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Sedimentological and pollen studies of Lake Priyadarshini, Eastern Antarctica

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ABSTRACT

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A shallow sediment core from a freshwater Antarctic Lake-Priyadarshini, in Schirmacher Oasis, Eastern Antarctica has been studied for grain size, mineralogy and pollen assemblage. The silty clayey sediments from the lake bed have a simple clay mineral assemblage consisting of illite and chlorite with dominant quartz and feldspar in clay-size fraction. A low-hydrolyzing, periglacial depositional environment is reflected from this assemblage. The pollen analysis identifies three pollen zones based on the fluctuations in the retrieved palynomorphs which apparently manifest palaeoclimatic oscillations during Holocene.

Key-words—Antarctica, Lake, Sedimentology, Pollen, Palaeoclimate, Holocene.

पूर्वी अन्टार्कटिका अवस्थित प्रियदर्शिनी झील का अवसादकीय एवं परागकण सम्बन्धी अध्ययन

राजीव सिन्हा, छाया शर्मा एवं मोहन सिंह चौहान

सारांश

पूर्वी अन्टार्कटिका के शिरमेचर मरु उद्यान में स्थित प्रियदर्शिनी नामक ताज़े जल की अन्टार्कटिक झील से प्राप्त एक उथले अवसादी क्रोड का कणों की आमाप, खनिज विज्ञान एवं परागाणु समुच्चय जानने हेतु अध्ययन किया गया. झील संस्तर से प्राप्त पांशु मृत्तिकीय अवसादों में सामान्य मृत्तिकीय खनिज अवसाद पाए गए हैं. इन अवसादों के मृत्तिकीय आमाप प्रभाजन में प्रचुर मात्रा में क्वार्ट्ज़ एवं फ़ेल्ड्स्पार की लब्धि के साथ-साथ इल्लाइट एवं क्लोराइट भी पाए गए हैं. इस समुच्चय से कम जल अपघटनी, परिहिमनदीय निक्षेपणीय पर्यावरण प्रदर्शित हुआ है. परागकण विश्लेषण से तीन परागाणु मण्डल अभिनिर्धारित किए गए हैं, जो पुनर्प्राप्त परागाणुरूपों के उच्चावचन पर आधारित हैं तथा इनसे होलोसीन कल्प में पुरापर्यावरणीय दोलनों का होना सुस्पष्टतः प्रदर्शित होता है.

संकेत शब्द—अन्टार्कटिका, झील, अवसादविज्ञान, परागकण, पुरापर्यावरण, होलोसीन.

INTRODUCTION

LAKE Priyadarshini, with a total area of 0·75 km^2, is one of the largest lakes in the Schirmacher Range of Eastern Antarctica and is closest to the Indian Station - Maitri. Schirmacher Range of Antarctica is a group of low-lying hills of 50-200 m height and exposes six major lithounits namely, (i) banded gneiss, (ii) garnetiferous alaskites, (iii) garnet-biotite gneiss, (iv) calc gneiss, khondalites & associated migmatites, (v) augen gneiss, and (vi) streaky gneiss (Sengupta, 1988).

Schirmacher Range is interspersed with a number of fresh-water glacial lakes. The size of these lakes varies from a few hectares to a few km^2 and the maximum depth of water in them varies from a few meters to about 150 m. Depending upon their topographic setting, they occur as inland lakes, ice margin lakes, or epishelf lakes. Lake Priyadarshini, located at about 255 m away from Maitri (Fig. 1), has been described as a proglacial lake formed at the edge of the ice cap during the deglaciation phase (Holocene?). Earlier works on this lake have been focussed on the ecobiological aspects (Ingole & Dhargalkar, 1998) and thermal structure (Sinha *et al.*, 1999). The water and sediment influx to the lake are through melt water during warmer periods of spring and summer. The bathymetric contours drawn in Fig. 1 show that the maximum depth of water in Lake Priyadarshini is around 6 m occurring in the centre of the lake. Most parts of the lake are quite shallow with an average depth of around 3 m. The present study reports the sedimentological and pollen data from one of the cores collected from Lake Priyadarshini by one of the authors (RS) during the XVI Indian Scientific Expedition to Antarctica (Dec.'96-Mar.'97). Preliminary inferences about the palaeoclimatic fluctuations have been derived from the limited pollen analysis data generated in view of the current status when no worthwhile palynostratigraphic studies have hitherto been carried out from the Antarctic lakes covering entire Holocene. Only one published pollen diagram from nearby King George Island (Vander Knapp & Leeuwen, 1993) is available based on 33 cm thick pollen analysed section with the radiocarbon date covering about 333 years BP.

MATERIAL AND METHODS

Sediment coring was carried out to obtain the lake bottom sediments using a HYDRO-BIOS gravity corer at 3 sites in Lake Priyadarshini (Fig. 1). The cores were drained, dried, cut into pieces of 5 cm each and stored in polythene bags for further analysis in the laboratory. After draining the excess water, the total core recovery was about 45-60 cm from different sites. The cores show alternate layers of sediment (sandy, silty or clayey material frequently with organic matter) and

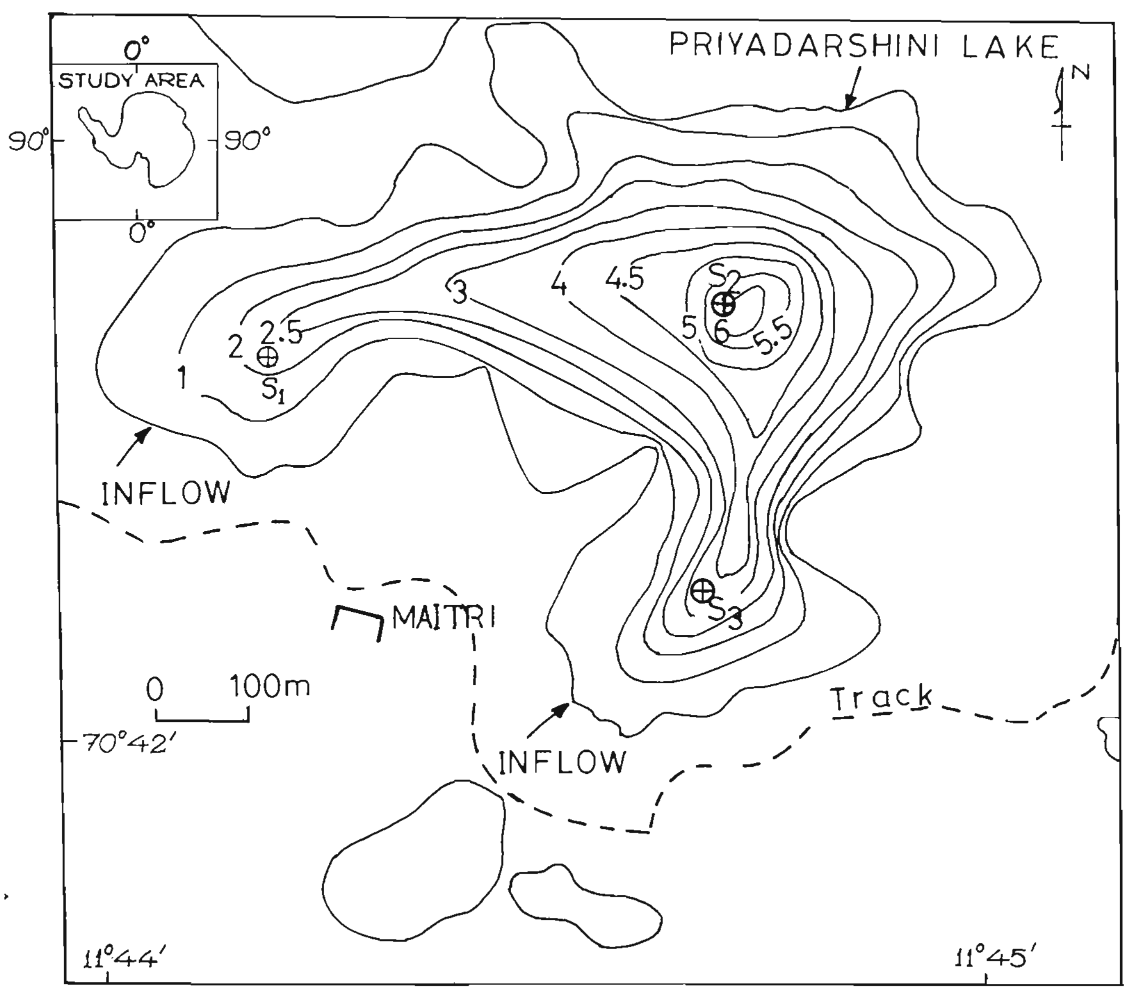

Fig. 1 — Location of coring sites in Lake Priyadarshini, Schirmacher Oasis, Eastern Antarctica.

algal material which indicates successive terrigenous deposition and algal growth. One of the cores namely S1 was selected for sedimentological and palynological study and is provided with solitary radiocarbon date of 7190 ± 300 years BP (BS- 1584) determined for the column between 20-50 cm depth.

The laboratory analysis of the sediment samples included grain size analysis by dry sieving and mineralogical analysis by X-ray diffractometer model ISO-DEBYFLEX 1001 of RICH. SEIFERT & CO.

For pollen analysis, the standard procedure of acetolysis (Erdtman, 1943) through the use of 10% aqueous KOH solution, 40% HF and acetolysing mixture (9:1, acetic anhydride and concentrated sulphuric acid) was employed to liberate the pollen/spores and algal remains from the sediments.

SEDIMENTOLOGY OF LACUSTRINE SEDIMENTS

The grain size distribution in Lake Priyadarshini core is more or less uniform (Fig. 2a) except for a slight increase in clay fraction with depth. Most of the core sediments are dominated by medium silt and clay fractions with little sand, and can be classified into "silty clay" category (after Gorsline, 1960, in McBride, 1983). This may indicate more or less uniform sediment supply into Lake Priyadarshini through gentle catchment slopes. The major sedimentation is through settling of suspended load.

The X-ray diffraction analysis from the bulk samples of core sediments of Lake Priyadarshini shows the presence of quartz, feldspar, illite and chlorite with minor amount of mixed-layered minerals (Fig. 2b). The peak heights in the XRD chart reflect the relative proportion of different minerals. The detrital quartz and feldspar represent the principal allogenic phases, derived from gneissic and charnockitic rocks around the lake basins. The fact that these two minerals have persisted down to clay-size fraction indicates little, if any, chemical weathering of glacially derived source material. A relatively simple clay mineral assemblage and particularly the absence of complex silicates indicates only subtle post-depositional changes. This is apparently a manifestation of periglacial environment of the Antarctic region with a short summer period and lim-

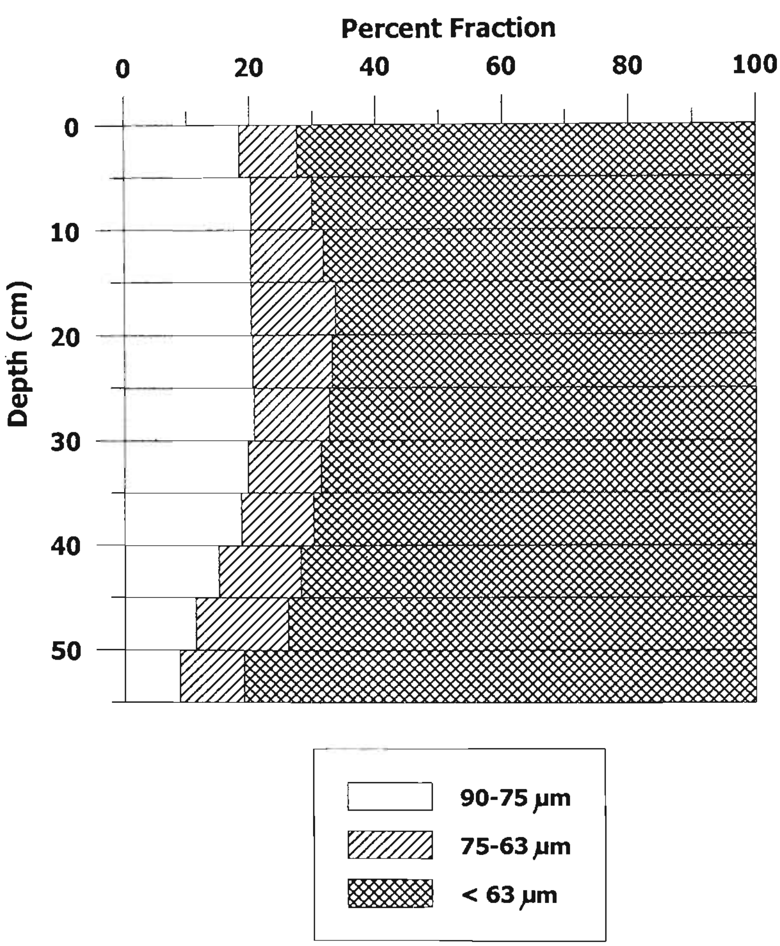

Fig. 2a — Grain size distribution of core sediments from Lake Priyadarshini; dominance of silty clay fraction throughout the core indicates sedimentation mainly through setting of suspended load.

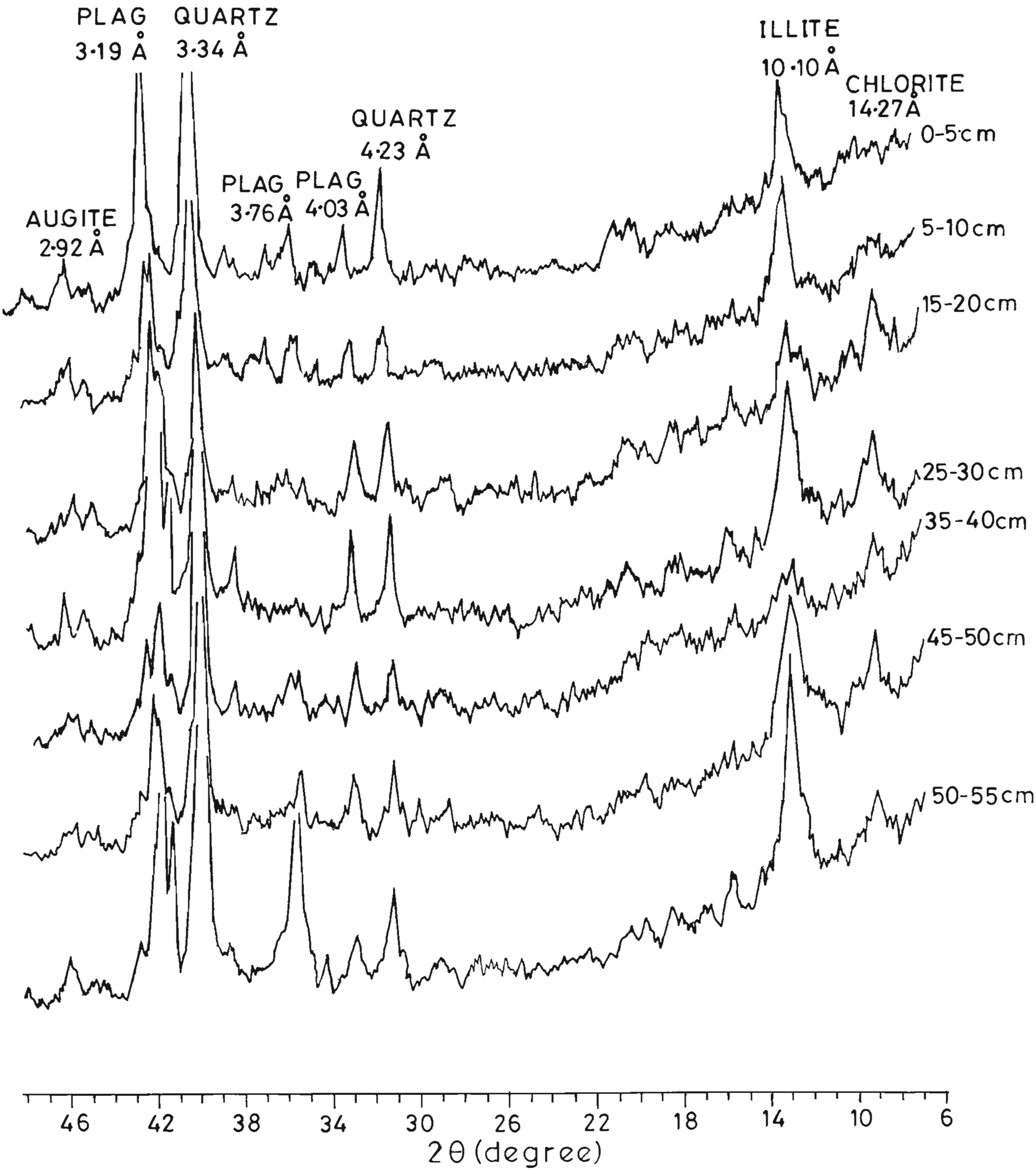

Fig. 2b — X-ray diffraction charts showing mineralogy of core sediments from Lake Priyadarshini.

PLATE 1 — Taxa recovered from core sediments, Lake Priyadarshini, Eastern Antarctica →
(magnification x 1000 for all grains except otherwise mentioned)

1-3	Poaceae	10-11	Unidentified pollen	16.	Unidentified pollen	23-28.	Acritarch
4-5.	Chenopodiace[illegible] Amaranthaceae	12.	Caryophyllaceae	17-20.	*Cosmarium*	29.	Unidentified pollen
6-7	*Salix*	13.	Unidentified pollen	21	*Larix* ? x 500	30.	Moss spore x 2000
8-9.	Asteraceae ([illegible]florae)	14-15.	Cyperaceae	22.	*Alternaria*	31-32.	Fungal spores

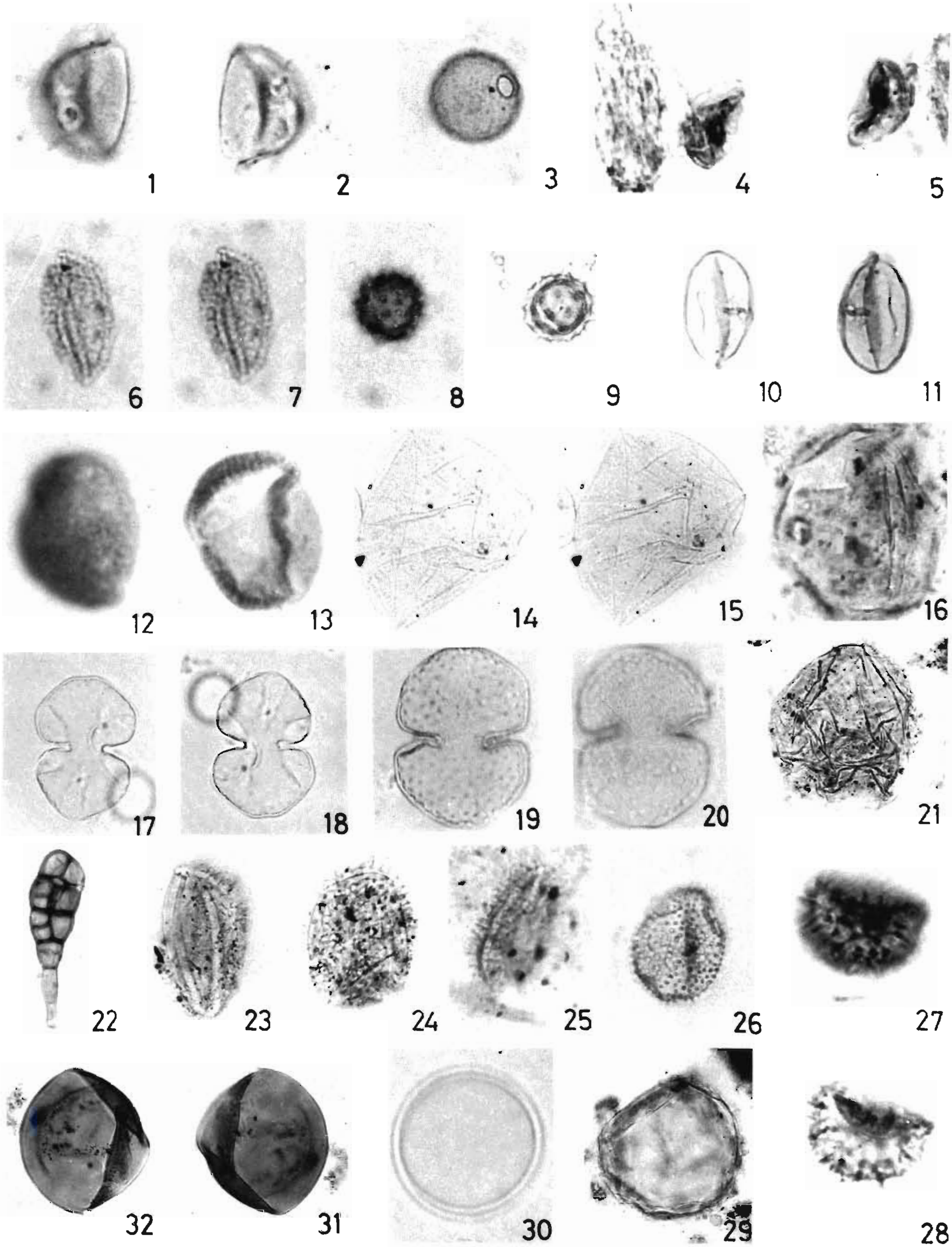
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PLATE 1

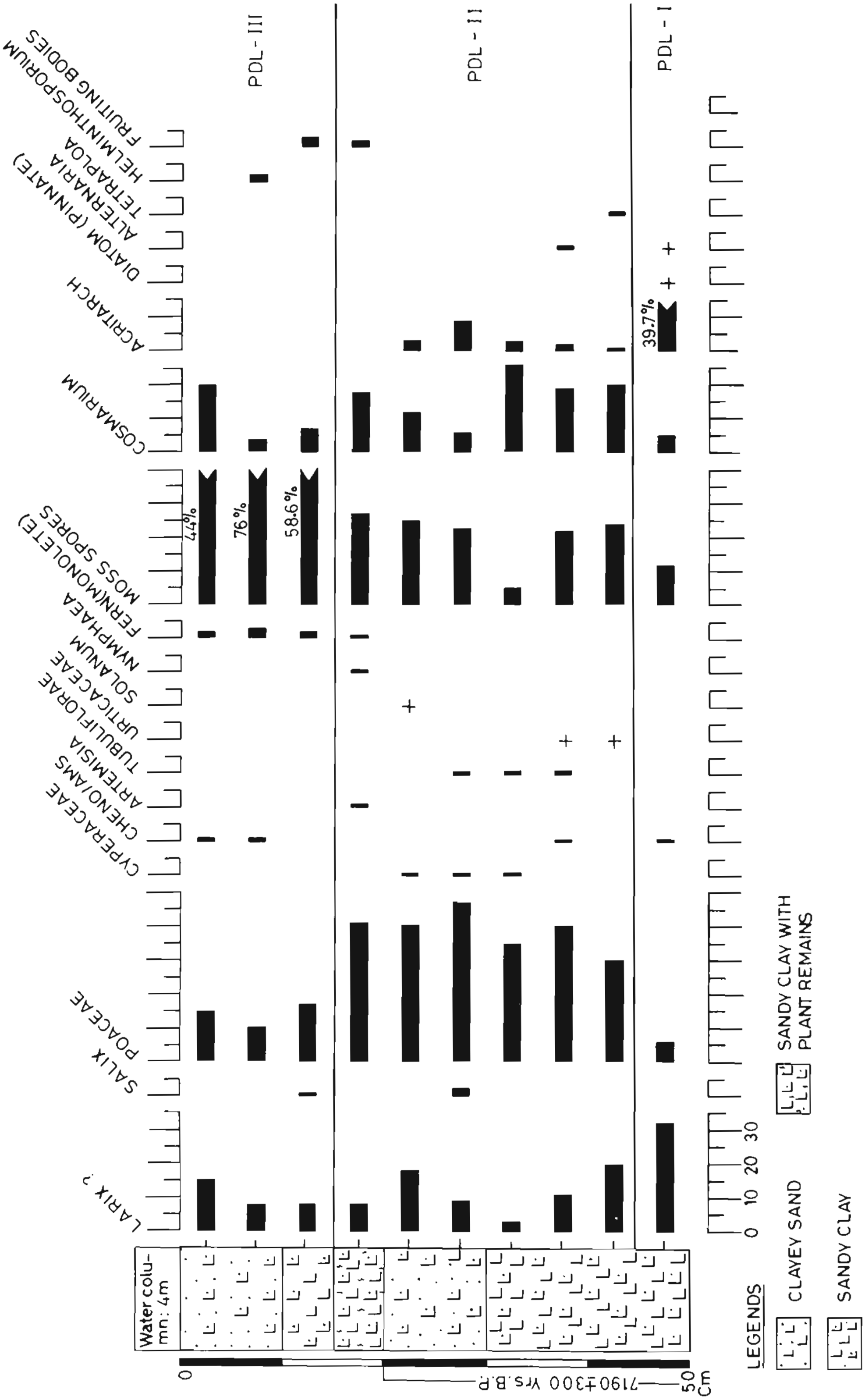

Fig. 3 — Pollen diagram from Lake Priyadarshini, Schirmacher Oasis, Antarctica (Percentage calculated in terms of total palynomorphs)

ited moisture supply, which has not encouraged chemical weathering processes (Sinha & Chatterjee, *in press*).

POLLEN ANALYSIS

The investigation of 10 samples from this core has yielded low pollen as compared to moss spores and other remains of lower plants. The Antarctica continent is floristically almost barren and restricted to only two occurring vascular plant species i.e., *Deschamsia antarctica* (Poaceae) and *Colobanthus quitensis* (Caryophyllaceae) and their distribution is confined to western fringe or Antarctic peninsular region. Apart from the local mosses- *Polytrichum alpinum*, *Drepanocladus uncinatus*, preponderance of algae and often seen thick growth of various lichens on exposed rocky substratum have been reported (Smith, 1984). The recovered pollen spores taxa (Pl. 1) from the sediment core have been grouped as trees, shrubs, herbs, ferns, moss, algae, acritarch, etc. and are arranged in the same order as seen in the pollen diagram (Fig. 3). To facilitate a better understanding of the climatic oscillations in the region, the pollen diagram has been divided into three pollen zones (PDL-I, PDL-II & PDL-III) from bottom to top. These pollen zones are pre-fixed with the initials 'PDL' after the name of site of investigation i.e., Priyadarshini Lake.

Pollen Zone PDL-I (50-45 cm)—The solitary sample from this zone brings out poor pollen assemblage. Pollen cf. *Larix* (32%) is very frequent, whereas Poaceae (6%) is recorded in low frequency and Cheno/Am (1%) in extremely low values.

Acritarch (39.7%) is present in high value. Moss spores (12%) are quite frequent, whereas the fresh water alga - *Cosmarium* (5%) is lowly present. Diatom (pinnate) and fungal spore-*Tetraploa* are extremely sporadic.

Pollen Zone PDL-II (45-15 cm)—This pollen zone is characterized by enhanced but fluctuating values of Poaceae (30-40%). Pollen cf. *Larix* (3-20%) declines considerably in this zone. *Salix* (2%) is recorded sporadically together with *Artemisia* (1·5%), Cyperaceae, Tubuliflorae (1% each), Urticaceae and *Solanum* (under 1% each). Fern spores (monolete 1%) are present scantily at the extreme top of this pollen zone.

Moss spores (5-27%) alongwith *Cosmarium* (6-23%) are encountered in fluctuating but much increased frequencies. Acritarch (1-8%) is recorded consistently, though in reduced frequencies than witnessed in pollen zone PDL-I. *Alternaria* and *Tetraploa* (1-1·5% each) fungal spores are meagrely represented.

Pollen Zone PDL-III (15-0 cm)—This uppermost zone reveals decline in Poaceae (10-17%) and slight increase in cf. *Larix* (8-15%). Cheno/Am (2%) is better represented than in Pollen Zone PDL-II. Fern spores (monolete 2-3%) are consistent and frequent than witnessed earlier. Moss spores (44-76%) are recorded in much higher values, whereas *Cosmarium* (7-20%) after a decline in the beginning resumes the enhanced frequency at the top of this pollen zone.

DISCUSSION

Illite and chlorite are the main clay minerals derived from metamorphic bed rocks or reworked glacial deposits. The very low, paradoxical presence of mixed-layered minerals may indicate the possibility of clay mineral transformation very close to the sediment-water interface or its formation during interglacial period in glacial sediments.

Based on the available solitary radiocarbon date of 7190 ± 300 years BP determined at 20-50 cm depth, the rate of sediment accumulation has been calibrated to 1cm/200 years for the core. This sedimentation rate has been used to extrapolate the date of 10,000 years BP for the beginning of lithocolumn. On the basis of witnessed fluctuations in the overall representation of the palynomorphs, three distinct phases have been recognized in the present pollen sequence indicating palaeoclimatic oscillations from base towards top.

Phase I

The overall vegetational composition suggests that around 10,000 years BP the region was under cold and dry climate. Keeping in view the frequent encounter of *Cosmarium*, a fresh water alga, showing moderate values, coupled with preponderance of Acritarch, an indicator of shallow freshwater/marine environment (Staplin, 1961; Wall, 1965; Smith & Saunders, 1970; Sinha *et al.*, 1998), it is envisaged that the lake was probably shallow and small in expanse during this phase. *Larix* pollen is supposed to have drifted in the region by strong winds from the nearby continent/islands, where it grows abundantly. Long distance transport of palynomorphs exotic to Antarctica has been discussed by Kappen and Straka (1988), Smith (1991) and Wynn-Williams (1991). Similar observations have been made in the investigation of moss-cushions gathered from Priyadarshini Lake and its surroundings (MS under preparation).

Phase II

This phase covering the major part of the sequence, begins around 9,000 years BP and demonstrates the expansion of terrestrial flora, as it was much varied in composition. Among the recovered taxa, substantial representation of Poaceae pollen demonstrate that the region was extensively covered with grass, whereas transported pollen of sedges (Cyperaceae), Urticaceae, Tubuliflorae and *Artemisia* having scanty representation are supposed to have come from the nearby islands. The pollen of *Salix*- an arboreal element, has also been encountered but in extremely low values. Improvement in the pollen depositional assessment is indicative of a change in the local environment as a consequence to the retreat of ice and probably the inception of warm climate in the region. During this phase, the lake probably had a wider spread than seen earlier as evidenced from the proliferation in the representation of *Cosmarium* on one hand and decline in acritarchs on the other.

Phase III

Climate once again seems to have deteriorated around 3,000 years BP as inferred from the sharp decline in Poaceae values and disappearance of most of the herbaceous elements. Nevertheless, Chenopodiaceae/Amaranthaceae despite their low frequencies were better represented than seen before. Mosses alongwith ferns are represented very well- the former is known to withstand extremely harsh climatic conditions. The lake during this phase became shallower as indicated by the marked reduction in the frequencies of *Cosmarium*. However, towards the end of this phase, the improvement in the values of *Cosmarium* once again denotes the expansion of lake due to amelioration of climatic conditions which has continued till the recent time.

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