Paleoentomology – Towards the Next Decade

by Alan V. Morgan and Anne Morgan

The study of fossil insects has a long history and, despite the small number of specialists involved, it has made important contributions to our understanding of ancient environments and of the development of the modern insect world. The authors summarize the historical growth of paleoentomology and some of its applications to paleoclimatology, the history of CO₂ accumulation, and even nuclear waste disposal. (Ed.)

What is Paleoentomology?

Given a slight twist in the course of history, Charles Darwin might, perhaps, have been the first of the modern paleoentomologists. Certainly his interests in beetles, natural history, and contemporary geological processes would have stood him in good stead to pursue this multi-disciplinary field. Paleoentomology deals with lithified fossil insects, especially those of the Carboniferous, Jurassic and early Tertiary periods, and with fossil specimens composed of unaltered chitin that are closely related to, if not identical with, species living today (Fig. 1). This article concentrates on insects of Quaternary age (although modern species can be traced into late Tertiary time), and to members of certain families, especially Coleoptera.

The importance of paleoentomological research has yet to be fully understood, and it still largely remains as one of the untapped areas of Quaternary research. The field has many disadvantages, which have served to discourage potential researchers. However, the results achieved by a small group of scientists over the last three decades merit careful examination because they provide a different way of looking at traditional interpretations of Quaternary and Holocene events. Because of its multi-disciplinary nature, paleoentomology has also contributed much valuable information to modern insect studies.

The New Discipline Grows

Geologists have been familiar with fossil insect assemblages for at least 150 years (Lyell 1833). In the closing decades of the last century the popular wisdom that many of the species reported from Tertiary deposits were still extant was replaced by the concept of intense speciation. Practically all the insects that had lived prior to the "ice ages," or were of "interglacial" origin were deemed to be extinct forms (Seudder, 1895, 1900; Wickham, 1917). In the 1930s and 1940s Scandinavian entomologists had swung the pendulum back. Fossil Coleoptera of late Quaternary age were again matched with extant forms (Henriksen, 1933; Lindroth, 1948), and the foundation was set for current research. Most of the Scandinavian workers except Lindroth turned their attentions elsewhere, and the centre of research activity moved to Britain in the mid-1950s.

A fortuitous set of circumstances allowed the expansion of the subject area at Birmingham in central England, where there was a geology department with strong Quaternary interests and three scientists (F.R. Coope, F.W. Shotton and P.J. Osborne) deeply involved with biology, entomology and archaeology. Additionally, the region was endowed with a relative abundance of organic materials suited to fossil insect research, and the advent of radiocarbon dating was creating renewed interest in Quaternary research.

The three decades that have passed since the first faunal investigations at Chelford and Upton Warren have seen the establishment of research programs in North America, South America, Europe (Belgium, Denmark, France, Germany, The Netherlands, Poland, Sweden and Switzerland) the U.S.S.R. and New Zealand. Advances in other areas of the geological sciences have led to new methods of examining paleoentomological materials and the research front is being stimulated by a variety of approaches and interests. Additionally, the successful identification of fossil Coleoptera has initiated research interests in other families of fossil insects, notably the Trichoptera (caddis-flies), the Diptera (largely chironomids), and Hymenoptera (ants).

Clues to Ancient Climates

The aim of paleoentomology has been to provide details of the environment that supplement information from other fields. Traditionally, this has been in "natural" environments (not influenced by man), and the first success was to establish that different faunal assemblages had colonized Britain in the late Quaternary Period. Species in the various assemblages have been matched to modern counterparts often living today in northern Scandinavia or in Siberia. Because different species of beetles are frequently confined to certain substrates, habitats, and plant species, detailed environmental reconstructions could be made for the landscape surrounding the deposition site (Fig. 2). Certainly by the late 1960s, it was realised that the different assemblages could be recognized as chronostratigraphic indicators. Middle Devensian (Wisconsinan) assemblages were differentiated from subtly different ones of Early and Late Devensian age, and even the latter were sub-divided into quite short time intervals.

Because many of the species were sensitive to temperature, it was also possible to attempt climatic interpretations of the conditions under which the assemblages lived. Two important factors emerged. The first was the realization that a short-lived, but intense, climatic warming had occurred in Middle Devensian time (the Upton Warren Interstadial) centred around 42,000 yBP. Temperatures reconstructed from the insect assemblages at a number of locations in southern Britain indicate an interval as warm as, or warmer than, present day central England, that is an interglacial climate. A similar episode of warmth has

recently been determined for an insect assemblage in southwestern Ontario, dated at >50,000 yBP (Pilny and Morgan, in press).

Secondly, assemblages that post-date the last ice indicate an extremely rapid climatic amelioration in

Figure 1: Generalized carabid beetle with parts labelled that are usually found in Quaternary and northern Tertiary sediments. Courtesy of John V. Matthews.

Figure 2: Fossil beetle remains from a Late Pleistocene site in New York State. Complete (upper right, centre left), and broken (lower left) elytra, heads and thoraxes of a variety of different families are represented. Scale bar is 5mm long.

western Britain after 13,500 yBP, a period of extreme warmth before 12,500 yBP, a slide into the Siberian cold of the palynologically famous Younger Dryas, and an equally rapid climb out at 10,000 yBP (Coope et al., 1971). These dramatic climatic oscillations were later confirmed by the deep-sea interpretations of the shifting polar front in the European sector of the Atlantic (Ruddiman and McIntyre, 1973). Interestingly, these extreme temperature fluctuations and climatic reversals have not been detected in fossil insect assemblages of similar age in the North American mid-continent (Morgan, in press).

One of the more fascinating results is the apparent rapidity of response to climatic change demonstrated by the Coleoptera, especially when compared with the perceived record determined from pollen. The palynological lag-time first recognized by Coope et al., (1971), also appears to be present in North America (Morgan and Morgan, 1980), and has been more recently recognized in southern Scandinavia (Lemdaal, 1985). It seems that certain members of rapidly moving insect assemblages have the ability to colonize open landscapes permitting an independent interpretation of the environment prior to the establishment of more slowly

developing plant communities. In some cases this may complement palynological data (Ashworth et al., 1981), in others it provides a different viewpoint (Nielsen et al., 1986).

Contributions to Entomology

Aspects of interest to modern entomologists concern the longevity of recognizable species. Genitalia preserved in body cavities illustrate valid specific identification back to Middle Wisconsinan time (Angus, 1973). To judge by morphological similarity, many species exceed the duration of the Quaternary Period, and certain species in northern latitudes seem to be recognizable as far back as the Pliocene time (Matthews, 1976). Tremendous distributional shifts, which were quite unsuspected from the viewpoint of modern zoogeography, illustrate that the Quaternary faunal assemblages were exceptionally dynamic, with migrations of thousands of kilometres as a normal occurrence, even in Late Wisconsinan time. Also of interest is the longevity of species assemblages, indicating uniformity in group relationships through some of the largest ecological disruptions of the late Cenozoic (Fig. 3).

Recently, isotopic investigations have provided some interesting correlations between latitude and meteoric water intake in the composition of modern insect chitin. The full implications of past precipitation patterns and the analyses of fossil insect chitin have yet to be explored, but the research promises new insights into a different application of paleoclimate research.

Some Matters of Technique

The advent of cheap and easily available computing facilities has materially assisted the organization of fossil insect data. Bibliographic data together with ecological records for modern assemblages and fossil faunas have been entered in electronic databases at the University of Waterloo since 1978. Much of this information is now available for micro-computers. Objective attempts at climatic interpretation using computerized data bases have been made through joint research at the Universities of Birmingham and East Anglia (Atkinson et al., 1986), and statistical methods of analyzing fossil assemblages have been examined at a number of institutions.

In these days of "mission orientation" in research activity it is hard to pursue some of the basic needs of paleoentomology, such as the collection and observation of insect communities. However, the point should be made that the days of the "natural historian" did not die at the turn of the century. Indeed, with the pace of destruction of habitats, if

not whole ecosystems, the need for basic data gathering is even more important today than it was in the past.

Applications to Other Disciplines

In addition to the obvious contributions to Quaternary and entomological research together with the general

Figure 3: Pronotum of the rove beetle *Anotylus gibbulus* Eppelsheim from ?Sangamonian sediments, Toronto, Ontario, the only specimen yet recorded from North America. Fossils of the same species have been found at many sites in central England, and examples living today have been found in the Caucasus and at Vladivostok. Scale bar is 1mm long.

advancement of scientific knowledge, there are a number of specific areas to which paleoentomology can contribute, for example to nuclear waste disposal and to the study of climatic change. Quantities of medium, and in some cases high, level nuclear wastes are stored in above-ground, or slightly sub-surface facilities, pending investigation of deep storage containment. Questions raised by those responsible for the safe distribution of this highly toxic commodity, often involve the types of environmental interactions that waste storage facilities will encounter through time, usually in the range of several tens of thousands to several hundreds of thousands of years. Past environmental changes for given areas can be demonstrated by paleo-insect communities, and these can be utilized to project changes in future environments.

Similarly, the unique perspective provided by fossil insect assemblages in their rapid response to past climatic change can be used to provide background data to present studies of atmospheric accumulation of carbon dioxide. For example, insect assemblages, currently believed to be of last interglacial (Sangamonian/Eemian/Ipswichian) age, at latitude 71°N in Baffin Island contain treeline species. These indicate a mean July temperature between 5 and 6°C warmer than the same area today, and a mean annual temperature almost 4°C above that of present. If the assemblages are of last interglacial age, then the present concept of a 2-4°C warming because of man-induced CO₂ might be catastrophically underestimated, since the potential exists for a natural 4°C warming. Such a natural warming trend, coupled with a man-made temperature rise could force mean annual temperatures up by 6-8°C. An increase of this magnitude would have widespread implications in the melting of polar ice-caps, dislocation of climates, disruption of agriculture, and potential human conflict.

Over the last fifteen years there has been an increasing use of paleoentomology in archaeological investigations. The technique was pioneered by Osborne's analyses of Roman and Bronze age sites in Britain (Osborne, 1969), and now has been applied to many different sites in England, Iceland and

Greenland. These investigations have produced much information of agricultural, sociological, and historical importance, and have provided a wealth of detail to supplement traditional archaeological techniques (Buckland et al., 1974).

Despite its very considerable potential, paleoentomology is one of the youngest branches of the Quaternary sciences with, as yet, less than two dozen active researchers. Given time, increased funding and additional workers, the study of fossil insects will contribute substantially to understanding the Quaternary.

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