plumstead, E. P. 1962. Fossil floras of Antarctica. *In:* Trans-Antarctic Expedition, 1955–1958. Sci.Rep. 9, Geology, 154 p., 28 pl.

Pryor, M. E. 1967. Ecological observations in the Mirnyy area in 1962. Transl. *Soviet Antarc. Exped. Inform. Bull.* **6**(2): 174–77.

Rogacheva, E. V. 1969. Terrestrial vertebrates and biogeography of antarctic dry land. (Bibliography for the 1950–65 period). Antarktika: Dokl. komis., Moskva, Nauka, 145–200.

Saiz, Francisco, Ernst T. Hajek & Wladimir Hermosilla. 1970. The colonization of introduced litter by subantarctic soil and moss arthropods. *In:* Holdgate, Antarctic ecology, Academic Press, London, 897–907.

Schlatter, R. 1967. Observaciones ecologico-cuantitativas de los artropodos terrestres en la Isla Robert (Antartica Chilena). Tesis Univ. de Chile, Santiago.

Schlatter, R., W. Hermosilla & F. di Castri. 1968. Estudios ecologicos en Isla Robert (Shetland del Sur). 2. Distribucion altitudinal de los artropodos terrestres. *Inst. Antart. Chile, Publ.* 15.

Schopf, James M. 1969. Ellsworth Mountains: Position in West Antarctica due to sea-floor spreading. *Science* **164:** 63–66, 3 fig.

1970. Gondwana paleobotany. *Antarc. J. U.S.* **5**(3): 62–66, 10 fig.

Schuster, R. M. 1969. Results of bryological field work in the Antarctic Peninsula, austral summer 1968–1969. *Antarc. J. U.S.* **4**(4): 103–4 (*Belgica* record; 65° 38′ S).

Shiba, Minoru. 1969. Taxonomic investigations on free-living mites in the subalpine forest on Shiga Heights IBP area, II. Prostigmata. *Bull. Nat. Sci. Mus. Tokyo* **12**(1): 65–115, ill.

Sitnikova, L. G. 1968. O novom pantsirnom kleshche *Petrozetes oblongus* nov. gen., nov. sp. (Acarina: Oribatei) iz Antarktidy. *Sovet. Antark. Eksped., Inform. biull.* **67:** 75–76 (Engl. transl. in *Soviet Antarc. Exped. Inform. Bull.* **7**(1): 38, 1969).

Strandtmann, R. W. 1967. Terrestrial Prostigmata (Trombidiform mites). *Antarc. Res. Ser.* **10:** 51–80, ill.

Strandtmann, R. W. & Donald A. Pittard. 1968. Arthropods of the Convoy Range. *Antarc. J. U.S.* **3**(4): 124–25, ill.

Strandtmann, R. W., Don Pittard & Paul Schaefer. 1967. Prostigmatic mites and other terrestrial arthropods of Antarctica. *Antarc. J. U.S.* **2**(4): 106–7.

Strandtmann, R.W. & P. J. Tilbrook. 1968. Some Prostigmata (Acari) from Signy Island, South Orkney Islands, and Deception Island, South Shetland Islands. *Brit. Antarc. Surv. Bull.* **17:** 51–57, 3 fig.

Strong, Frank E., R. L. Dunkle & R. L. Dunn. 1970. Low-temperature physiology of antarctic arthropods. *Antarc. J. U.S.* **5**(4): 123.

Strong, Jack. 1967. Ecology of terrestrial arthropods at Palmer Station, Antarctic Peninsula. *Antarc. Res. Ser.* **10:** 357–71, ill.

Tasch, Paul. 1969. Antarctic paleobiology: New fossil data and their significance. *Antarc. J. U.S.* **4**(5): 198–99, ill.

1970. Paleolimnology of some antarctic nonmarine deposits. *Antarc. J. U.S.* **5**(4): 85–86.

In press. Antarctic and other Gondwana insects and conchostracans. New Data: Significance for drift theory. Abstract of paper presented at the 2nd Symposium on Gondwana Stratigraphy (South Africa).

Tasch, Paul & Edgar F. Riek. 1969. Permian insect wing from Antarctic Sentinel Mountains. *Science* **164:** 1529–30, 2 fig.

Tilbrook, P. J. 1967a. The terrestrial invertebrate fauna of the maritime Antarctic. *Phil. Trans. Roy. Soc. Lond.* B **252:** 261–78, ill.

1967b. Arthropod ecology in the maritime Antarctic. *Antarc. Res. Ser.* **10:** 331–56, ill.

1970a. The terrestrial environment and invertebrate fauna of the maritime Antarctic. *In:* Holdgate, Antarctic ecology, Academic Press, London, 886–96, ill.

1970b. The biology of *Cryptopygus antarcticus*. *In:* Holdgate, Antarctic ecology, Academic Press, London, 908–18, ill.

Voss, William J. & Spurgeon B. Strandtmann. 1969. Arthropods of southern Victoria Land. *Antarc. J. U.S.* **4**(4): 110.

Wise, Keith A. J. & A. V. Spain. 1967. Entomological investigations in Antarctica, 1963–64 season. *Pacif. Ins.* **9**(2): 271–93.