Spores and pollen from glacial erratics in the Grove Mountains, East Antarctica

A. M. Fang,[1] X. H. Liu,[2] W. M.Wang, [3] and J. I. Lee[4]

[1]Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China (fam@mail.igcas.ac.cn)
[2]Institute of Tibet Plateau Research, Chinese Academy of Sciences, Beijing 100029, China (xhliu@mail.igcas.ac.cn)
[3]Nanjing Institute of Geology and Palaeontology, Chinese Academy of Science, Nanjing 210008 (wmwang@nigpas.ac.cn)
[4]Korea Ocean Research and Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea (jilee@kordi.re.kr)

Summary Glacial erratics containing sparse spores and pollen derived from a suite of glaciogene strata hidden beneath the Antarctic Ice Sheet have been found in the Grove Mountains, east of the Lambert Glacier drainage system, Antarctica. The assemblage includes angiosperm and gymnosperm taxa of possible Neogene age with a minor recycled component. The miospores differ from those described from several other Cenozoic Antarctic localities, but include some similar taxa to the Pliocene Meyer Desert Formation. As a primary conclusion, we suggest that the occurrence of these pollen assemblages present new evidence for a large scale glacial retreat event in the Grove Mountains of east Antarctica.

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Introduction

Because of the extensive coverage of the ice sheet, Cenozoic strata that contain fossils are very scarce and only outcrop sporadically in Antarctica. Therefore, more biostratigraphic data are needed to reconstruct the Cenozoic biostratigraphic framework in Antarctica, which is the basic evidence for recovering the glacial and climatic evolutionary histories of this continent. During the field surveys made by the Chinese National Antarctic Research Expedition (CHNARE) team in the Grove Mountains, east Antarctica (Figure 1), large quantities of glacial erratics of Cenozoic sedimentary rocks were found in the moraine banks that are extensively distributed in this area. Lithologically, most of the erratics are glaciogenic diamictons, so they are supposed to be derived from a suite of glaciogene strata hidden beneath the Antarctic Ice Sheet in the Lambert glacier drainage system (Fang et al., 2004). By micropalaeontological analyses, these sedimentary erratics contain some Cenozoic spores and pollen grains. Here we report the preliminary results from the sporo-pollen study on the samples collected during the last geological field surveys made by CHNARE.

Regional backgrounds

The Grove Mountain Range is situated within the largest ice sheet drainage system of the Lambert-Amery ice shelf in east Antarctica, between the two ice-free areas of the Prince Charles Mountains (PCM) and the Larsemann/Vestfold Hills (Figure 1a). It is composed of 64 isolated nunataks distributed as 5 parallel island chains extending from SSW to NNE within an area of about 3,200 km^2 (Figure 1b). The East Antarctica Ice Sheet (EAIS) flows in a northwestward direction from the inland continent through this region into the Lambert Rift.

In recent years, detailed investigations on Cenozoic sedimentary rocks that were responsible for the reconstruction of regional ice sheet movements in Prydz Bay and its inland basins have been carried out in this region, which greatly improved the understanding of the evolution of the Lambert Glacier as well as the EAIS (Labia et al., 1997; Quilty, 1992; Harwood et al., 2000, Whitehead and McKelvey, 2001; Hambrey and McKelvey 2000a, b). Cenozoic sedimentary erratics in the Grove Mountains were apparently produced by the activities of the Lambert Glacier, and therefore, they also contain the same invaluable information (Fang et al., 2004; Fang et al., 2005). Furthermore, because of its special position, these erratics also provide correlations between different units of Cenozoic sedimentary rocks found in the Prince Charles Mountains and the Larsemann/Vestfold Hills.

Samples and methods

All the samples analyzed were collected from a debris belt named the “west-Dike Detritus Strip” which is lying over the blue ice to the west of Mt. Harding in the center of Grove Mountains (Figure 1c). According to different degrees of lithification and consolidation as well as differences in their textural characteristics, these erratics can be subdivided into 4 types of lithofacies (Fang et al., 2005). All together 12 samples from the 4 lithofacies have been selected to conduct sporo-pollen analyses in the laboratory of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Routine sporo-pollen analyzing procedures dealing with Quaternary sediments (Faegri and Iversen, 1989) were used as references to process all the samples in the laboratory. Pollen grains were identified and counted on 4 to 6 slides for every sample, however, for those samples that contained very sparse pollen grains, almost all the grains in the extracted residues were checked for identification.

Results

The abundance of pollen and spores in the erratics varies greatly from sparse to rare, with a maximum concentration of less than 10 grains per 10g of dry sediments, which occurs in sample S1604. After having observed all slides made from these 12 samples, a total of 191 grains of pollen and spore have been obtained. By further identification, they belong to a total of 27 pollen taxa and 7 spore taxa, including: Toroisporis (Lygodiaceae), Granulatisporites (Pteridaceae?), Osmunda (Osmundaceae), Polypodiaceae, Magnastriatites (Parkeriaceae), Deltoidospora, Araucardiaceae, Taxodiaceae, Podocarpus (Podocarpaceae), Dacrydium (Podocarpaceae), Pinus (Pinaceae), Keteleeria (Pinaceae), Picea (Pinaceae), Tsuga (Pinaceae), Chenopodiaceae, Artemisia (Asteraceae), Asteraceae, Gramineae, Fraxinoipollenites (Oleaceae), Oleoidearumpollenites (Oleaceae), Oleaceae, Operculumpollis, Nothofagidites (Nothofagus), Rhus, Quercus (Fagaceae), Juglans (Juglandaceae), Pterocarya (Juglandaceae), Liquidambar (Hamamelidaceae), Ulmus (Ulmaceae), Ulmoidepites (Ulmaceae), Tilia, Proteacidites (Proteaceae) and Tricolpopollenites. These are characterized by species of genus Pinus, Picea, Podocarpus, Osmunda, Nothofagus, Chenopodiaceae, Artemisia and Quercus. Some of these grains were decayed and considered to be recycled from older sedimentary rocks.

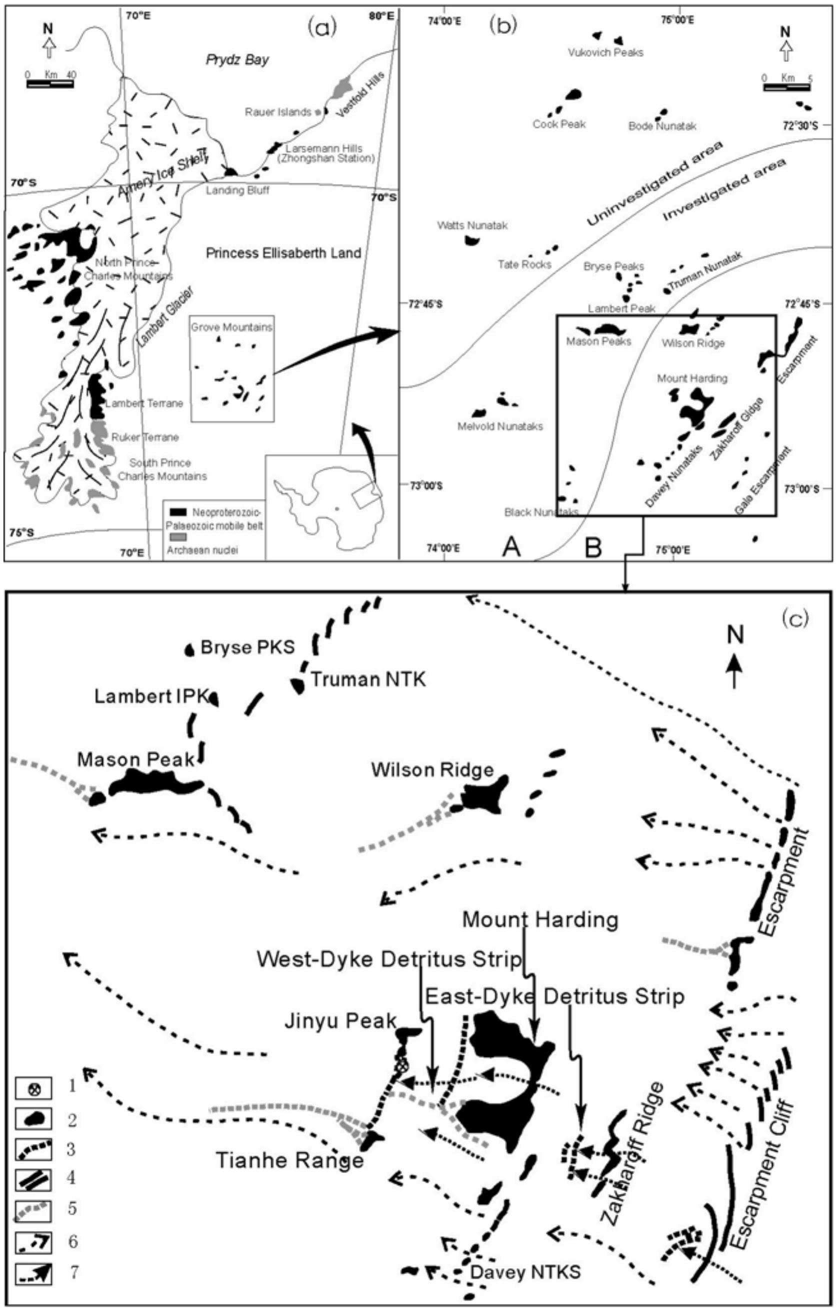

Figure 1 Location (a) and geographic map (b) of Grove Mountains and sampling position(c) (modified after Liu et al., 2003, Fang et al., 2004. 1. sample location; 2. nunataks; 3. terminal moraines; 4. ice-cliff; 5. lateral moraines; 6. modern ice flows; 7. ice flows in last glacial maximum.

From the occurrences of pollen and spores in the samples we studied, the abundances of the gymnopspermous pollens (such as Pinaceae, Podocarpus and Araucardiaceae) and the angiosperm pollen (such as Chenopodiaceae and Atemisia) are relatively high, while those of the fern spores are very low. Among the major types of sporo-pollen, Pinus is the predominant component, and Picea, Podocarpus, Chenopodiaceae, Osmunda, Quercus and Artemisia are the subordinate. In addition, there are also a few sporo-pollen grains from the species of shrubs (Nothofagus) and ferns. Therefore, palaeo-flora represented by these pollen assemblages is a complex one.

Besides these common characteristics, the sporo-pollen found in the lithified samples (S1501 and Nj02) differ from those in the unlithified samples in that the former does not contain any herbacous pollen, while the latter contains some pollen grains of Chenopodiaceae, Artemisia, Asterace or Gramineae. As a result, the sporo-pollen assemblages that occurred in these samples might belong to different ages, which is correspondent to the results obtained from our former studies (Fang et al., 2004).

Discussions

Source analysis

Although some of the sporo-pollen grains occurred in the studied samples might be recycled from some older sedimentary sequences by erosion and transportation of ancient glaciers as they have broken shells with dark colors. We believe that these grains have not transported since most of the sporo-pollen grains are well preserved and they are different from those transported or recycled pollen as reported in the surface samples in Rose Sea (Truswell and Drewry, 1984) and Prydz Bay (Macphail and Truswell, 2004a,b). Furthermore, the source areas of the rocks that bear these pollen and spores are assumed to be local, or from up-glacier areas flow lines originating in the Grove Mountains according to our previous work (Fang et al., 2004). Therefore, we conclude that these pollen assemblages are *in situ* deposits.

Correlations

Compared with pollen assemblages found in the Sirius Group in Transantartic Mountains (Askin and Markgraf 1986, Hill and Truswell, 1993, Webb and Harwood, 1987, 1993) and in the sequences of drill holes of CIROS-1 and CRP-2/2A from the McMurdo Sound (Mildenhall 1989) and CRP from the southern Victoria Land (Raine, 1998; Askin and Raine, 2000), pollen assemblages found in the erratics of the Grove Mountains show much more diversity since components inside the latter are fairly monotonous. They do, however, contain more similar plant species from the vegetation of the Meyer Desert Formation (Ashworth and Cantrill, 2004).

Furthermore, compared with plant microfossils recovered from the stratigraphic sequences penetrated during Ocean Drilling Program (ODP) of Leg 188 and Leg 119 in the Prydz Bay (Macphail and Truswell, 2004a, 2004b), the glacial erratics from the Grove Mountains contain more pollen grains from herbaceous species and *in situ* components. This suggests they represent a younger *in situ* terrestrial flora, while the later are supposed to be recycled from old strata ranging in age from Permian and Early Jurrassic to late Eocene, Oligocene and early Miocene (Macphail and Truswell, 2004a, 2004b).

Ages

The composition of the pollen assemblages from this study shows that they are similar to a southern hemisphere Neogene flora since most species in these assemblages lived in a Neogene Weddellian biogeocenose. The major pollen types, such as the Penaceae, *Podocarpus*, *Araucardiaceae*, Chenopodiaceae and *Artemisia* are common components of a Neogene flora in Gondwana continent.

The occurrence of pollens of the herbaceous angiosperm and their abundance in a sporopollen assemblage are the most important indicators for distinguishing and subdividing a Neogene stratum (Wang, 2004). Although the abundance of the pollen of the herbaceous angiosperm species is not so high in the sporopollen assemblage we studied, some *Atemisiaepollenites*, Chenopodiaceae and Gramineae species did occur in the semi- to weakly-lithified samples analyzed (S1507, S1509, S1514, S1604, S1605, S1606, Nj04, Nj05, Nj07 and Nj08), therefore, it can be inferred that the formation age of the sporopollen assemblage in these samples be classified as Neogene.

As for the sporopollen assemblage in the lithified erratics, such as samples 1501 and Nj02, they do not contain any pollen of the herbaceous angiosperms, indicating they must be older than the herbaceous angiosperm-bearing assemblage suggesting this assemblage might have formed in the Miocene or Oligocene age.

Summary

Spores and pollen grains from the glacial erratics found in moraines of the Grove Mountains, east Antarctica provide useful information in revealing the Cenozoic glacial and climatic evolutions of the region. Most of the pollen and spores originated from local sources except for some older exotic components that might have been recycled from the basement sedimentary rocks as a result of the ice sheet, so they are considered to be *in situ* sporo-pollen assemblages. Furthermore, because of the inland geographic location of the Grove Mountains, these pollen assemblages should represent a continental flora that survived at a certain period of time in this region. Compared with Neogene microfossil assemblages reported in places within the Antarctic continent or its surrounding areas, the pollen assemblage found in the erratics of the Grove Mountains contains more similar plant species than the vegetation of the Meyer Desert Formation, however, it also has Northern Hemisphere characteristics (most similar to that derived from modern Chinese floras), which is unusual because it has never been recorded before from Antarctica or a from Southern Hemisphere fossil pollen assemblage. Based on the finding of some diagnostic pollen, such as *Artemisia* and Chenopodiaceae, these assemblages may belong to the late Tertiary (most probably Pliocene). Considering current climatic and environmental conditions in the Grove Mountains (Liu et al., 2003), there must have been a climate much warmer than today and a large scale glacial retreat for the formation of these fossils in the local erratics in the Grove mountains, thus supporting a dynamic EAIS.

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References

Askin, R. A., and V. Markgraf (1986), Palynomorphs from the Sirius Formation, Dominion range, Antarctica, Antarct. J. U.S., 21(5), 34-35.

Askin, R. A., and J. I Raine (2000), Oligocene and early Miocene terrestrial palynology of the Cape Roberts drillhole CRP-2/2A, Victoria Land Basin, Antarctica, Terra Antartica, 7, 493-501.

Ashworth, A.C., and D. J. Cantrill (2004), Neogene vegetation of the Meyer Desert Formation (Sirius Group), Transantarctic Mountains, Antarctica, Palaeogeogr. Palaeoclimatol. Palaeoecol., 213, 65-82.

Faegri, K , and J. Iversen (1989), Textbook of pollen analysis (4th ed.), Wiley, Chichester.

Fang, A. M., X. H. Liu, J. I. Lee, X. L. Li, and F. X. Huang (2004), Sedimentary environments of the Cenozoic sedimentary debris found in the moraines of the Grove Mountains, east Antarctica and its climatic implications, Prog. Nat. Sci., 14, 223-234.

Fang, A. M., X. H. Liu, X. L. Li, F. X. Huang, and L. J. Yu (2005), Cenozoic glaciogenic sedimentary records found in the Grove Mountains of East Antarctica, Ant. Sci., 17, 237-240.

Harwood, D. M., A. McMinn, and P. G. Quilty (2000), Diatom biostratigraphy and age of the Pliocene Sorsdal formation, Vestfold Hills, east Antarctica, Ant. Sci., 12, 443-462.

Hambrey M. J., and B. C. McKelvey (2000a), Neogene fjordal sedimentation on the western margin of the Lambert Graben, East Antarctica, Sedimentology, 47, 577-607.

Hambrey, M. J., and B. C. McKelvey (2000b), Major Neogene fluctuations of the East Antarctic Ice Sheet: Stratigraphic evidence from the Lambert Glacier region, Geology, 28, 887-890.

Hill, R. S., and E. M. Truswell (1993), *Nothofagus* fossils in the Sirius Group, Transantarctic Mountains: leaves and pollen and their climatic implications, in The Antarctic Paleoenvironment: a perspective on Global Change (Part Two), edited by J. P. Kennett, and D. A. Warnke, pp. 67-73, American Geophysical Union, Washington D. C.

Labia, A. A., and Z. V. Pushina (1997), Cenozoic glacial-marine sediments from the Fisher Massif (Prince Charles Mountains), in The Antarctic Region: Geological Evolution and Processes, Proceedings VII International Symposium on Antarctic Earth Science, edited by C. A. Ricci, pp. 977-984, Terra Antartica Publishers, Siena.

Liu, X. H, Y. Zhao, and X. C. Liu (2003). Geology of the Grove Mountains in East Antarctica, Science in China (Series D), 46, 305-319.

Macphail, M. K., and E. M. Truswell (2004a), Palynology of Neogene slope and rise deposits from ODP sites 1165 and 1167, in Proceedings of the Ocean Drilling Program, edited by A. K. Cooper, P. E. O'Brien, and C. Ritchter, pp. 1-20, Sci. Res., 188.

Macphail, M. K., and E. M. Truswell (2004b), Palynology of site 1166, Prydz Bay, East Antarctca, in Proceedings of the Ocean Drilling Program, edited by A. K. Cooper, P. E. O'Brien, and C. Ritchter, pp. 21-43, Sci. Res., 188.

Mildenhall, D. C. (1989), Terrestrial palynology, in Antarctic Cenozoic History from the CIROS-1 Drillhole, McMurdo Sound, Antarctica, edited by P. J. Barrett, pp. 119-127, Dept. Sci. Ind. Res. Bull., Wellington, New Zealand.

Quilty, P. G. (1992), Late Neogene sediments of coastal east Antarctica - an overview, in Recent Progress in Antarctic Earth Science, edited by Y. Yoshide, pp. 699-705, Terra Scientific Publishing Company, Tokyo.

Raine, J. I. (1998), Terrestrial palynomorphs from Cape Roberts Project drillhole CRP-1, Ross Sea, Antarctica. Terra Antartica, 5, 539-548.

Truswell, E M., and D. J. Drewry (1984), Distribution and provenance of recycled palynomorphs in surficial sediments of the Ross Sea, Antarctica, Mar. Geo., 59, 187-214

Wang, W. M. (2004), On the origin and development of Artemisia (Asteraceae) in the geological past, Bot. J. Linnean Soc., 145, 331-336.

Webb, P. -N., and D. M. Harwood (1987), Terrestrial flora of the Sirius Formation: its significance for Late Cenozoic glacial history, Ant. J. U.S., 22, 7-11.

Webb, P. -N. and D. M. Harwood (1993), Pliocene fossil *Nothofagus* (southern beech) from Antarctica: phytogeography, dispersal strategies, and survival in high latitude glacial-deglacial environments, in Forest development in Cold Climates, edited by J. Alden, J. L. Mastrantonio, and S. Ødum, pp. 135-165, Plenum, New York.

Whitehead, J. M., and B. C. McKelvey (2001), The stratigraphy of the Pliocene-lower Pleistocene Bardin Bluffs Formation, Amery Oasis, northern Prince Charles Mountains, Antarctica, Ant. Sci., 13, 79-86.