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Middle to Late Miocene vegetation and climate from the Siwalik sediments (Karnali River section), far western Nepal

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ABSTRACT

The palynological study of the Siwalik sediments from the Karnali River section west Nepal revealed a significant number of palynomorphs for climatic interpretation. Out of 110 mudstone and silty clay samples collected from the Chisapani Formation (Lower Siwalik), 31 samples were found to be rich in pollen and spores. In total more than 35 genera of plant assemblages are recorded from this formation. The Pteridophyte spores are belonging to families Cyatheaceae, Lycopodiaceae, Parkeriaceae, Polypodiceae and Pteridaceae. The angiosperm pollen were represented by families Acanthaceae (*Justicia* sp.), Anarcardiaceae, Caprifoliaceae, Combretaceae (*Terminalia* sp.), Compositae, Fagaceae (*Quercus glauca* and *Q. lanata*), Palmae, Poaceae, Polygonaceae (*Polygonum* sp.), and Typhaceae (*Typha* sp.). The gymnosperms were few in number representing from Pinaceae (*Abies, Picea, Pinus* and *Tsuga*) and Podocarpaceae (*Podocarpus*). The lower part of Chisapani Formation is mainly dominated by Fungal and Algal remains along with plenty of Pteridophytes and Palm pollen. This indicates that the area was humid swampy lowland with tropical to subtropical climatic condition. In the upper part gymnosperm pollen such as *Abies, Picea, Pinus* and *Tsuga* indicate significant change in the climatic conditions during and after 9.6 Ma. Palynomorph evidence suggest that tropical to subtropical climate prevailed during 16 to 12.5 Ma which was gradually becoming colder during 9.6 Ma in the foreland basin of the Nepal Himalaya.

Keywords: Siwalik, Miocene, palynology, climate, Karnali, Nepal

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INTRODUCTION

The Middle Miocene to Lower Pleistocene Siwalik sediments in Nepal are exposed at the southern margin of the Main Boundary Thrust (MBT) and north of the Himalayan Frontal Thrust (HFT). The total thickness of the fluvial sediments of the Nepalese Siwalik Group ranges from 4-6 km, however this is not uniformly distributed, being less in the east and increasing gradually towards west. The lithostratigraphy and magnetostratigraphy of these sediments have been studied in last three decades (Tokuoka et al. 1986; Corvinus 1988a; 1988b; 1990; 1993; Appel et al. 1991; Appel and Roesler 1994; Gautam and Appel 1994; Sah et al. 1994; Dhital et al. 1995; Gautam and Pant 1996; Adhikary and Rimal 1996; Roesler et al. 1997; Roesler and Appel 1998; Gautam and Roesler 1999; Ulak and Nakayama 1998; Nakayama and Ulak 1999, Gautam and Fujiwara 2000, Gautam et al. 2000; Sigdel et al. 2010). The Siwalik sediments yielded a significant amount of vertebrate and invertebrate fossils which are widely used for correlation and to understand the ecology and depositional environment (Munthe et al. 1983; West and Munthe 1983; West et al. 1983; West 1984; West et al. 1991; Corvinus 1993, 1994; Khosla et al. 1995; West, 1996; Gurung 1998; Corvinus and Rimal 2001). Similarly significant investigations have been done in the plant mega-fossils in the different sections of the Siwaliks from the different part of the country (Awasthi and Prasad 1990; Prasad 1990a; 1990b; 1994; 1995; Prasad and Awasthi 1996; Prasad and Pradhan 1998; Prasad et al. 1997; Prasad et al. 1999; Konomatsu and Awasthi 1999; Prasad and Pandey 2008). However, the palynological investigation from the Siwalik sediments in Nepal is very poorly recorded (Sarkar 2000; Hoorn et al. 2002). This is because the fine grained sediments (clay, shale, mudstone, silty clay) that could yield plant microfossils are highly oxidized and therefore the pollen and spores are poorly preserved in such sediments. This research aims to document the palynomorph assemblages from the Chisapani Formation (Lower Siwalik) sediments in the Karnali River section west Nepal using Light Microscope (LM) and Scanning Electron Microscope (SEM) and interpret the palaeoclimate on the basis of past vegetation.

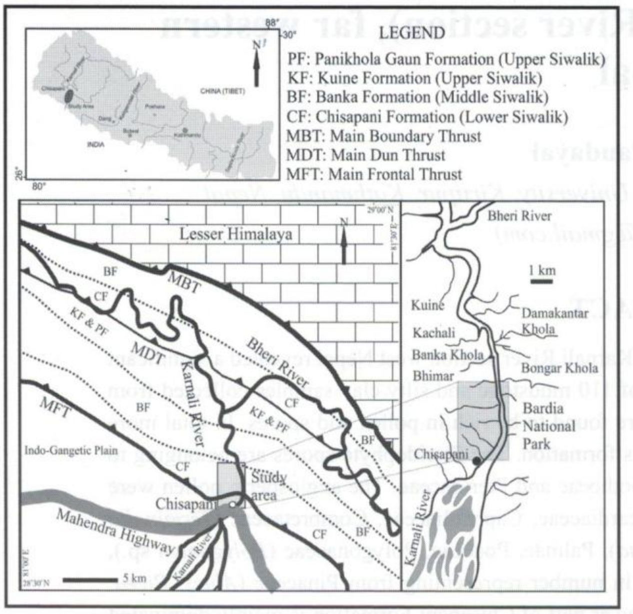

Fig. 1: Location map (above) and geological details of the of the study area (below) redrawn after Gautam and Fujiwara (2000), Robinson et al. (2006) and Sigdel et al. (2010).

GEOLOGY OF THE STUDY AREA

Sigdel et al. (2010) divided the Siwalik sediments in the Karnali River section into four lithostratigraphic units as Chisapani Formation, Banka Formation, Kuine Formation and Panikhola Gaun Formation. The Chisapani Formation (Lower Siwalik) consists of very fine- to medium-grained sandstone alternating with multi-coloured bio-turbated mudstones. This formation is well exposed near the Chisapani bazaar area along the right bank of the Karnali River. The Chisapani Formation can be further divided in Lower, Middle and Upper Members on the basis of sandstone-mudstone ratio and increasing grain size in sandstone beds towards the top. The thickness of the sandstone beds ranges from tens of centimetres to ten meters. The sandstone beds generally contain parallel- and cross-laminations and ripple marks. Several plant fossils (leaves) impressions are recorded from this section. The age of this formation is supposed to be 16 to 9.6 Ma (Gautam and Fujiwara 2000). The Chisapani Formation can be broadly correlated with Bankas and Chor Khola Formation (Jungali Khola member and lower part of the Shivagarhi member) in the Surai Khola area, Arung Khola Formation in the Tinau Khola section and Rapti Formation in Amlekhganj-Hetauda area. The total thickness of the Chisapani Formation is 2045 m.

The Banka Formation (Middle Siwalik) is well exposed near the Banka village along the right bank of the Karnali River. This Formation consists of medium- to thick-bedded medium- to coarsegrained sandstone with occasional silt and mudstone beds. The sandstones are tending to be coarse and pebbly in the upper part of this formation. The mixture of biotite, feldspar and quartz form famous 'salt and pepper' texture in sandstones. Several plant fossil impressions are found in this formation; however their preservation is very poor. This formation is also divided into lower, middle and upper members. The Banka Formation has been correlated with Surai Khola Formation in Surai Khola area, Binai Khola Formation in Tinau Khola section and Amlekhganj Formation in Amlekhganj-Hetauda area. The thickness of this formation is 2740 m and the age is 9.6 to 3.9 Ma (Gautam and Fujiwara 2000; Sigdel et al. 2010).

The Kuine Formation (Upper Siwalik) is exposed in the Karnali River section near Kuine village. This formation composed of well-sorted clast-supported conglomerate with occasional sandstone and mudstone beds. The thickness of the conglomerate beds reach up to 30 m. The Kuine Formation can be correlated with Dobata Formation and Lower Part of Dhan Khola Formation in the Surai Khola section, Chitwan Formation in Tinau Khola section and Churia Khola Formation in Amlekhganj-Hetauda section. The Panikhola Gaun Formation (Upper Siwalik) consists of poorly sorted matrix supported conglomerate with some sandstone and mudstone intercalations. The clast are pebble, cobble even boulder in size. The thickness of individual conglomerate bed exceeds 25 m. The Panikhola Gaun Formation can be correlated with Dhan Khola Formation in Surai Khola section, Deorali Formation in Tinau Khola section and Churia Mai Formation in Amlekhganj-Hetauda section.

MATERIALS AND METHODS

In total 110 samples were collected from mudstone and silty clay horizons from the Chisapani Formation in the Karnali River section. Generally the mudstones are supposed to be good for palynological sampling but in Karnali River section the lower part of Chisapani Formation is highly oxidized therefore continuous sampling was not possible. It was necessary to make deep trenches to get the fresh samples and to avoid contamination from the modern pollen in atmosphere and in surrounding rock exposures. Samples were prepared following the method described by Ferguson et al. (2007) in Senckenberg Research Institute laboratory at Frankfurt am Main, Germany. About 200 gm of sample from each horizon was crushed to make powder and treated with Hydrochloric acid (HCL) to remove carbonate contain in it. It was then treated with Hydrofluoric acid (HF) to remove silicate minerals. This was followed by treating of samples with acetolysis solution (Acetic anhydride and conc. Sulphuric acid in 9:1 ratio).

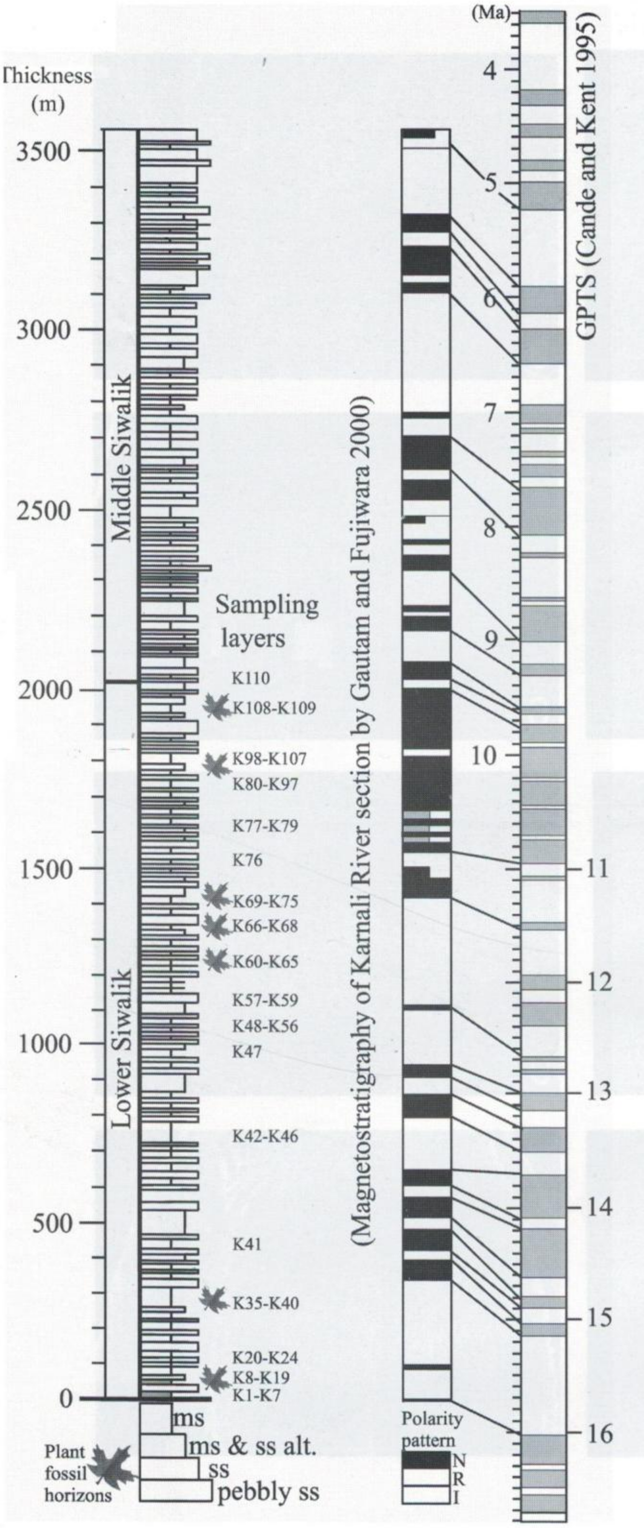

Fig. 2: Lithostratigraphy and magnetostratigraphy of the Siwalik sediments from the Karnali River section with palynological sample horizons (Redrawn after Gautam and Fujiwara 2000).

Centrifuging and washing of samples with distilled water and glacial acetic acid is necessary in each step. Finally the organic matter was separated using heavy liquid ($ZnCl_2$ with specific gravity 2.0). The palynomorphs were studied under Light Microscope (LM) and Scanning Electron Microscope (SEM) using single pollen grain technique (Ferguson et al. 2007) at Institute of Palaeontology, Vienna University, Austria.

RESULTS

Out of 110 samples collected from Chisapani Formation (Lower Siwalik) only 31 samples contain pollen and spores. The bottom part of this formation is mainly dominated by Pteridophytes, fungal and algal remains while in upper part the angiosperms pollen along with gymnosperm pollen are significant in number. In total more than 35 genera of plant assemblages are recorded from this formation. The Ptridophyte spores are belonging to families Cyatheaceae, Lycopodiaceae, Parkeriaceae, Polypodiceae and Pteridaceae. The angiosperm pollen were represented by families Acanthaceae (*Justicia* sp.), Anarcardiaceae, Caprifoliaceae, Combretaceae (*Terminalia* sp.), Compositae, Fagaceae (*Quercus glauca* and *Q. lanata*), Palmae, Poaceae, Polygonaceae (*Polygonum* sp.), and Typhaceae (*Typha* sp.). The gymnosperms were few in number representing from Pinaceae (*Abies, Picea, Pinus* and *Tsuga*) and Podocarpaceae (*Podocarpus*). The common pollen and spores are presented in Plates I-VII.

PALAEOCLIMATE INTERPRETATION

The palynomorphs assemblages in Chisapani Formation in Karnali River section are very poorly preserved. Sometimes pollen and spores are highly decayed, distorted and destroyed. The criteria for identification such as arrangement of apertures and surface ornamentations are not clear. The investigation of palynomorphs under Scanning Electron Microscope (SEM) along with LM had been useful to identify the specimen accurately in order to extract the ecological information and to interpret it in terms of palaeoclimate. The lower part of Chisapani Formation is mainly dominated by Fungal and Algal remains along with plenty of Pteridophytes and Palm pollen. This indicates that the area was humid swampy lowland with tropical to subtropical climatic condition. The tropical-subtropical climate is evidenced by the presence of fern spores from family Parkeriaceae (Plate-VI). Different species of Palm pollen were recorded from the lower part of this formation (Plate-III). Palm trees prefer mostly tropical to subtropical climate. The middle part of this formation is highly oxidized therefore appropriate sample horizon for palynological

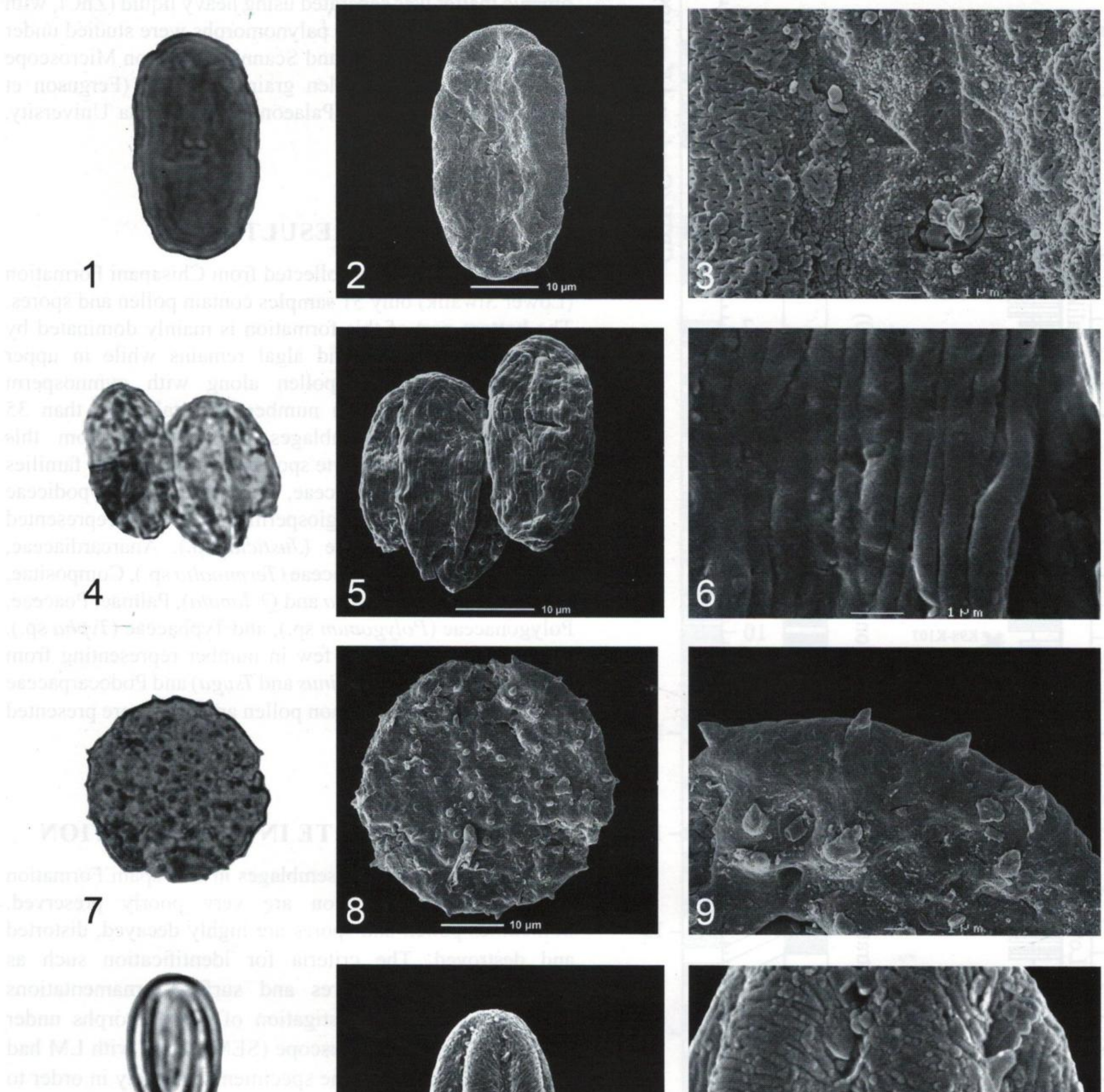

Plate I
Acanthaceae, *Justicia* sp., (1, LM; 2 and 3, SEM); Anarcardiaceae (4, LM; 5 and 6, SEM); Caprifoliaceae (7, LM; 8 and 9, SEM); Combretaceae, *Terminalia* sp, (10, LM; 11 and 12, SEM).

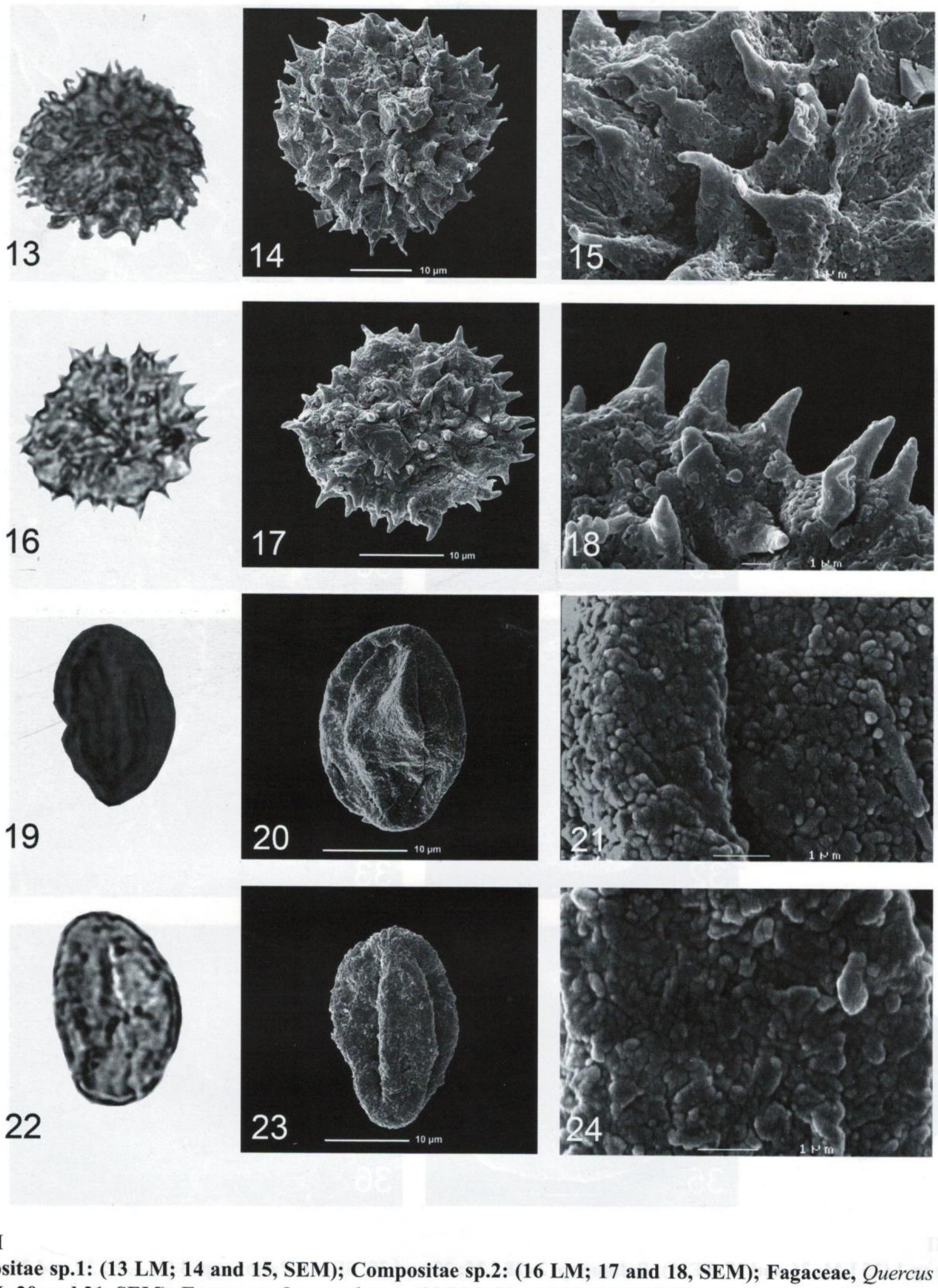

Plate II

Compositae sp.1: (13 LM; 14 and 15, SEM); Compositae sp.2: (16 LM; 17 and 18, SEM); Fagaceae, *Quercus glauca* (19 LM; 20 and 21, SEM); Fagaceae, *Quercus lanata* (22 LM; 23 and 24, SEM).

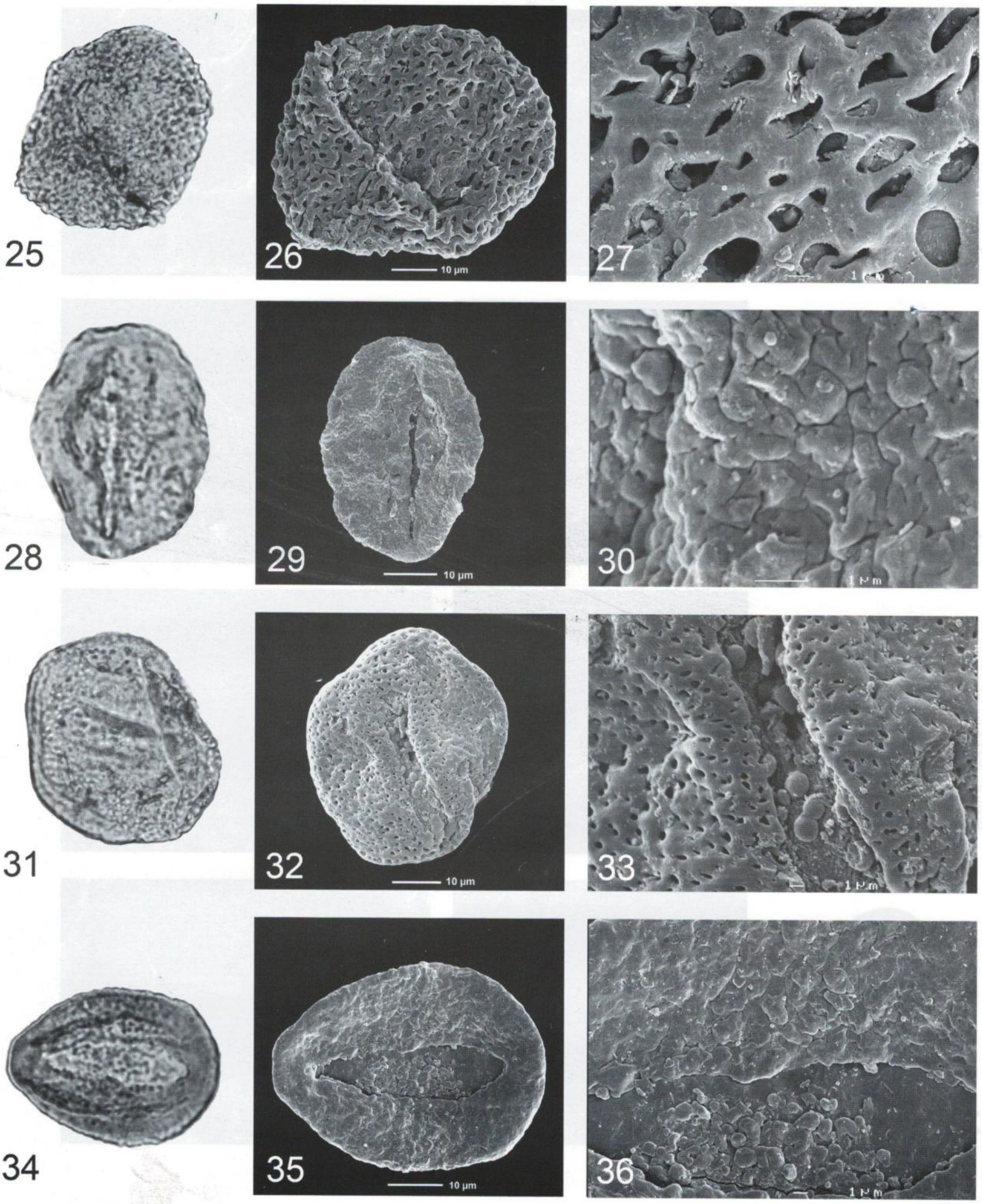

Plate III
Palmae sp.1 (25 LM; 26 and 27, SEM); Palmae sp. 2 (28 LM; 29 and 30, SEM); Palmae sp. 3 (31 LM; 32 and 33, SEM); Palmae sp. 4 (34 LM; 35 and 36, SEM).

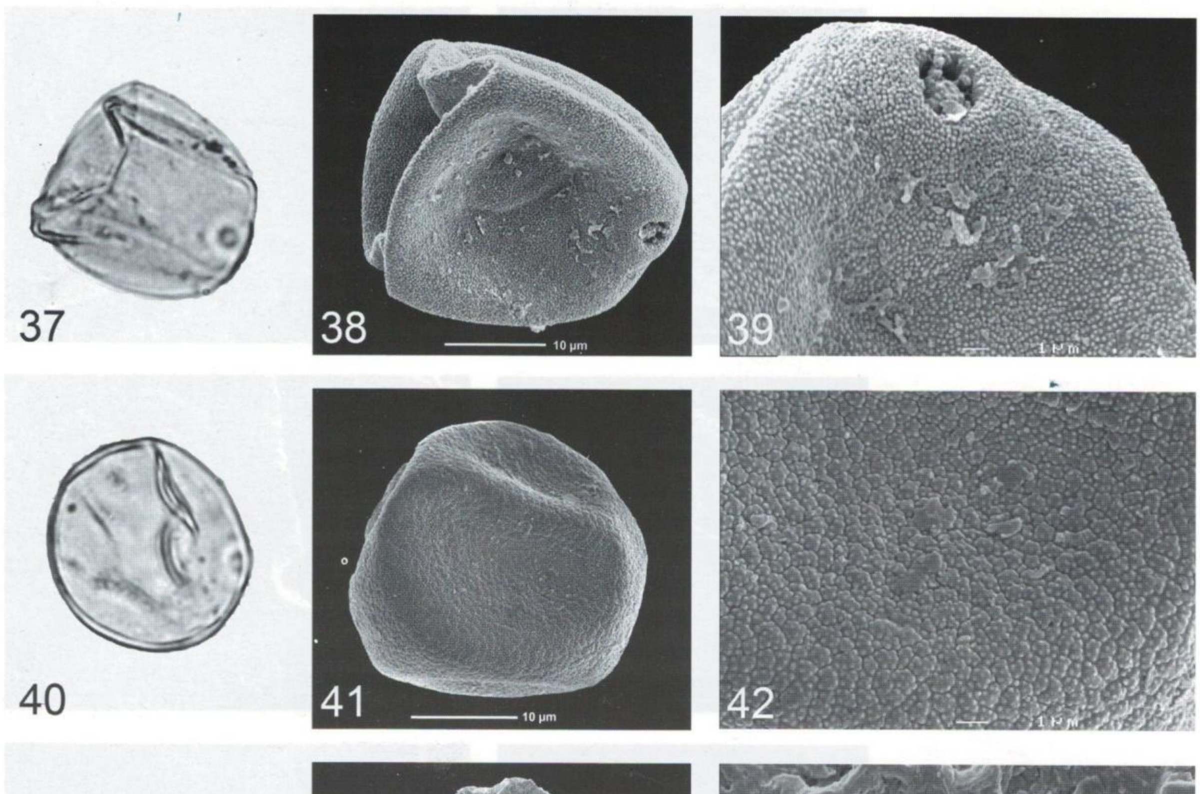

Plate IV
Poaceae sp. 1 (37 LM; 38 and 39, SEM); Poaceae sp. 2 (40 LM; 41 and 42, SEM); Polygonaceae, *Polygonum* sp.(43 LM; 44 and 45, SEM); Typhaceae, *Typha* sp. (46 LM; 47 and 48, SEM).

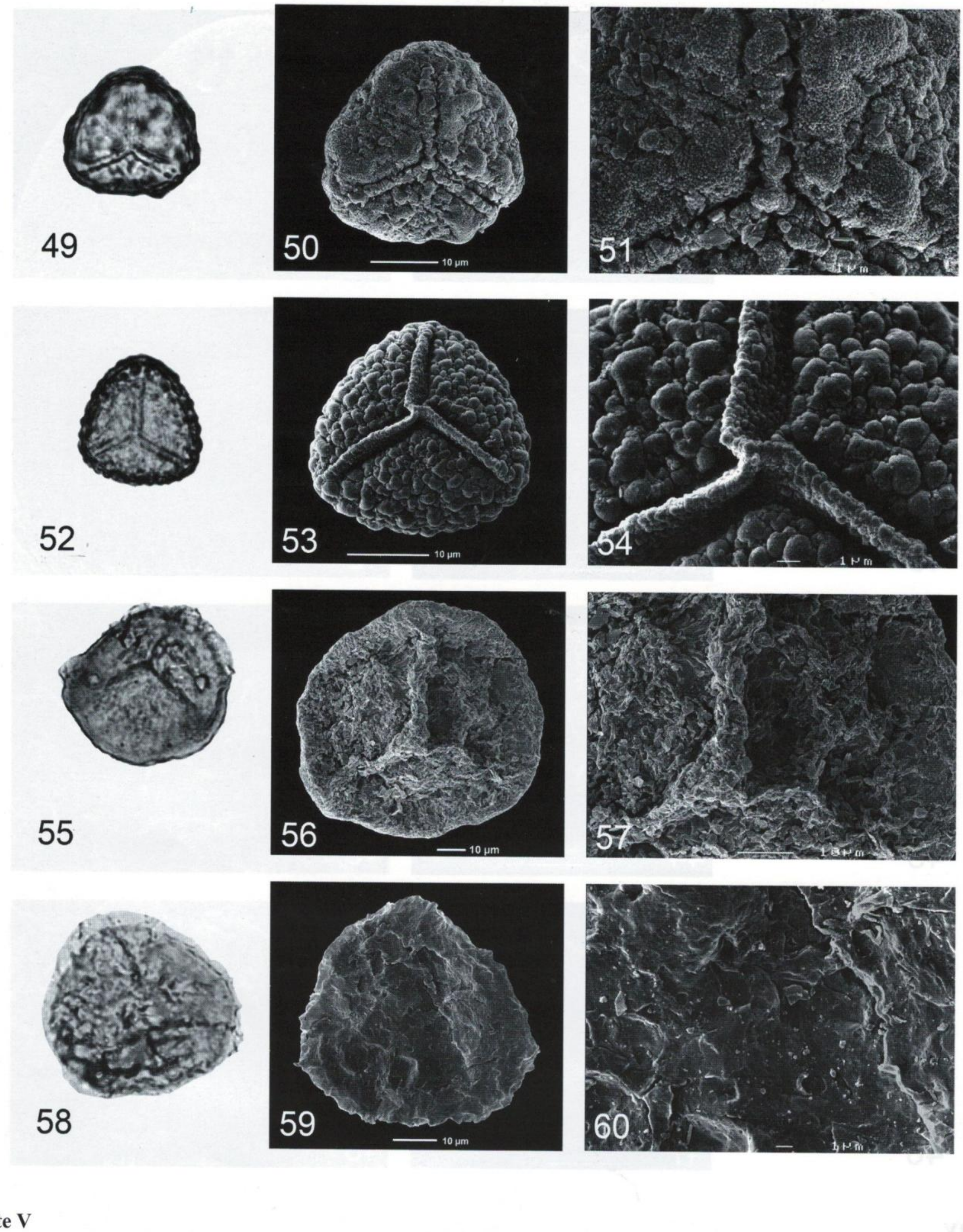

Plate V
Cyatheaceae sp. 1 (49 LM; 50 and 51, SEM); Cyatheaceae sp. 2 (52 LM; 53 and 54, SEM); Lycopodiacae, *Lycopodium* sp.1 (55 LM; 56 and 57, SEM); Lycopodiacae, *Lycopodium* sp.2 (55 LM; 56 and 57, SEM).

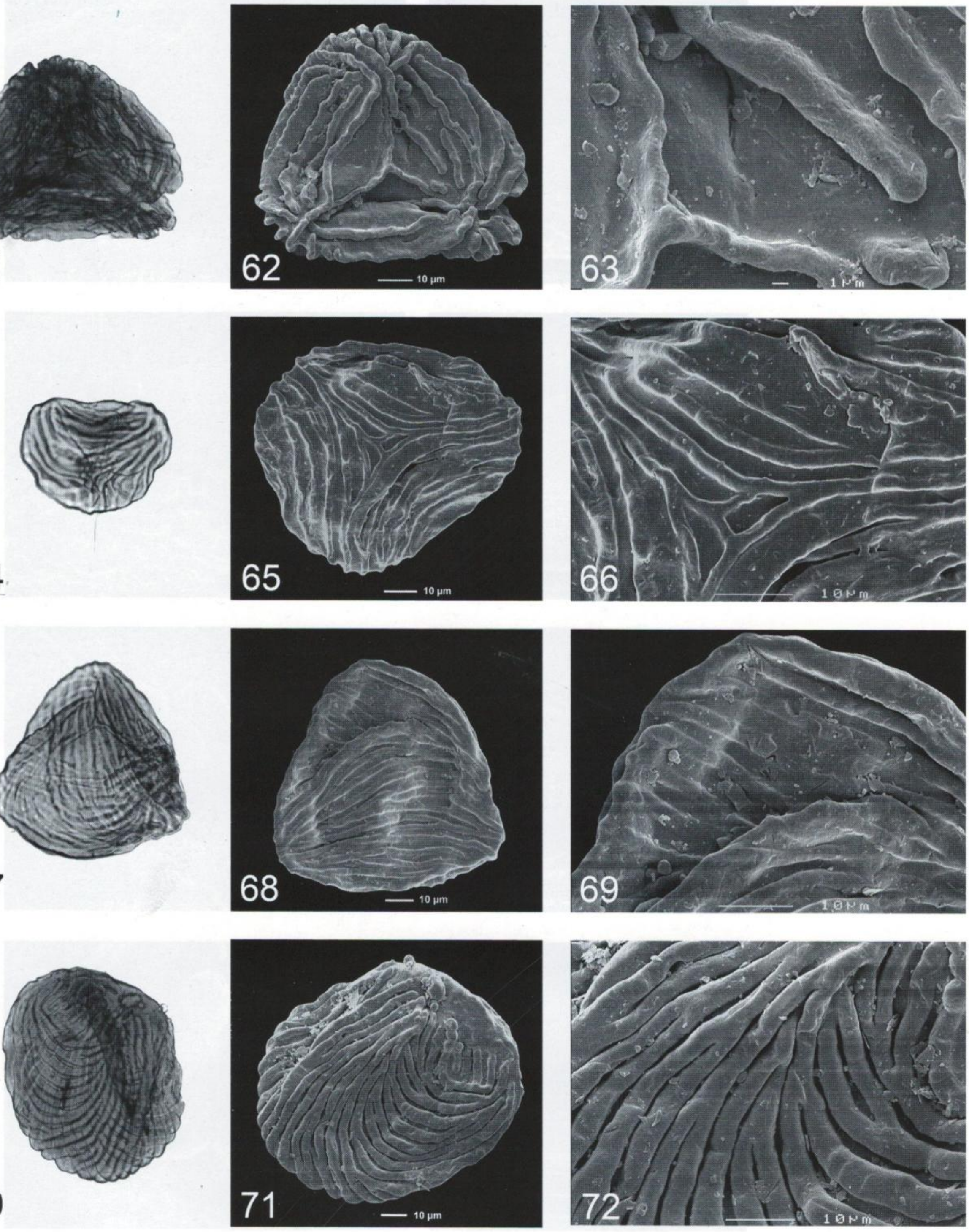

Plate VI

Parkeriaceae, *Ceratopteris* **sp.1 (61 LM; 62 and 63, SEM); Parkeriaceae,** *Ceratopteris* **sp. 2 (64 LM; 65 and 66, SEM); Parkeriaceae,** *Ceratopteris* **sp. 3 (67 LM; 68 and 69, SEM); Parkeriaceae,** *Ceratopteris* **sp. 4 (70 LM; 71 and 72, SEM).**

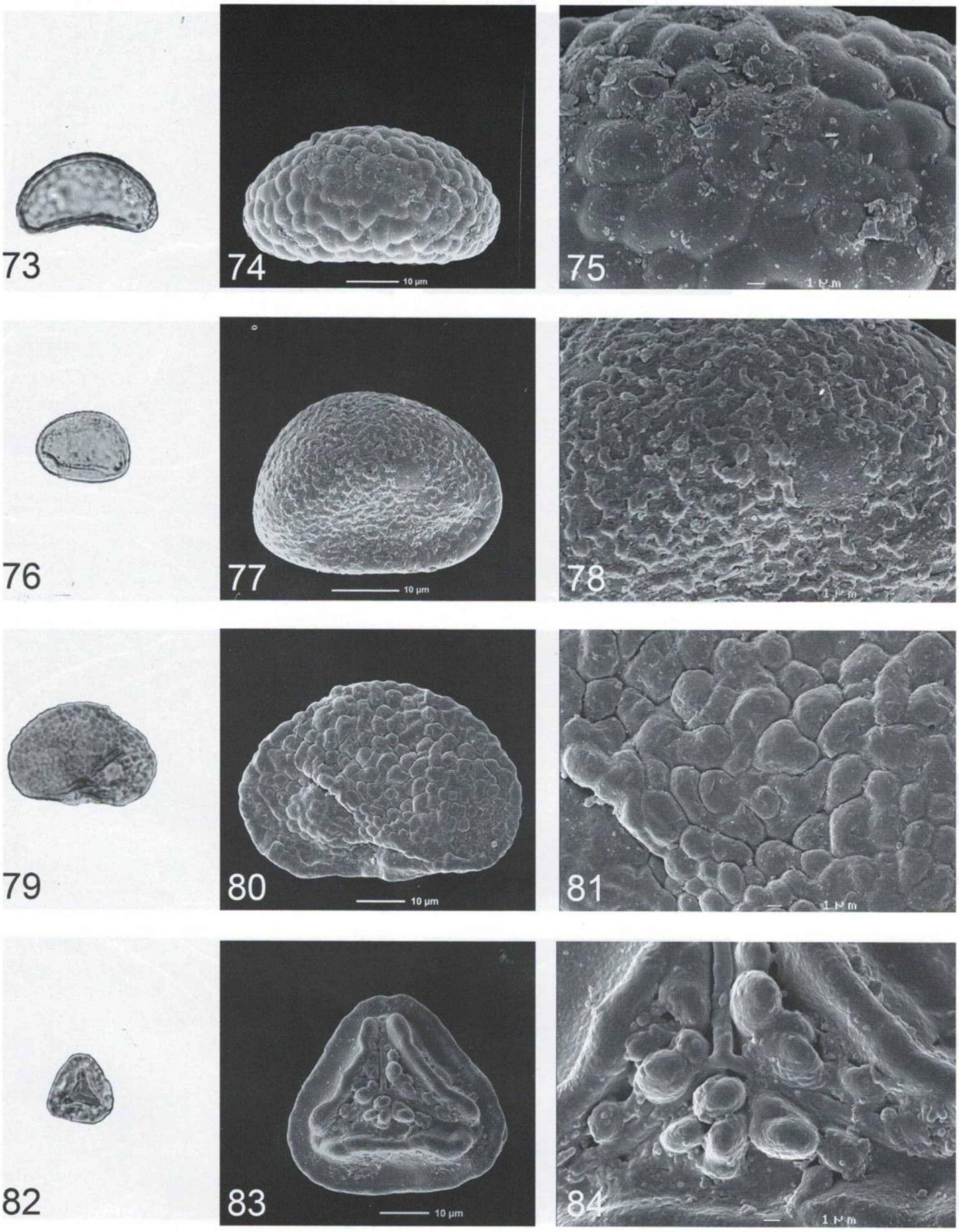

Plate VII

Polypodiaceae sp.1 (73 LM; 74 and 75, SEM); Polypodiaceae sp. 2 (76 LM; 77 and 78, SEM); Polypodiaceae sp. 3 (79 LM; 80 and 81, SEM); Pteridaceae, *Pteris* sp. (82 LM; 83 and 84, SEM).

sampling was not possible. The upper part of this formation shows high number of angiosperm pollen mainly from the plants growing in tropical to subtropical areas. The angiosperm pollen from *Justicia* (Acanthaceae), *Terminalia* (Combretaceae), Anarcardiaceae, Caprifoliaceae indicates the tropical climatic condition. The low altitude growing *Quercus* species are also recorded from the upper part of Chisapani Formation. The warm climate preferring gymnosperms such as *Pinus roxburghii* and *Podocarpus* are found abundantly. The wetland plants such as *Polygonum* and *Typha* were also abundant in the palynomorph assemblages. Emergence of gymnosperm pollen such as *Abies, Picea, Pinus* and *Tsuga* indicate significant change in the climatic conditions in the upper part of the Chisapani Formation. It seems that tropical to subtropical climate prevailed during 16 to 12.5 Ma, which was gradually becoming colder during 9.6 Ma and afterwards.

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