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Pollen Analysis of Surface Deposits and Holocene Lake Sediment of Schirmacher Oasis, Central Dronning Maud Land (CDML), East Antarctica

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Abstract

Thirtyfive moss tufts, lichen patches, frozen soil and glacial ice samples collected from Schirmacher Oasis, East Antarctica has been pollen analyzed in order to understand the interplay of pollen and spores deposited in the sediments. The occurrence of diversified pollen-spore types suggests their long distance transport of thousands of kilometers ranging from tropical to temperate floristic regions from distant continents and surrounding Islands of Antarctic mainland. The palynological study of a 50 cm sediment profile from Long lake under 4-6 meter water column reflects two fold climatic oscillations viz., cool & humid and cool & more humid since last 2000 years BR The palynological data has provided an insight into the potential of the lake sediment studies from the polar region. The occurrence of palynodebris under lichen patches in Antarctic environment is interesting which needs more detail study. The study of air catches also supports the study of pollen dispersal in polar region.

Keywords: Palynology, Lake Sediment, Schirmacher oasis, East Antarctica

Introduction

A large part of Schirmacher Oasis, Central Dronning Maud Land (CDML), East Antarctica is covered by lakes, ponds and pools. The elevation of the oasis ranges between 0-228 m with an average of about 100 m. The gentle slopes and plain areas are mostly covered with a thin blanket of moraine.

The continent's hostile climate precludes most terrestrial life out of which mosses and lichens are the most widespread vegetation where the ground is exposed and moisture is available. In the Schirmacher Oasis the Precambrian crystalline basement of East Antarctic platform is exposed over an area of about 30 sq km. The polymetamorphic rock sequence consisting dominantly of biotite-garnet gneiss and pyroxene bearing granulites with minor intercalation of marbles and calc-silicate rocks,

ultramafics, amphibolites and other metabasites is traversed by a number of distinctly younger basalt (dolerite) dykes (Sengupta 1986). The rocks have undergone multiple episodes of metamorphism, migmatization and deformation.

Only two existing known vascular plant spp.—*Deschampsia arttarctica* (Fam.—Poaceae) and *Colobanthus quitensis* (Fam.—Caryophyllaceae), apart from Mosses—*Polytrichum alpinum, Drepanocladus uncinatus,* aquatic algae and luxuriant growth of lichens viz., crustose type *(Acarospora, Rhizocarpon,* etc.) and foliose type *{Umbilcaria)* are exposed on rocky stratum and ground (Fig. 3). The main objective of the present work is to understand the distribution of palynodebris on Antarctic surface deposits initially and subsequently this transmitted pollen data could be used to decipher Early Holocene chmatic oscillation exhibited by lake sediment in Polar Region. A three fold climatic oscillations has been observed from the Priyadarshini lake sediment core which is dated back to 8,000 years BP in earlier study (XIX IAE). The present report is based on the studies carried out on samples collected during XX IAE. The data generated from the present study supports the data of many Scientists working on transport of exotic palynomorphs into the Antarctic region (Kappen and Straka, 1988, Smith, **1991,** Wynn - Williams, 1991, Van der Knaap et al., 1993).

Materials and Methods

Palynological samples including moss tufts, lichen patches, frozen soil and glacial ice samples were obtained from different lake sites and dry valleys of Schirmacher Oasis, (Fig.l). Fifty grams of moss soils and 5-10 grams of lichen soil were taken for pollen analysis and for

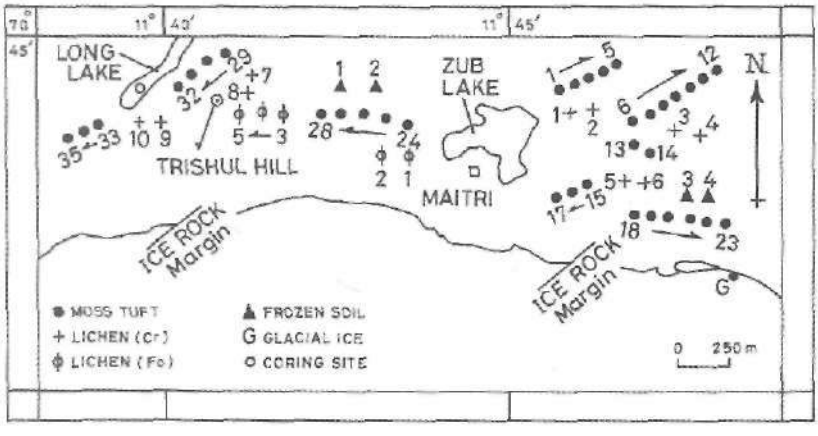

Fig. 1: Location of sampling sites, Schirmacher oasis, East Antarctica

determination of accurate relative frequencies of various microbiota in the measured amount of sediment. Bulk glacial ice samples collected in bucket from which one liter of melt water was obtained. This water was then further reduced to 100 ml after sieving. Two sediment profiles (50 - 60 cm) were collected from "Long lake" (70°45'20" S : 11°4'E) for palynostratigraphical studies (Fig. 2). Sediment profile samples were collected in the interval of 5 cm in each case using a HYDROBIOS gravity corer (Kiel, Germany) for palynological studies. For the radiometric dates the samples were collected at an interval of 10 cm. The corer with a 1 meter long core tube was dropped into the lake at specific sites with some additional weights attached to it which was allowed to sink to the lake bottom. After about 5 minutes, it was pulled back, sealed and brought back to the base camp and cut into pieces of 5 cm each which was stored in double polythene bags in frozen condition. The total length of the sediment core was reduced to 50 cm after it was drained of excess water. These samples stored in double polythene bags were taken for palynological and other chemical analysis in the laboratory. The standard maceration technique (Erdtman,1943) was followed for the all samples.

Fig. 2: Coring site in Long lake, Schirmacher oasis, East Antarctica

During two consecutive expeditions (XIX & XX) daily air sampling was done by exposing glycerine smeared glass slides using Burkard personal air sampler (U.K) starting from 40°S latitude down to Antarctica mainland during onward and return voyage. The exposed slides were processed immediately after collection in proper permanent mounting medium for microscopic studies.

Pollen Rain

Air catches

Burkard volumetric air sampler was employed for air sampling over the period from December, 2000 to March 2001 and during to and fro journey from Cape Town to Maitri, East Antarctica. The safranin stained slides were exposed daily for ten minutes and were studied microscopically. In total thirty one slides were found productive in my two visits to Antarctica. Total assemblage of aeromicrobiota consisted of pollen grains (7 types), fungal spores (22 types), desmid like *Cosmarium* and varia (plants and insect body parts, algal/fungal filaments, etc.). The highest counts were fifty in numbers which were recorded on 31.12.2000 (41° 8'S ;18° 10'E, average temperature 11° C, wind speed 17 KT) and was followed by forty and twenty three on 2.1.2001 (46U 00' S ; 17tJ 08'E, temperature 0.3° C, wind speed 12 KT) and 3.1.2001 (49! 00'S : 17° 21'E, temperature .2° C, wind speed 9 KT) respectively (Table 1). The pollen belonging to the families like Asteraceae, Rosaceae, Oleaceae, Fabaceae, Chenopodiaceae-Amaranthaceae and Poaceae in low concentration was recorded. The fungal spores such as *Alternaria, Helminthosporium, Curvularia, Cladosporium, Cercospora* along with small hyaline and coloured spores were recorded. Very rare occurrence of airborne Desmid like *Cosmarium* was also noticed both over Southern Ocean & Antarctic main land. The study indicates that there is a regular transport of microbiota in the polar air across the Antarctic main land. Very little information is available on the flora of nearby Islands and also on aerial transport pattern of microbioparticles into Antarctic territory with respect to their viability, dispersal, suspension and gravitational sedimentation.

Surface deposits

Pollen-spore data is designated as the proxy climate signal for the interpretation of past vegetation and environment. Detailed palynological studies on a large number of samples are required in order to make a pollen deposition model.

An extensive survey was done during XX IAE in sequel to the XIX IAE to obtain as many samples as possible from Schirmacher Oasis. Out of the thirty five moss sediments samples collected only fifteen were found to be productive whereas eleven out of fifteen samples proved productive yielding seven crustose forms and four foliose forms (Tables 2 & 3). All four frozen soil samples and the three glacial ice samples were productive

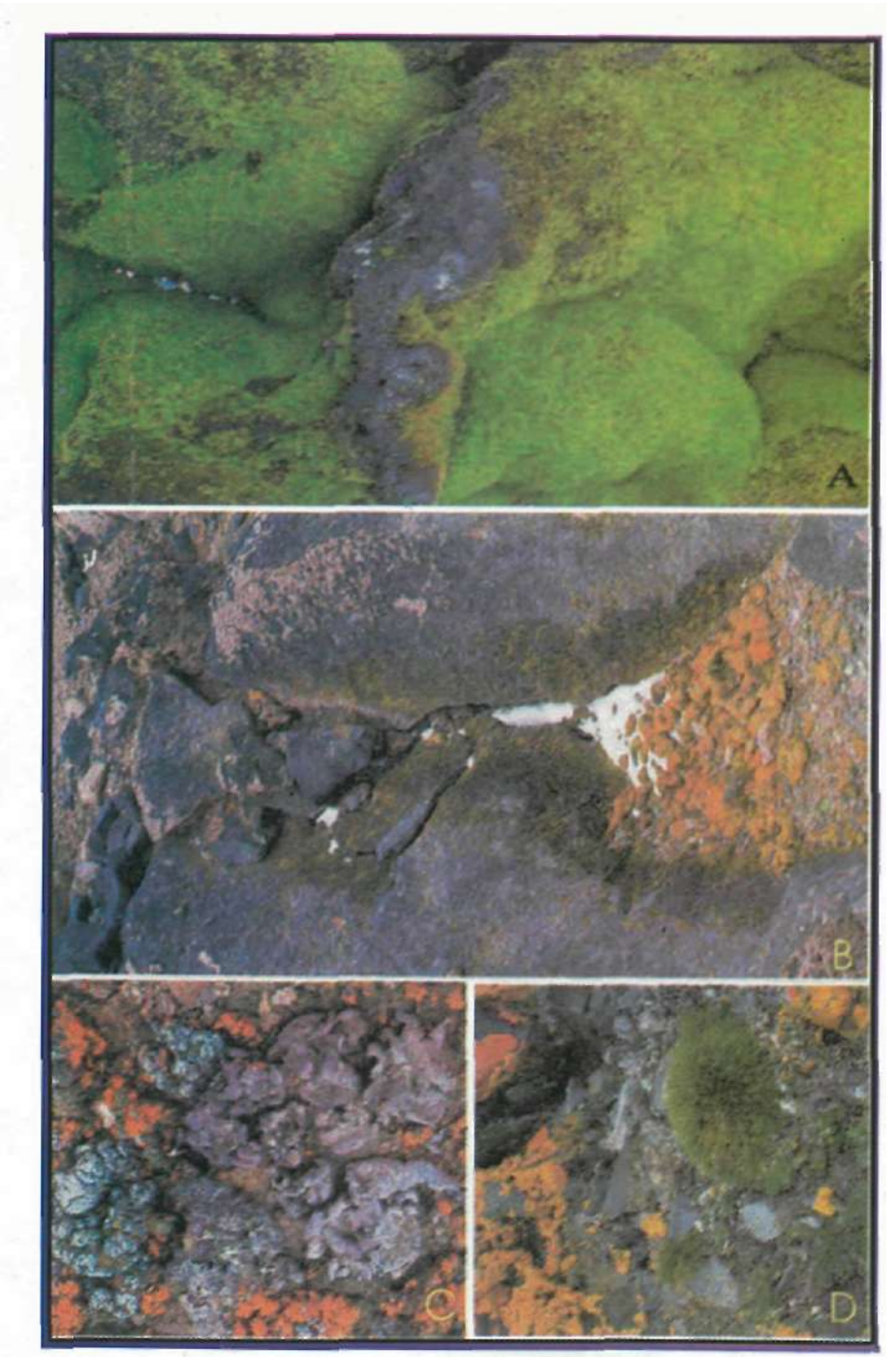

Fig. 3: A. Thick moss tuft, B. Growth of moss & lichen at damp site, C. Growth of foliose lichen, D. Patch of Antarctic grass only found in Antarctic Peninsula

Table 1: Aerospora over Southern Ocean & Schirmacher Oasis

Lat.: Long.	41° 8'S : 18° 10'E	46°0'S : 17°06'E	49°0'S : 17°21'E	52°52'S : 16°29'E	56°0'S : 15°21'E	58°0'S : 14°06'E	61°15'S : 14°14'E	69°55'S : 10°26'E	69°64'S : 11°31'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E
Taxa ↓ / Date of Exposure →	31.12.00	2.1.01	3.1.01	4.1.01	5.1.01	6.1.01	7.1.01	8.1.01	9.1.01	10.1.01	11.1.01	14.1.01	16.1.01	18.1.01	20.1.01	24.1.01
Alternaria	3	2	2	1	1						3	6	1	3		2
Haplosporella	4	3	1				1									
Helminthosporium	1	1		2					2							1
Curvularia	4	3							2							
Cladosporium																
Ascospores	5	6	3						2							7
Conidiophore																1
Nigrospora		3														2
Rust spores		2							5		2	4				
Fungal hyphae	5	3	2	2	3	1	2	1		1						
Fruiting body 1		1														
Fruiting body 2																1
Fruiting body 3																
F.Spore 1									2	2						
F.Spore 2					2				2	4				1		
F.Spore 3												2				
F.Spore 4		2												1	1	
F.Spore 5			2			3										
F.Spore 6								1								
F.Spore 7	2	2	1													
Algal Cyst			1								1					
Algal filament	4	2														
Cosmarium												1	3			
Poaceae	4	1	2		2	2	2	2								2
Cheno/Ams	3	2	2						1	1			1			3
Asteraceae 1	2	2	1	1		3		1	1							
Fabaceae	2															
Rosaceae		1	1													
Oleaceae	4	3	1										2	4		
Unknown	5	6	1									1	1			2
Plant Fragments			1								2				2	
Insect Wing/leg	2		2		2	3	2	1	2	1	1				1	1
Total Count	50	45	23	6	10	12	7	6	19	9	9	14	8	9	4	22
Av. Temperature (°C)	11	0.3	0.2	-2	2.3	-2	2.1	-2	-2	-2	2.6	-1	-1	-1	-1	-1
Av. Wind Speed (KT)	17	12	9	11	13	10	12	12	16	19	12	13	8	10	13	15

Lat.: Long.	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	70°37'S : 11°37'E	69°32'S : 11°58'E	69°32'S : 11°58'E	69°32'S : 11°58'E	69°32'S : 11°58'E	69°32'S : 11°58'E	59°55'S : 11°95'E	46°20'S : 15°47'E
Taxa ↓ / Date of Exposure →	3.2.01	6.2.01	9.2.01	12.2.01	16.2.01	18.2.01	22.2.01	24.2.01	1.3.01	6.3.01	9.3.01	12.3.01	13.3.01	14.3.01	16.3.01
Alternaria			1	1		3	1		1	1		2	2	1	1
Haplosporella															
Helminthosporium	1	2										2			
Curvularia			1			1									
Cladosporium			1			1									
Ascospores							6								
Conidiophore															
Nigrospora							1								
Rust spores	2		4				3				2				
Fungal hyphae		2	1			1	2	1			2				2
Fruiting body 1						1									
Fruiting body 2			1		1	2									
Fruiting body 3			2												
F.Spore 1															
F.Spore 2						2									
F.Spore 3															
F.Spore 4															
F.Spore 5															
F.Spore 6			1												
F.Spore 7															
Algal Cyst											1	1			
Algal filament															2
Cosmarium					3	1							1		
Poaceae		1	2	1											
Cheno/Ams					1										
Asteraceae 1			2		1	1									
Fabaceae						5									
Rosaceae			2	1											
Oleaceae										1				1	
Unknown			2		1				1						
Plant Fragments					1	3		2				2	1	1	
Insect Wing/leg			1	1										1	1
Total Count	3	5	21	4	8	21	13	3	2	2	5	7	4	4	6
Av. Temperature (°C)	-1	0.2	-1	-1	0.3	-2	-6	-5	-3	-3	-4	0.8	1.2	3.5	6.3
Av. Wind Speed (KT)	15	22	11	18	24	19	18	16	14	13	16	12	13	8	9

Table 2: Pollen data from Moss sediments, Schirmacher oasis, East Antarctica

	Moss 1	Moss 2	Moss 3	Moss 4	Moss 5	Moss 6	Moss 7	Moss 8	Moss 9	Moss 10	Moss 11	Moss 12	Moss 13	Moss 14	Moss 15	Moss 18	Moss 21	Moss 22	Moss 23	Moss 25	Moss 26	Moss 27	Moss 29	Moss 32	Moss 34
Subtrop/Temperate Arboreals	4	5	4	3	3	4	5	4	5	2	3	2	8	3	4	0	8	12	11	13	0	0	0	0	0
Tropical Arboreals	3	2	2	3	2	3	3	5	4	5	4	4	0	4	5	3	4	6	8	7	0	1	0	0	0
Deschampsia	6	6	7	7	5	3	8	4	3	4	2	6	11	6	3	6	16	7	14	16	2	0	1	1	0
Other Grass	4	5	8	4	4	8	4	5	3	3	5	4	4	2	4	6	3	8	14	10	0	0	1	0	0
Caryophyllaceae/ *Colobanthus*	3	2	1	2	3	3	2	4	3	5	3	3	3	2	3	5	2	4	3	3	1	0	0	0	1
Other Non Arboreals	4	7	3	3	3	3	2	3	3	4	3	4	5	5	5	4	5	8	6	4	0	1	0	0	0
Fern Spores	3	0	2	0	2	1	4	0	2	4	1	4	4	5	4	0	0	2	4	2	0	0	0	0	0
Bryophytic Spores	2	2	3	11	6	3	5	8	5	11	7	7	3	3	5	6	7	5	7	6	5	7	5	3	6
Cosmarium	3	7	5	9	3	3	9	10	3	6	4	8	8	6	8	7	9	11	5	11	6	6	7	5	8
Other Alga	12	6	9	8	8	6	7	3	5	8	5	8	5	6	3	12	3	3	3	9	6	12	9	7	9
Diatom	9	3	0	3	3	5	2	2	2	3	2	2	0	2	6	3	2	8	2	1	4	5	6	11	8
Fungal Remains	7	6	0	5	6	3	0	3	8	3	6	10	0	0	4	2	1	15	18	21	6	7	9	7	5
Acritarchs	3	3	6	5	8	4	8	6	5	7	9	7	3	3	5	7	8	0	8	7	8	9	7	5	8
Unidentified	7	4	5	0	3	1	3	2	2	2	1	3	9	7	12	4	7	4	1	8	3	3	2	5	3
Total count	70 (24)	58 (27)	55 (25)	63 (22)	59 (20)	50 (24)	62 (24)	59 (25)	53 (21)	67 (23)	55 (20)	72 (23)	63 (31)	54 (22)	71 (24)	65 (24)	75 (38)	93 (45)	104 (56)	118 (53)	41 (3)	51 (2)	47 (2)	44 (1)	48 (1)

Sample numbers 16, 17, 19, 20, 24, 26, 30, 31, 33, 35 are barren. () shows total pollen found.

Table 3: Pollen spectra from Lichen Patches

Taxa ↓ / Sample No. →	Crustose 1	Crustose 2	Crustose 3	Crustose 4	Crustose 5	Crustose 6	Crustose 10	Foliose 1	Foliose 2	Foliose 3	Foliose 4
Grass	1	2	0	0	3	0	2	1	3	1	1
Chenopodiaceae	0	0	0	0	0	1	0	1	1	0	1
Caryophyllaceae	0	0	0	0	0	0	0	1	0	1	1
Tubuliflorae	0	0	0	0	0	0	0	0	1	1	0
Artemisia	0	0	0	0	0	0	0	1	1	0	1
Urticaceae-Moraceae	1	0	0	0	0	0	0	0	0	1	0
Ulmus	0	0	0	0	0	0	0	1	0	1	1
Betula	0	0	0	0	0	0	0	1	0	0	1
Distorted Pine Wing	0	1	0	0	0	0	2	2	0	0	2
Pinus	0	2	0	0	0	0	0	1	1	0	1
Monolete Fern	0	1	0	0	0	2	0	1	0	0	1
Bryophytic Spore	2	0	0	0	0	0	0	3	1	3	3
Oscillatoria	1	1	0	0	0	0	0	7	0	3	5
Nostoc	1	6	0	0	0	0	0	1	2	0	1
Pediastrum	0	0	0	0	1	0	0	2	1	0	2
Navicula	1	1	0	0	0	0	2	2	0	3	2
Nitzchia	1	3	0	0	0	2	0	0	0	7	0
Cosmarium	8	3	2	0	5	2	1	11	16	21	17
Fungal Hyphae	2	1	2	2	2	2	2	2	0	3	2
Alternaria	1	1	0	0	0	0	2	2	0	3	2
Ascospore	0	2	1	1	0	4	3	3	0	0	3
Fruiting Body	1	2	0	0	0	0	0	0	1	0	0
Plant Fragment	0	1	0	0	0	0	2	4	3	3	2
Insect Body part	0	0	0	0	0	0	1	1	1	0	1
Total Count	20 (2)	26 (5)	8 (0)	3 (0)	11 (3)	13 (1)	31 (9)	48 (9)	32 (7)	51 (5)	50 (10)

Crustose lichen Nos. 6,7 & 9; Foliose lichen No 5 , found barren
( ) Total Pollen

in low frequency (Table 4). The pollen spectra present had the predominance of non arboreals over arboreals taxa. Among arboreals *Larix, Pinus, Betula, Ulmus* etc. are of subtropical to temperate in origin. Few tropical texa wee also recovered. The above taxa had drifted from far off to the site of deposition during favorable climatic condition. Occurrence of grass sp. like the *Deschampsia antarctica* and *Colobanthus quitensis,* are the only herb species in the sediments although in low value, is indicative of local deposition. However these species are not growing presently in the study area. *Cosmarium,* algal remains including Diatoms are frequently encountered. Incidence of fungal spores & dispersed organic matter are indicative of their saprophytic nature which could have been transported along with the exotic elements and incorporated in sediments. Pollen analysis of sediments under the lichen patches was done for the first time. Few microbiota including pollen grains have been recorded. The pollen analysis of three glacial ice samples shows presence of exotic taxa like *Betula, Pinus,* grasses, algal and fungal elements, Acritarch, etc. Two years' air data supports the pollen dispersal & deposition in surface sediment of polar region.

Lake sediment

Out of the two sediment cores collected from Long lake during XX IAE one was radiometrically dated at 2000 ± 90 and 1500 ±110 years BP at 50 & 30 cm depth respectively (Fig. 4). The core comprises the alternate layers of silty clay with organic matter and algal growth having pH ranges from 7-8 .The palynological studies reflect two distinct palaeoclimatic oscillations on the basis of fluctuation in the value of different microbiota during last 2000 years BP. In the first phase the palynoassemblage indicate cool & humid climate period in which condition the lake became shallow and small in expansion. The occurrence of moderate value of Cosmarium (5-8%), algal cysts along with preponderance of Diatom (15-20 %) and Acritarchs (10-12%) show freshwater/marine environment. Tree taxa like *Betula,* Moraceae are recorded in very low value whereas, among non arboreal taxa grasses were dominated (22-25%). The grass pollen recorded in the assemblage are grouped in three categories because of its different sizes and characters i.e *Deschampsia;* (Antarctica grass), Poaceae (20-40 im) & Poaceae (40-80 im) respectively. Chenopodiaceae and Caryophyllaceae are recorded in very low frequency. All the elements have drifted from distant island/continents by traveling thousands of kilometres through upthermic

Table 4: Pollen Spectra from Soil and Glacial Ice

Taxa / Sample No.	Frozen soil 1	Frozen soil 2	Frozen soil 3	Frozen soil 4	Glacial ice 1	Glacial ice 2	Glacial ice 3
Picea	2	2	1	0	0	0	0
Pinus	1	1	1	0	0	1	3
Betula	2	3	2	3	1	2	1
Ulmus	2	1	2	0	1	1	0
Alnus	2	2	1	1	1	0	0
Artemisia	1	2	2	0	2	1	3
Tubuliflorae	1	2	2	1	1	1	2
Caryophyllaceae	2	1	2	2	2	2	1
Deschampsia	2	2	3	2	2	2	2
Other grass	2	2	2	4	1	2	6
Cyperaceae	2	1	0	2	1	2	2
Cosmarium	8	11	8	7	2	3	5
Pediastrum	7	3	4	3	3	4	3
Other alga	2	6	5	2	0	3	3
Diatom	2	3	3	3	6	9	17
Dinoflagellates	2	2	5	3	4	6	4
Acritarch	3	4	8	4	4	4	3
Fungal remains	1	3	2	2	6	9	9
Insect body parts	2	3	2	3	1	2	1
Bryophyte spores	3	6	2	3	1	3	1
Unknown	3	2	5	2	1	1	3
Total count	52 (19)	62 (19)	62 (18)	47 (15)	40 (12)	58 (14)	69 (20)

( ) shows total pollen

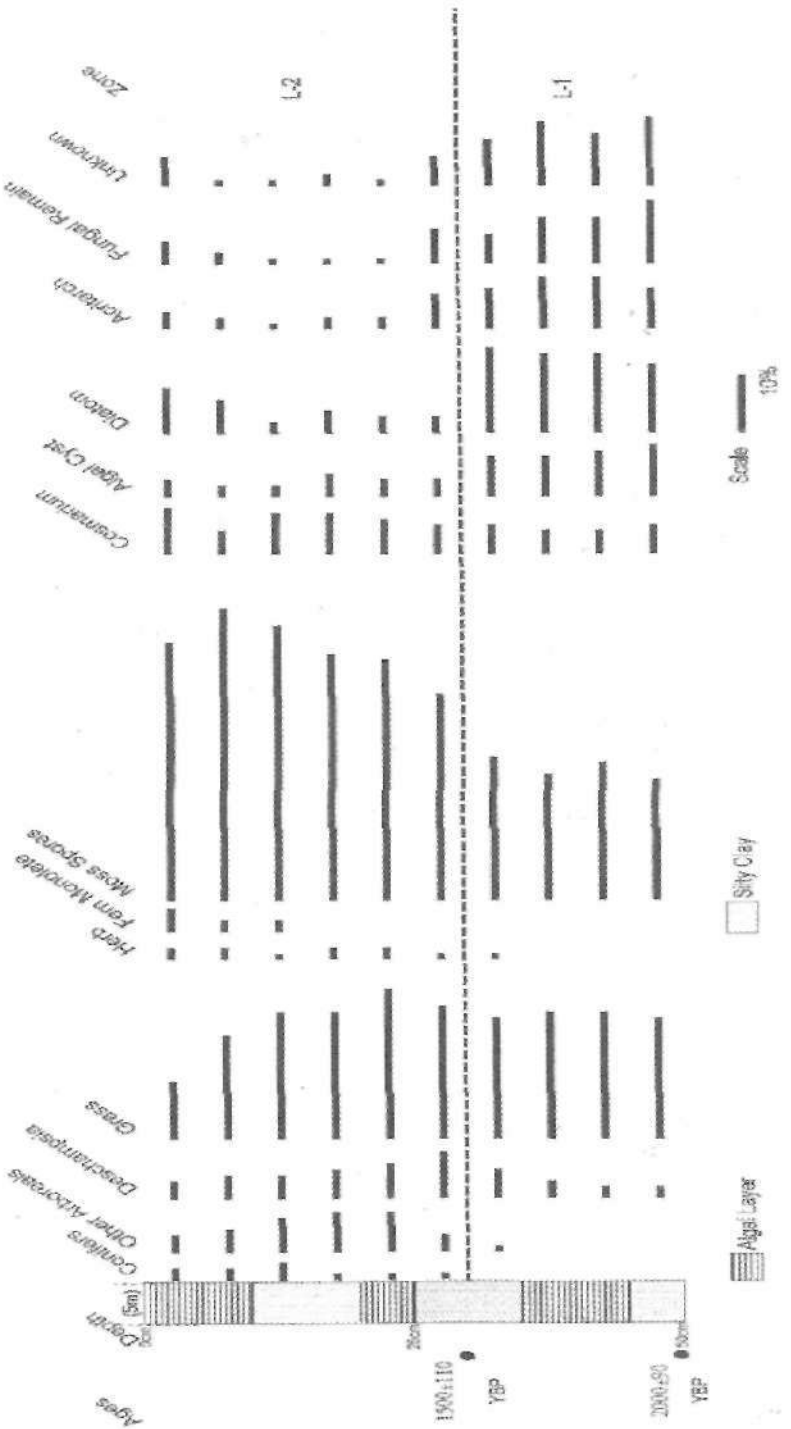

Fig. 4: Pollen Diagram from Long lake, Schirmacher Oasis

winds (Fig. 5). Moss spores (24-28%) are represented in high value. Fungal spores and fruiting body, encountered in good values are saprophytic in nature. The total assemblage suggests the cool & humid climatic regime during 2000 years BP.

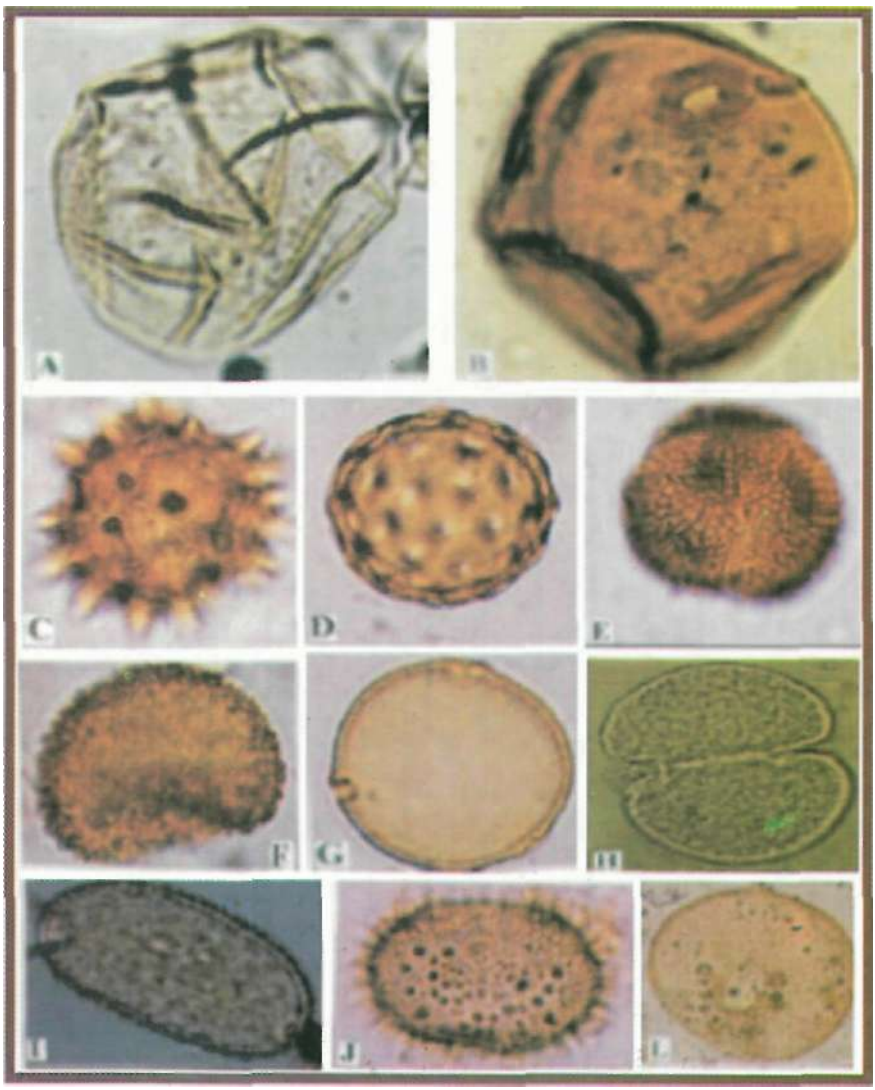

Fig. 5: Palynomorphs recovered from various sediment, East Antarctica Explanation—
A. *Larix x 2000, B. Poaceae x 2000, C. Tubuliflorae (Asteraceae),*
D. Chenopod' •ceae-Amaranthaceae, E. Oleaceae, F. Monolete Fern spore,
Urticaceae-Moraceae, H. Cosmarium x 2000,
I. nknown, J. Acritarch, L. Algal cyst

In the second phase during around 1500 years BP there is improvement in overall palynoassemblage indicating more humid climatic condition. This is suggested by the increased value of Moss spores (30-45%) in comparison to the preceding phase. The value of *Cosmarium* (12%) has increased whereas, Diatom & other algal elements has slightly decreased. The low value of Acritarchs (1.5-4%) along with slightly high value of *Cosmarium* indicate widening of the lake than before. During this phase the grasses both *Deschampsia* & Poaceae have improved their values as compared to the preceding phase. The total assemblage although indicates cool and more humid climate, the appearance of a number of transported arboreal pollen taxa like *Larix Betula, Podocarpus,* Oleaceae, Moraceae along with few herbaceous taxa in low values depicts amelioration of the climate at the upper zone during onward 1500 years BP. Monolete fern spores were scanty. Fungal fruiting body and spores were encountered in low value. The higher representation of moss spores in the assemblage during this phase is supportive of extremely harsh climatic condition which has persisted till the present with a little alteration of climate, i.e. onset of warming as evidenced by the occurrence of arboreal taxa at the uppermost pollen zone (L2).

Conclusion

Palynological investigations of various surface deposits and lake sediment of Schirmacher Oasis have generated quite inspiring pollen data to deduce palaeoclimatic interpretation in polar region. The information on the biogeographical distributions of species in the Circum-Antarctic region is incomplete, and the plant species at Marion Island (tree less vegetation consisting mainly of mire & bog communities dominated by Bryophytes & grasses) show strong affinities with those of Kerguelen Province (upland wind desert dominated by cushion plants), the sub-Antarctic phytogeographical province to which the Islands belong (Scott et al., 1985). Still there is limited data to support the long distance transport of microbiota for accurate interpretation of Polar palaeoclimate. Despite the poverty of Antarctic vascular plant flora, containing only two species may have discouraged pollen analytical work but the pollen diagram can be made through the study of lake sediment from Antarctica. The palynomorphs encountered can be divided into a strictly local and a long distance transported, extraregional component. Therefore, explanation of changes in past local vegetation should first be attempted in terms of changes in past local factors such as hydrology, slope processes, snow cover and nutrient status, since past climatic change often plays an indirect

role by influencing these factors.Moreover, the detailed palynostratigraphical study on more deeper sediment profiles, moss peat and glacial clay varves are required which is existing in the vast Schirmacher region for understanding local peat development for reconstruction of past climate, palaeowind current and plant colonization in and around polar region.

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