Some Applications of Palynology

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Origins of the Subject

Palynology, a word coined from the Greek verb *palynein*, to spread or strew around (Hyde & Williams 1945) refers to the study of pollen grains, the spores of ferns and mosses, and other microscopic objects. It is a wide ranging subject and includes such basic topics as pollen and spore development, morphology, chemistry and dispersal as well as the more practical application of pollen analysis in fields as diverse as hay fever, archaeology, biogeography, honey research, palaeoecology and geology (for example in the search for oil).

Although pollen grains have been objects of curiosity since the invention of the microscope - Nehemia Grew (1682) published descriptions of the pollen of the plants mercury, borage, mallow and others - it was not until 1916 that they were used seriously as a research tool. In that year Lennart von Post published his classic paper "Forest Tree Pollen in South Swedish Peat Deposits" and laid the foundations of modern pollen analysis. His method, which he referred to as "pollen statistics", made use of the fact that wind borne pollen grains are deposited in great numbers on any surface and accumulate in sedimentary deposits. A record of vegetation change is thus preserved in a wide variety of sediments, as in lakes, ponds, bogs, or on the sea floor. Pollen statistics made it possible to escape the limitations imposed upon Quaternary* geologists of the day who were trying to elucidate post-glacial history in Scandinavia by studying either macro-remains, leaves, seeds and fruits etc, preserved in successive layers of peat, or by determining the stratigraphy* of the peat deposit itself. Von Post emphasised that accurate identification of pollen grains and a sound knowledge of their production and dispersal were necessary for the reliable application of his method.

New Zealand Studies

The potential of von Post's pollen statistics was not lost upon his Scandinavian colleagues, but because the paper was published in an obscure Swedish journal during the turmoil of World War I, the method was only slowly adopted around the world. Although Erdtman (1924) reported podocarp pollen in Chatham Islands peat, "pollen statistics" were not introduced into New Zealand until twelve years later. Then, using Southland and Otago samples collected in 1909 by a visiting Swedish geologist, Lucy Cranwell & von Post (1936) demonstrated a post-glacial succession from open grassland and shrubland of the late-glacial through pure podocarp forest to the more familiar forests of today in which beech (*Nothofagus*) either plays an important role or is dominant. Just as von Post was able to correlate the successive stages of vegetation he recorded in Sweden with climatic events, so Cranwell and von Post were able to make similar correlations for southern New Zealand. Thus, they suggested that the grassland period represented the cold of the closing stages of the last glaciation, followed by a mild and generally moist climate of the podocarp phase which deteriorated into cooler conditions leading to the spread of *Nothofagus*.

The implications of these results for ecologists and Quaternary geologists were clear, but further work was delayed by World War II, following which DSIR began to explore the possibilities of pollen analysis for New Zealand. In the decade following the war, Botany Division initiated studies on air-borne pollen and pollen in honey, and revived work in vegetation history, led by the late W.F. (Bill) Harris. Of these, the first, with the clear objective of providing pollen calendars for doctors treating hay-fever patients, was the most

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* See glossary at end for definitions of technical terms

productive (Filmer & Harris 1947, Clark 1951, Licitis 1953). During this period R.A. (Ash) Couper, New Zealand Geological Survey, began work in stratigraphic palynology which resulted in his classic study of the pollen grains and spores of fresh-water deposits of Upper Cretaceous and Tertiary age (Couper 1953). His work was later very useful in searches for petroleum-bearing rocks in our region.

For the next twenty years DSIR alone supported palynology in New Zealand on a continuing basis. At about the end of this period the 9th congress of the International Quaternary Association was held in Christchurch (1973). This provided the opportunity to demonstrate the contribution palynology could make to resolving Quaternary problems and further encouraged university departments to develop their own palynological skills. Some had tried earlier. Soon after the war Martin Te Punga, Victoria University College, (1948) published descriptions of fossil pollen grains in Kaitangata coal beds and years later Howard Lintott, University of Canterbury, (1963) produced a post-glacial pollen diagram from Kettlehole Bog at Cass. After the congress the universities began to encourage students to tackle palynological topics and some appointed staff to teach the subject. Progress was slow at first, but as the value of the work, and its quality, became obvious, the momentum increased until a trickle of work has now become a flood with major contributions in different branches of palynology coming from universities, Landcare Research and the Institute of Geology and Nuclear Sciences.

Nothofagus

Nothofagus, the southern beech, indigenous to Australia, New Zealand, New Caledonia, New Guinea and South America, provides a good example of the wide range of pollen analytical and morphological work undertaken. For many years it was realised that extant species of *Nothofagus* were represented by two distinct pollen types, the *menziesii* type and the *fusca* type, represented in New Zealand by *N. menziesii* and *N. fusca*, *N. truncata* and *N. solandri* s.l., respectively (Fig 1). It also became apparent that another pollen type occurred as a fossil in Tertiary sediments in Australia, New Zealand and South America. It was first described as the *cranwellae* type (Couper 1953), but later became known as the *brassi* type because of its obvious affinity with the pollen of the recently discovered *Nothofagus* species in New Guinea, of which van Steenis (1952) designated *N. brassi* as the type species. Palynologists were able to work comfortably with these three informal groups which, however, with the exception of the *brassi* type, did not conform with current taxonomic classification, a primary division of which was based upon the presence or absence of the deciduous habit. This difficulty was resolved when it was realised that the deciduous habit had arisen on more than one occasion during the evolution of the genus and therefore could not be used as the basis for classification (Hill & Read 1991, Hill & Jordan 1993). These authors focused on a wider set of characters such as floral structure, pollen morphology, wood anatomy and leaf structure, and recognised four subgenera, *Nothofagus, Fuscospora, Lophozonia* and *Brassospora.* In the meantime further study of fossil *Nothofagus* pollen by palynologists (Dettmann et al. 1990) showed that besides an ancestral type known from the Late Cretaceous, there are six other pollen types, two within *Fuscospora,* three within *Brassospora* and the one within *Lophozonia* (*menziesii* type).

The origins of *Nothofagus* are now much better known as a result of the palynological studies noted above. The genus, represented by an ancestral type, entered New Zealand in the Late Cretaceous about eighty million years ago rather later than it did in south eastern Australia (Dettmann et al. 1990). The sub-genus *Fuscospora* (*fusca* type pollen) first appeared in New Zealand some sixty million years ago and was followed twenty million years later, in the Eocene, by the sub-genera *Lophozonia* (*menziesii* type) and *Brassospora*. Of these three sub-

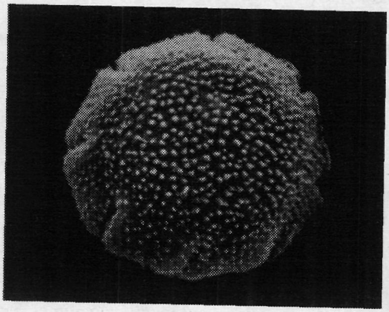

Fig. A

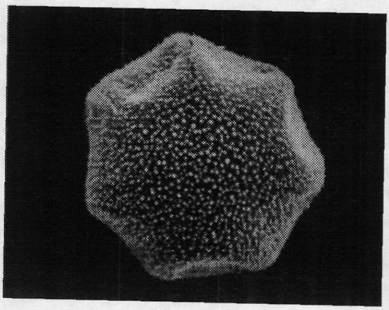

Fig. B

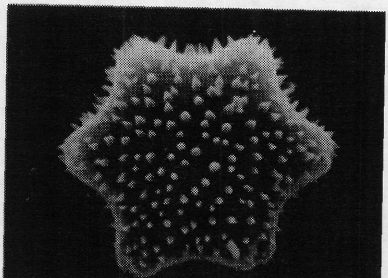

Fig. C

Caption for Fig 1:
The three main pollen types of *Nothofagus* in New Zealand: A: *Fusca* type (*N. solandri* var. *cliffortioides*), x100; B: *Menziesii* type (*N. menziesii*), x750; C: *Brassi* type (*N. pullei*), x1500. From Landcare Research collection.

genera *Brassospora* failed to survive into the Quaternary and judged by the number of fossil taxa which formerly occurred in the country, some sixteen in all, each of which may represent several species, the present flora is no more than a remnant of a formerly very diverse genus. The palaeoecology of *Nothofagus* in New Zealand is now well documented and the reader is referred to the overview recently published by McGlone et al. (1996).

Vegetation Disturbance

The New Zealand landscape has always been subject to change and I will now briefly discuss the application of pollen analysis to problems relating to disturbance involving both natural phenomena and human interference. The alternation between grassland and forest, reflecting long-term differences between glacial and interglacial periods, is well documented in pollen diagrams, as are the devastating effects of human impact upon the environment. Equally, the effects of violent, but short term events such as earthquake, volcanic eruption, fire and storm, can also be identified by pollen analysis although sometimes very close sampling is necessary to detect these.

In Canterbury the evidence for forest destruction was recognised from the earliest days of European settlement, but was only clearly articulated when Molloy et al. (1963) concluded that dated charcoal in the mountain and downland soils of Canterbury and Otago represented the devastation of fires resulting from human occupation about 700 years ago. Later McGlone (1983) summarised data from pollen diagrams throughout New Zealand and showed that the rapid decline in forest pollen, accompanied by an equally rapid increase in bracken spores, grass pollen and charcoal in the upper levels of pollen diagrams was also attributable to fires resulting from the activities of these first immigrants into New Zealand. Subsequently changes in pollen frequencies, and charcoal counts, detected by fine resolution analysis, i.e., pollen analysis of samples taken at very close age intervals (sometimes 1cm apart), have been shown to be correlative with events such as: the Taupo eruption of 1800 yrs B.P.; the impact of both Polynesian and European settlers; and of recent major storms of the intensity of the Esk Valley disaster (1938) or of Cyclone Bola in 1988.

Studies from central North Island provide a good example of this work (Wilmshurst 1997, Wilmshurst & McGlone 1996, Wilmshurst et al. 1997). Pollen diagrams from Lake Tutira and elsewhere in Hawkes Bay, clearly record changes in the vegetation of the area resulting from the devastating fires following occupation of the area by Polynesian immigrants and to a lesser extent changes caused directly or indirectly by the Taupo eruption of 1800 years BP. The pollen diagrams further show that localised disturbance by fire, interpreted as the result of lightning strike, has been a continuing process marked by minor fluctuations in the curves for principal taxa, by a temporary increase of pollen of colonist plants such as tutu, herbs and minor fluctuations in the charcoal curve. This clear demonstration of continuing short term, local disturbance not only offers insights into the response of the vegetation to various degrees of disturbance, but also provides clues as to the possible response to future events whether they be storm, earthquake, eruption or fire.

Honey Studies

Pollen analysis has many other applications than those already mentioned. Some depend upon the fact that nectar bearing plants rely on insect visits to effect pollination. Pollen studies (e.g. Moar 1985) are used to determine the geographical origins of a honey, the floral source of a particular honey, and as a method for quality control of the product. It is more reliable than the traditional tests based on taste, colour and odour.

The method depends upon the fact that pollen is taken up in the nectar by foraging bees and is incorporated into the honey store when the bee returns to the hive. The detail of any analysis depends upon the desired outcome. Therefore, in order to determine the geographical origins of a honey analysis is based upon counts of 300 - 500 pollen grains which allows recognition of a pollen spectrum from a particular area as well as the calculation of relative pollen frequencies to provide a rough approximation of nectar sources. Thus a New Zealand honey containing goats rue (*Galega officinalis*) pollen originates in the Manawatu, honey with thyme (*Thymus*) comes from Central Otago, and a honey in which rewa rewa (*Knightia excelsa*) is frequent originated in the North Island. On the international scene a pollen analyst in the northern hemisphere would conclude that a honey yielding a spectrum including both manuka and white clover pollen derived from New Zealand. Indeed, the presence of such pollen in so called English clover honey has been used to convict dishonest Englishmen for selling their local honey mixed with New Zealand clover honey as pure English honey.

Determination of the floral source of a honey demands examination by the more stringent quantitative pollen analysis from which is derived the absolute number of pollen grains in a 10 gram sample. Tablets containing a known number of *Lycopodium* spores, generally between 10,000 - 12,000, are added to the sample which is otherwise prepared and the grains counted by standard procedures. By this method it is possible to determine whether a honey is unifloral, i.e. derived from a single source, or whether the honey is derived from a variety of sources. Absolute counts demand a knowledge of the pollen production of the species involved. Thus a prolific producer of pollen e.g. kamahi, will contain many more pollen grains in relation to its nectar content than a poor pollen producer such as thyme. The pollen of the first is "over-represented" and that of the second is "under-represented" in relation to a medium or "normal" pollen producer such as white clover. To be accepted as a unifloral clover honey a sample must contain a minimum of 45% clover honey as laid down by the International Commission for Bee Botany. On this basis a unifloral kamahi honey must contain a minimum of 60% kamahi pollen in contrast to the minimum of 20% required of a unifloral thyme honey. Similarly unifloral manuka and matagouri honey must contain 70% respectively of the principal pollen type whereas a rewa rewa honey is accepted as unifloral if it contains no less than 10% rewa rewa pollen.

In Europe honey imports are subject to pollen analysis. Unless a named product conforms to accepted standards, as outlined above, it may be returned to the country of origin at the exporter's expense.

Modern Pollen Rain Studies

Other applications of palynology in New Zealand include studies of pollen or spores of living plants and studies of air-borne pollen e.g. as a means of adding precision to the interpretation of fossil pollen counts, or as a tool in understanding the causes of hay fever. Both depend upon the dispersal of wind-borne pollen of native and exotic species. Another application, only recently taken up seriously, both here and overseas, is that of forensic palynology. There is not much published information, but the method has been successful in proving responsibility for particular crimes both in New Zealand and overseas and generally depends upon comparing pollen spectra from a suspect's clothing or some other object with pollen spectra from the scene of a crime. One early success overseas resulted in a murder conviction when comparable pollen spectra obtained from the clothing of suspect and victim proved that the suspect was lying as to his movements at the time of the murder. In New Zealand Mildenhall (1990) was able to show that deer velvet in the possession of a suspected thief had been taken from a farm yard and not in dense native forest as claimed.

Sometimes it is necessary to monitor by pollen analysis products imported into New Zealand, and supplementary bee foods are one of these. One such import came under suspicion because of uncertainties regarding the country of origin and the fear that it could introduce disease into the New Zealand bee population. The importer claimed that any pollen contained in the product was added locally, but when told that the pollen spectrum was atypical of this country stated that it originated in Europe. A detailed pollen analysis established that the product, or at least the pollen contained in it, came from many different environments in North America, including deserts, forests, grasslands and wastelands. The product was destroyed at the importer's cost.

Conclusion

The modern practice of palynology has come a long way since publication of von Post's classic paper on pollen statistics. It has contributed so much to so many branches of science - archaeology, biogeography, palaeoecology, medicine (hay fever and related allergies), forensic science, stratigraphy, systematics, and taxonomy that its future seems assured. Fifty years ago it was considered to be at the cutting edge of the palaeoenvironmental sciences - today some of these applications have been taken over by other techniques such as isotopic dating, but it still remains one of the most useful tools available in the many fields of endeavour indicated above.

Glossary

Quaternary: The geologic period following the Tertiary, about 2 million years long and including the Pleistocene (characterised by a series of major glaciations, and the Holocene (the last 10 000 years).

Stratigraphy: The study of the order of succession of strata e.g. in the earth's crust, peat bog etc.

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