MID-CRETACEOUS PALYNOFLORA FROM CENTRAL MID-PACIFIC OCEAN

A Thesis

by

SHIH-YI HSIUNG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2011

Major Subject: Geology

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Approved by:

Co-Chairs of Committee, Anne Raymond
                         John Firth
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ABSTRACT

Mid-Cretaceous Palynoflora From Central Mid-Pacific Ocean. (August 2011)

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Albian (late Early Cretaceous) pollen and spores were used to reconstruct the floral history of Allison Guyot in the Albian period to better understand pollen and spore distributions on mid-oceanic islands, to investigate whether Allison Guyot supported land plants in the Albian, and to test previous hypotheses about the development of the guyot. Albian spores found in Allison Guyot sediments from ODP (Ocean Drilling Program) Leg 143 Site 865 include: *Laevigatosporites ovatus, Cyathidites minor, Cicatricosisporites sp., Baculatisporites comaumensis, Ceratosporites equalis, Gleicheniidites senonicus, Leptolepidites verrucatus, Retitriletes circolumenus, Lycopodiacidites dettmannae, Osmundacidites wellmanii, Cicatricosisporites hughesii, Impardecispora excavate,* and others. Albian pollen from these samples include *Callialasporites dampieri,* Ephedra, and others. The high abundance of terrestrial palynomorphs in these samples suggests that Allison Guyot was exposed in the Albian and supported land plants. The high frequency of spores (more than 90 percent) reflects a flora dominated by ferns.

DEDICATION

I would like to dedicate this degree to my family and friends. Thank you for all the support and love during the time it took me to pursue a master's degree. Without you, this experience would have been overwhelming. Thanks for sticking with me through the tears and the laughter.

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CHAPTER I

INTRODUCTION

Terrestrial palynomorphs in marine environments have been used for

biostratigraphy (Loboziak, Melo, Quadros, and Streel, 1997), to investigate the

paleoecology of adjacent land masses, and to investigate current and wind directions

(Hooghiemstra, 1988). The source of pollen and spores in marine sediments is usually

plants on continents or islands, which are close to those marine localities. Rivers, winds,

and ocean currents, including both surface currents and turbidity currents deliver

palynomorphs, pollen and spores, from parent plants to the shore and sometimes to the

open ocean, miles away from land (Cross et al., 1966; Traverse and Ginsburg, 1966;

Farley, 1987; Ogg, 1992; Sun et al., 1999). The concentration of pollen and spores is

related to the distance between the parent plants and depositional locations. Shallow

marine sediments adjacent to continents (~200 km) commonly contain abundant

terrestrial palynomorphs. Vanderkaars and De Deckker (2003) found terrestrial pollen

and spores, Asteraceae, Chenopodiaceae, Acacia, and others, in 38 cores taken offshore

Western Australia. Muller (1959) (Orinoco Shelf Expedition) found Anacardiaceae,

Pteridaceae, Cyatheaceae, and other terrestrial pollen and spores, more than 30 species,

in the sediments of the Gulf of Paria and on the outer shelf north and east of Trinidad.

Terrestrial palynomorphs in near shore marine sediments have been used to

reconstruct sea level, and to investigate ancient climates. Woodroffe and Gridrod (1991)

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This dissertation follows the style of the *Palynology.*

used the global distribution of mangrove pollen to trace sea-level fluctuations during the Quaternary. Hooghiemstra (1988) used palaeo-isopollen maps to provide evidence for the latitudinal position of the northeast trade winds and the African Easterly Jet and for the average northernmost and southernmost position of the intertropical convergence zone during the last glacial-interglacial transition. Luo, Sun, and Jian (2005) used the frequency of pollen rain to trace Millankovitch cyclicity in sediments.

Terrestrial palynomorphs are abundant near the shore, but rare in open ocean sediments. Koreneva (1968) reported on the pollen and spores recovered from marine sediments and cores collected during the 26th voyage of the *Vityaz* in the South Pacific Ocean, from the Marshall Islands (~ 100 km north) to New Zealand (~ 500 km south) (Fig. 1). Koreneva (1968) is the English translation of a longer paper published by this author in the journal of the Geological Institute of Moscow (Geologischeskiy Institut, Moscow, Trudy) in 1964. In it, Koreneva (1968) reported the concentration of palynomorphs per gram of sediment, which she determined by weighing sediment samples prior to processing, mounting the entire sample, and counting all the pollen and spores on all of the slides. She found abundant terrestrial pollen and spores, over 400 grains per 10 g of sediment, in a marine core approximately 200 km to the east of New Zealand. Conversely, she found ten or fewer terrestrial palynomorph grains per 10 g of sediment in a marine core and a surface sample of marine sediment collected respectively, approximately 80 km to the west, and approximately 230 km to the west of New Zealand (Koreneva, 1968). The prevailing wind direction in New Zealand, which is from the west, appears to control the abundance of terrestrial palynomorphs in these

oceanic sediments. The core to the east and downwind of New Zealand contains abundant terrestrial palynomorphs; cores to the west and upwind contain few terrestrial palynomorphs.

Koreneva (1968) recorded the abundance of terrestrial palynomorphs along a north to south transect from the Marshall Islands to New Zealand. Aside from the samples and cores collected close to New Zealand, most of the terrestrial palynomorphs found in marine sediments along the transect were spores. Along the transect, only one marine surface sediment sample (Sample 3851), which lay at approximately 18.3°S, 171° E, about 300 km east of Vanuatu (the former New Hebrides) contained abundant terrestrial spores (approximately 90 grains per 10 g sediment). Koreneva found no terrestrial palynomorphs in Core 3852 that lay north of Sample 3851, approximately 375 km from Vanuatu. Similarly, she found no terrestrial palynomorphs in Core 3850 that lay to the south of Sample 3851, approximately 200 km from Vanuatu. Prevailing winds, which may have carried pollen from Viti Levu, the southern Fiji Island to Sample 3851, might explain the enigmatic distribution of terrestrial palynomorphs at these three sites. No islands lie to the west of Core 3850 and prevailing winds from Vanua Levu, the northern Fiji Island, may have missed Core 3852. The only other marine cores or sediment sample along the *Vityaz* transect that contained terrestrial spores was Sample 3859, which contained 10 spores in 10 g of sediment (Koreneva, 1968).

Koreneva (1968) is unique in its focus on terrestrial pollen in an open ocean setting. Recent investigations of terrestrial pollen and spores in the South China Sea (Sun et al., 1999) and Java and Banda Seas, north of Australia (van der Kaars, 2001)

found significantly higher concentrations of terrestrial pollen and spores in marine

sediments. However, these authors investigated ocean sediments from sites that were

closer to the continental shelf than sites in Koreneva's (1968) study. Sun et al. (1999)

reported extremely high concentrations of terrestrial pollen and spores from the lower

continental slope of southern China (400,000 grains per 1 g of sediment) and the

Luconia shoals, on the northern edge of the continental shelf of Borneo (40,000 grains

per 1 g sediment). Sun et al. (1999) reported extremely low terrestrial palynomorph

concentrations from deep ocean settings south of China; however the lowest pollen

concentration reported in their study, < 1000 grains per 1 g sediment, is much higher

than the highest concentration reported by Koreneva (1968: > 40 grains per 1 g

sediment). It is difficult to compare van der Kaars (2001) pollen concentrations with

those of Koreneva and Sun et al. (1999) because van der Kaars (2001) standardized his

concentrations using volume rather than weight. Nonetheless, van der Kaars (2001)

reported pollen concentrations of > 1000 grains per cm^3 of sediment, and fern spore

concentrations of > 1000 grains per cm^3 of sediment.

Because terrestrial pollen and spores are rare in marine sediments, few workers

report their absence. The scientific party of DSDP Leg 17 noted that no terrestrial pollen

and spores were recovered in cores from Site 167 on the Magellan Rise, which is at least

700 km from the closest island, Howland Island, although they did recover a few poorly

preserved dinoflagellate cysts. Significant studies based on terrestrial palynomorphs in

DSDP, ODP, and IODP cores include:

(1) Mudie (1989) found that the pollen-spore concentrations from Leg 104 (Site

642 to 644) show cyclical variations which appear to correspond to climate
fluctuations in Pliocene and younger sediments.

(2)   Mohr (1990) used terrestrial palynomorphs to date ODP Leg 113 (Site 693) as
      early Albian; Mutterlose and Wise (1990) also reported terrestrial spores from
      ODP Leg 113 (Site 692, 693).

(3)   Gee and Mohr (1992) used palynology to date Upper Jurassic and Lower
      Cretaceous sediments from ODP Leg 120.

(4)   Ogg (1992) found Cretaceous palynomorphs at ODP Leg 129 (Valanginian to
      Campanian).

(5)   Heusser and Van de Geer (1994) found a diverse and abundant palynomorph
      assemblage in the upper 40 m of DSDP Site 594, 200 km from the east shore of
      South Island, New Zealand. Koreneva (1968) also found abundant terrestrial
      palynomorphs in oceanic sediments on the east side of South Island, New
      Zealand.

(6)   Leroy and Dupont (1994) used pollen record of ODP Leg 108 Site 658 to find a
      strong aridification of the climate of northwestern Africa, which occurred
      during 3.26 Ma.

(7)   Jolley (1998) found that the rich terrestrial component of the pollen and spore
      flora from ODP Leg 152 (East Greenland Margin) is consistent with the Eocene
      temperature maximum.

(8)   Haberle and Maslin (1999) studied ODP Leg 155 Site 932 and found that the
      Amazon Basin forests were not extensively replaced by savanna vegetation

during the glacial period. The results also contradicted the refugia hypothesis.

(9) Pisias, et al. (2004) studied pollen record from ODP Leg 202 Site 1233 and the results suggest that climate variability during the past 75kyr in the Southeast Pacific is tightly coupled at periods longer than 3000 years.

Pollen and spores concentrations in marine sediments appear to be controlled by the mechanism of transportation from parent plants to the location of the sample, which includes wind and water. Terrestrial palynomorphs are rarely found in deep sea sediments unless there is a large island or continent nearby in the direction of prevailing winds or currents. In general, the abundance of palynomorphs in marine sediments decreases with increasing distance from islands and continents (Koreneva, 1968). Both the structure and shape of pollen and spores influence their long distance transport, deposition, and preservation in marine sediments. For example, Koreneva (1968) suggested that pollen was deposited closer to shore than spores. Turbidites carry pollen and spores both to continental shelves and to the deep sea (Ogg, 1992; Heusser, 1988; Baudouin et al., 2004). Baudouin et al. (2004, and references therein) gives an overview of pollen in turbidites on continental shelves sourced by deltaic fans. Ogg (1992) suggested that turbidity currents transported Cretaceous and Cenozoic pollen to Site 802; the source of Cretaceous pollen at this site may have been emergent seamounts on the Darwin Rise discussed by McNutt et al., (1990).

In this study, we investigate terrestrial palynomorphs from Albian sediments of Allison Guyot, in the central Mid-Pacific Mountains (ODP Leg 143, Site 865). This guyot has a thick limestone cap enclosed by a perimeter reef, indicating that it could

have included islands in the mid Cretaceous (Sager, Winterer, Firth, et al., 1993). It probably originated in the southern hemisphere between 12° and 17°S (Sager, Winterer, Firth, et al., 1993). Firth et al. (2009) discovered vertebrate teeth, including a saltwater crocodile, and terrestrial palynomorphs in mid-Cretaceous sediments from Allison Guyot. There are two principal hypotheses entertained for Pacific carbonate platforms including Allison Guyot: (1) "Death-by-Emergence-and-Submergence", which supposes that the platforms became exposed due to a short-term drop in relative sea level, and then drowned by relatively rapid deepening of sea level that outpaced subsequent carbonate production. (Winterer and Sager, 1995; Winterer and others, 1995; Jenkyns and Wilson, 1999); (2) "Death-in-the Tropics", which supposes that the northward conveyor-belt motion of the Pacific Plate brought the platforms into peri-equatorial waters, which were unfavorable to skeletal and inorganic carbonate production (Larson and others, 1995; Wilson and others, 1998; Jenkyns and Wilson, 1999). Shallow-water carbonate facies, indicative of both lagoonal and open marine conditions, that date to the Early Albian, suggest that Allison Guyot may have been periodically exposed throughout the Albian (Shipboard Scienctific Party, 1993). The guyot drowned near the end of the Albian (Röhl and Ogg, 1998): the uppermost shallow-water carbonate sediments of Allison Guyot date to the Albian/Cenomanian boundary (Jenkyns and Wilson, 1999). Jenkyns and Wilson (1999) found evidence for meteoric water in the calcite cements of some Central Pacific guyots (e.g. Site 886, Resolution Guyot, which is near Allison Guyot). However, clear evidence of meteoric water was not found on

Allison Guyot because there were so few clear calcite cements in the top 150 m of Allison Guyot sediments.

The remarkable calcrete sediments on Resolution Guyot provide evidence for a meteoric water system on this guyot. The presence of woody roots and traces of coal indicate the presence of land plants on Allison Guyot in the Albian (Shipboard Scientific Party, 1993). The abundance of terrestrial pollen and spores in Allison Guyot sediments supports the presence of land plants on Allison Guyot. The composition of this flora, which is dominated by spores, but also contains pollen from gymnosperm shrubs (*Ephedripites*) and trees (*Callialasporites*), suggests the presence of a meteoric water system on Allison Guyot. Similarities between the fern assemblage of Allison Guyot and the Albian fern flora of New Zealand suggest that Allison Guyot originated in the Southern Hemisphere.

CHAPTER II

LOCALITY AND STUDY MATERIAL

Locality

Flat-topped Cretaceous seamounts, most of which lie between 1 and 2 km below sea level, indicate the presence of ancient islands in the Pacific Ocean. These flat-topped seamounts were named "guyots" by Hess (1946). Presently, 80% to 90% of all Pacific guyots lie north of the Equator (Menard, 1964; Vogt, 1989, Jenkyns and Wilson, 1999). Hamilton (1956) reported shallow-water limestones of Cretaceous age on the top of certain guyots, which he interpreted as erosionally truncated volcanic islands. Subsequent drilling demonstrated the common presence of Cretaceous shallow-water facies and fossils above the volcanic base of many guyots. (Heezen and others, 1973; Winterer, Ewing, and others, 1973; Matthews and others, 1974; Winterer and Metzler, 1984; Grötsch and Flügel, 1992; Lincoln, Pringle, and Premoli Silva, 1993; Winterer and Sager, 1995; Flood, 1998; Jenkyns and Wilson, 1999) Generally, Pacific guyots are thought to have similar geological evolution throughout past time.

Allison Guyot, which is one of biggest Pacific guyots, has a thick limestone cap that reflects a sequence of ponded lagoonal sediments enclosed by a perimeter reef (Sager, et al., 1993). The first samples in the research were from Leg 143 Site 865 located at 18°26.41'N, 179°33.34'W, at 1518 m water depth and atop Allison Guyot in the central Mid-Pacific Mountains (Fig. 2). Allison Guyot has a thick limestone cap that reflects a sequence of ponded lagoonal sediments enclosed by a perimeter reef (Sager, Winterer, Firth, et al., 1993) (Fig. 3). It is speculated to have originated in the southern

hemisphere between paleolatitudes 12° and 29°S, probably between 12° and 17°S (Sager,

Winterer, Firth, et al., 1993), and between paleolongitudes 123° and 127° W (Winterer

and Sager, 1995). (Fig. 4) Allison Guyot was chosen for drilling because it has pelagic

limestone overlying shallow water limestone, and the age of reefal drowning could be

constrained. In addition, the limestone cap was thin enough that the oldest, deepest

lagoonal sediments could be cored (Sager, Winterer, and Firth, 1993). The total

thickness of the shallow-water carbonate section of Allison Guyot is around 700 m.

Basalt is below the carbonate section.

The age of the top of the shallow-water carbonate section of Allison Guyot, based

on the Sr-isotope curve, is close to the Albian-Cenomanian boundary (Jenkyns et al.,

1995). In addition, latest Albian planktonic foraminifera, *Rotalipora appenninica*, were

found in the shallow-water carbonate section (Grötsch and Flügel, 1992; Winterer et al.,

1993; Jenkyns and Wilson, 1999). The age of the oldest igneous rocks drilled on Allison

Guyot is 110.7± 1.2 Ma (early Albian: Pringle and Duncan, 1995). According to Sager et

al. (1993), Allison Guyot has a substantial pelagic cap, consisting of 140m of Paleocene-

lower Oligocene nannofossil ooze to sand. The cross section of Allison Guyot is shown

in Figure 5. The cessation of carbonate-platform sedimentation prior to the deposition of

the pelagic cap indicates the drowning of Allison Guyot.

Based on foraminifera and strontium-isotope ratios, the age of the cores that

contain terrestrial palynomorphs is Early Albian, close to the Aptian/Albian boundary

(Sliter, 1995; Jenkyns et al., 1995). Sliter (1995) identified foraminifera from core

interval 143-865A-79R as the *Hedbergella praetrocoidea-H. trocoidea* lineage or

perhaps juvenile *H. trocoidea*, which lived near Aptian/Albian boundary. Jenkyns et al. (1995) dated the core interval 700 to 800 mbsf depth as Early Albian; the samples used in this study came from the core interval 680 to 870 mbsf.

Study Material

In order to learn more about the Albian terrestrial flora of Allison Guyot, twenty three samples from the Leg 143 Site 865, Allison Guyot, were selected for this study. Samples were taken from cores 74, 78, 81, 85, 86, 87, 88, 89, 90, 92, and 94, which were close to a root in growth position (Section 143-865A-89R-3) and coalified woody material (Section 143-865A-89R-5) (Table 1).

(1) Core interval 143-865A-74R, 679.7 to 689.4 mbsf depth, 1 sample, wackestone with some dark gray clay seams, stylolites, compacted burrows, leached zones infilled by probable dolomite.

(2) Core interval 143-865A-78R, 718.3 to 728.1 mbsf depth, 1 sample, mudstone and wackestone with clayey sediment, foraminifers (miliolids) and gastropods, burrows infilled with rhombic crystals of dolomite, common stylolites.

(3) Core interval 143-865A-81R, 747.4 to 757.1 mbsf depth, 2 samples, packstone and wackestone with foraminiferal and other molds, some dolomite, disseminated organic matter, mm-cm-size black pebbles, and black clayey seams with pyrite.

(4) Core interval 143-865A-85R, 786.2to 795.8 mbsf depth. 1 sample, clayey limestone with appearance of peloids, foraminifers, and replaced gastropod shells, some with dolomite.

(5) Core interval 143-865A-86R, 795.8 to 805.4 mbsf depth, 2 samples, white to

gray clayey limestone (packstone) with foraminifers, bivalves, and gastropods.

(6) Core interval 143-865A-87R, 805.4 to 815.1 mbsf depth, 2 samples, gray to white intensively bioturbated, laminated clayey limestone with benthic foraminifers.

(7) Core interval 143-865A-88R, 815.1 to 824.8 mbsf depth, 2 samples, bioturbated clayey limestone (packstone), white to gray, with benthic foramminifers, gastropods, bivalves, ostracods, and sponge spicules, intercalated with thin, dark clayey layers.

(8) Core interval 143-865A-89R, 824.8 to 831.8 mbsf depth, 6 samples, parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers.

(9) Core interval 143-865A-90R, 831.8 to 841.1 mbsf depth, 4 samples, clayey limestone (packstone), large gastropods, peloids, foraminifers, abundant sponge spicules, and finely disseminated organic matter and pyrite.

(10) Core interval 143-865A-92R, 847.2 to 853.4 mbsf depth, 1 sample, black claystone, pyritic and locally green and laminated on a mm scale.

(11) Core interval 143-865A-94R, 863.1 to 870.9 mbsf depth, 1 sample, bioturbated clayey limestone, abundant carbonaceous particles, numerous gastropods, bivalves, some woody pieces replaced by pyrite, and few benthic foraminifers.

Methods

First 10 samples, weighing between 16.70 g to 20.88 g, from cores 143-865A-89R, -90R, -92R, and -94R (labeled 1-1 to 1-10, from youngest to oldest, Table 1) and Second 13 samples, weighing between 10.08 g to 10.89 g, from 143-865A-74R to 143-865A-89R (labeled 2-1 to 2-13, from youngest to oldest, Table 1), were processed for pollen extraction using the procedure in 'Palynological techniques-processing and microscopy' (Wood et. al, 1996). A solution of 10% potassium hydroxide (KOH) was used to remove humic compounds and make the material easier to view. This also helped to disperse some forms of consolidated organic materials to disperse. HCl was also used to remove carbonates. The silicate component was removed by soaking the samples in hydrofluoric acid (HF) overnight. The acetolysis process, which involved soaking samples in nine parts acetic anhydride and one part sulphuric acid, helped to remove cellulose.

After weighing, samples from 1-1 to 1-10 and from 2-1 to 2-13 were soaked in hydrochloric acid (37.5% HCl) until the reaction stopped. One tablet of tracer spore "*Lycopodium*", containing 12,500 spores of "*Lycopodium*", were added into each sample 1-1 to 1-5 with the HCl. Tablets of tracer spores were added to the first five samples in order to determine the abundance of spores in samples from Site 865 at the beginning of the research. I did not add tracer spores in the remaining 18 samples because Cretaceous reticulate and spinose spores of *Lycopodium* were found in the first five samples. Although I was able to differentiate Cretaceous and modern *Lycopodium* spores in these five samples, adding *Lycopodium* tracer spores to the remaining 18 samples might have complicated identification of Cretaceous Lycopodium in these samples. Samples were

washed in water three times and sieved with a stainless steel screen of 150 microns to remove coarse inorganic materials and debris during washing. The residue (silt) at the bottom of beakers was discarded after decanting the liquid following the last wash. The remaining liquid sat for more than 4 hours, allowing the palynomoprhs to settle to the bottom of the beaker. The liquid in the beakers was siphoned off and discarded. HF was added to beakers to cover the samples and beakers sat overnight. The next morning, the beakers were filled with samples with water and allowed to sit for three hours, after which the water was discarded. The step of filling the beaker with water and allowing the sample to sit for three hours was repeated. A solution 37.5% HCl and water (half and half) was used to rinse each sample into a 50 ml tube. Tubes were spun in a centrifuge for one minute and the liquid was discarded. Tubes were refilled with 37.5% HCl and the residue was completely mixed with the acid. Tubes were spun for 30 to 40 seconds and the liquid discarded. This step was repeated until the spun liquid became clear. The tubes were spun again and the HCl was discarded. Water was added to the tube, and mixed with the residue. Tubes were spun for tubes for 1 minute and the water discarded. This step was repeated one more time, and the residue was checked under the microscope.

Residue was moved to 15 ml tubes, and glacial acetic acid (CH_3COOH) was added up to the 10 ml mark. Tubes were caped and vortexed to mix residue and liquid. Tubes were then spun and the liquid discarded, and vortexed a second time. Wearing protective dress and working in a hood, a mixture of acetic anhydride and sulphuric acid was prepared by measuring nine parts acetic anhydride into a dry graduated cylinder,

using a clean pipet to add one part sulphuric acid. The ratio of acetic anhydride and sulphuric acid is 9:1. Into each sample tube, 5 ml acetolysis mixture was added and the sample was stirred with a stick. The sample tubes were placed in a heating block, which had been preheated for more than 30 minutes). Samples were heated for 5 to 8 minutes and stirred three times during heating, taking care to use a separate stick for each sample and to remove the wooden sticks after each stirring. Sample tubes were removed from the heating blocks and 1 to 2 ml of glacial acetic acid added. Tubes were capped and spun and the liquid decanted. Tubes were filled to the 7.5 ml mark with glacial acetic acid, capped, and vortexed. Water was added to the tubes and the tubes were spun. Following this, the liquid was decanted and the sample vortexed. The procedure of adding water, vortexing the samples to mix the water with the residue, followed by spinning the samples and decanting the liquid was repeated at least two times. Finally samples were vortexed and 1 to 3 drops of Safranin-0 were added into each tube and water was added to fill the tube. Tubes were spun and the liquid decanted. The step of adding water to fill the tube, spinning the tube and decanting the liquid was repeated. Then $ZnBr_2$ was added into each tube to the 4 ml mark. Tubes were stirred completely and water was carefully added such that it ran down the inside of the tube filling the tube to the 7 ml mark. Extreme care was used not to mix this water with the sample. Tubes were spun at the lowest speed for 5 minutes and then at speed 80 for 5 minutes. At this point in the process, the sample tubes had three layers of liquid. The upper two layers were siphoned off into 15 ml beakers. A 95% solution of ETOH was used to wash the residue and liquid into 1.5 ml tubes. These tubes were spun and the ETOH was decanted

and discarded. Four to five drops of glycerine was added to the sample and the sample was and stirred. Following this step, samples were allowed to sit for 24 hours for the ETOH to evaporate.

Due to the difficulty of disaggregating samples 1-1 to 1-10, by KOH, ultra sonication for 10 seconds was used in processing samples 1-5, 1-6, 1-7, and 1-9. Despite treatments with HCl and KOH, and repeated rinsing of samples, samples 1-5, 1-6, 1-7, and 1-9 retained a large amount of organic debris. This debris may be lignin.

In order to completely sample this site, 13 additional samples were requested from Leg 143 Site 865. Processing of these samples included HCl, HF, and acetolysis as described above. Sample 2-4, 2-5, 2-12, and 2-13 were processed with one drop of bleach for less than 10 seconds to remove organic matter.

After processing, we observed samples in a compound microscope at 40X, 60X and 100X and took photographs for our records and to verify identifications. In identifying specimens, we used Mildenhall (1994) and comparison of our specimens with specimens in slides from Ogg's (1992) study lent to us by the author. For the most part, we followed the systematic usage of Mildenhall (1994). However, we follow Pocock and Vasanthy (1988) in assigning plicate pollen with straight plicae to *Ephedripites* rather than *Equisetosporites*. Takahashi et al. (1995) reserved *Equisetosporites* for monoporate, spirally plicate pollen with psilate exine ribs.

CHAPTER III

RESULTS

Pollen and Spore Recovery

Samples 1-1 to 1-4, 1-6, 1-7, 2-11 and 2-12 have the highest recovery of

terrestrial palynomorphs. Samples 1-5, 1-8, 2-3, 2-8, and 2-10 contain few terrestrial

palynomorphs. Of these, 1-8 and 1-5 lay close to basalt layers. Samples 2-8 and 2-10

come from an interval (from sample 2-4 through 2-10) with abundant microforams and

leiospheres, but few terrestrial palynomorphs; however other of the samples from this

interval contain more terrestrial palynomorphs. Sample 2-3 contains a low abundance of

microforams, leiospheres and terrestrial palynomorphs.

Pollen Assemblage

13 pollen types, 28 spore types, 2 dinoflagellates, and leiospheres are found in

samples (Table 2 and 3, Plate 1-6). The palynomorphs can be related to plant taxa:

Filicopsida, including Cyatheaceae, Dicksoniaceae, Schizaeaceae, Osmundaceae,

Gleicheniaceae, Hymenophyllaceae, and Aspleniaceae; Bryophyta; Lycopodiaceae;

Selaginellaceae; and conifers including Araucariaceae and possibly, Podocarpaceae.

(Plate 1-6) The most common spore type is *Cyathidites minor* (Cyatheaceae). The

second abundant spore type is *Gleicheniidites senonicus* (Gleicheniaceae). Rare

palynomorphs, such as *Callialasporites dampieri*, *Cicatricosisporites hughesii*, and

Impardecispora excavate, occur only in one or two samples. The highest diversity of

palynomorphs occurs in samples 1-4 and 2-2 (25 species). Microforaminifera and

leiospheres are abundant in samples 2-4 to 2-10. The description of pollen and spore

types is shown below.

Systematic Description

Plate 1 Pollen Types
Fig. 1
Callialasporites dampieri, Balme (1957), Mildenhall (1994) 50 µm × 50 µm
Outline subcircular, with inner circle. Monosaccate, with narrow, continuous, radially folded saccus. No pores and colpi. Exine is etectate and psilate.

Fig. 2
Callialasporites segmentatus, Balme (1957), Mildenhall (1994) 53 µm × 50 µm
Outline subcircular, with inner circle. Monosaccate, with subcircular amb and narrow segmented, intensely radially folded saccate. Exine is etectate and psilate.

Fig. 3
? Podosporites, Schrank (2010) 30 µm × 20 µm
Outline elongate elliptical body, with two semi-circles on the two sides of the long axis. Bisaccate, with two sacs. Exine is intectate and reticulate (parts of pattern are pentagonal).

Fig. 4, 5
Unknown-1, 25 µm × 20 µm
Outline elliptical, with 4 straight, smooth ridges with thin crests. Stephanocolpate, with 4 colpi located between ridges. Exine is etectate and psilate.

Fig. 6, 7
Unknown-2 (? Picea), 135 µm × 87.5 µm
Outline elongate elliptical body, with two semi-circles on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate. Body surface is smoother than saccus surface. Reticulation is denser on body surface than on saccus surface.

Fig. 8
Unknown-3, 40 µm × 20 µm (body), 22.5 µm × 12.5 µm (sacci)
Outline elongate elliptical body, with two small flat elliptical saccus on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate.

Fig. 9, 10
Unknown-4, 52.5 µm × 45 µm (body), 42.5 µm × 20 µm (sacci)
Outline elongate subelliptical body (bullet-like), with two small elongate elliptical saccus on the two sides of the short axis. Bisaccate, with two saccus shrinking under body part. Exine is intectate and reticulate. Body surface is smoother than saccus surface.

Fig. 11, 12
Unknown-5, ~52.5 µm × 42.5 µm (body), ~37.5 µm × 22.5 µm (sacci)
Outline elongate subelliptical to rhombic body, with two small elongate elliptical saccus on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate. Surface is rougher than surface of Unknown-4.

Fig. 13, 14
Unknown-6, 47.5 µm (body-length), 32.5 µm (sacci-length)
Outline elongate subelliptical body, with two small elongate subelliptical saccus on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate.

Fig. 15, 16, 17
Unknown-7, ~37.5 µm × 32.5 µm (body), ~32.5 µm × 15 µm (sacci)
Outline elongate subelliptical body, with two small elongate subelliptical saccus on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate.

Fig. 18, 19
Unknown-8, 37.5 µm × 27.5 µm (body); 20 µm × 20 µm (saccus)
Outline elongate elliptical body, with two semi-circles on the two sides of the long axis. Bisaccate, with two saccus. Exine is intectate and reticulate. Body surface is smoother than saccus surface. Reticulation is denser on body surface than on saccus surface.

Plate 2 Spore Types
Fig. 1
Baculatisporites comaumensis, Cookson (1953), Potonie (1956) 37 µm × 25 µm
Outline circular. Trilete, with three laesura connecting to each other at one point and located on the same surface. Exine is intectate and verrucate to baculate.

Fig. 2
? *Biretisporites potoniaei,* Delcourt and Sprumont (1955) 38 µm × 38 µm
Outline subcircular, with one sharp apex. Trilete, with three laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 3, 4
Ceratosporites equalis, Cookson and Dettmann (1958) 20 µm × 18 µm
Outline circular. Trilete, with three laesura connecting to each other at one point. Exine is intectate and baculate (~2 µm length).

Fig. 5, 6
Cicatricosisporites hughesii, Dettmann (1963), Mildenhall (1994) 55 µm × 55 µm
Outline subtriangular, with convex sides. Trilete, with wide lumina between the narrow muri running parallel to the interradial margins of the spore. Exine is intectate and striate.

Fig. 7
Cicatricosisporites sp., Vajda and Raine (2003) 35 µm × 30 µm
Outline circular, with reticulate pattern. Trilete, with three laesura. Exine is intectate and striate.

Fig. 8
Cyathidites minor, Couper (1953) 20 µm × 20 µm
Outline subtriangular with round apexes and concave sides. Trilete, with three wide opening laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 9
? Foveosporites canalis, Balme (1957) 38 µm × 38 µm
Outline circular. Trilete, with three laesura connecting to each other at one point and diverging at the other ends. Exine is etectate and psilate (laevigate).

Fig. 10, 11, 12, 13
Gleicheniidites senonicus, Ross (1949) 30 µm × 30 µm
Outline subtriangular, with concave sides and laterally expanded apices. Tetrahedral trilete, with three protruding laesura connecting to each other at one point and extending to the equator. Exine is etectate and psilate (laevigate).

Fig. 14
Impardecispora excavate, Ravn (1995) 10 µm × 10 µm
Outline subtriangular, with two round apexes and think wall on three apexes. Trilete, with three laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 15
Laevigatosporites ovatus, Wilson and Webster (1946) 26 µm × 21 µm
Outline elliptical. Monocolpate, with one colpus located along the long axis. Exine is etectate and psilate (laevigate).

Fig. 16, 17
Leptolepidites verrucatus, Couper (1953) 48 µm × 40 µm
Outline subtriangular, with round apexes and convex sides. Trilete, with three laesura connecting to each other at one point. Exine is intectate and verrucate (5µm diameter).

Fig. 18
Lycopodiacidites dettmannae, Burger (1980) 30 µm × 25 µm
Outline circular, with spot pattern. Trilete, with three laesura connecting to each other at one point. Exine is intectate and baculate to echinate (spinose).

Fig. 19
Retitriletes circolumenus, Cookson and Dettmann (1958), Backhouse (1978) 30 µm × 25 µm
Outline circular, with reticulate pattern. Exine is intectate and reticulate.

Fig. 20
Ruffordiaspora australiensis, Cookson (1953), Dettmann and Clifford (1992) 50 µm × 37.5 µm
Outline triangular. Trilete, with three laesura connecting to each other at one point and located on the same surface. Exine is intectate and striate (1.5µm width).

Plate 3 Spore Types
Fig. 1, 2
Osmundacidites wellmanii, Couper (1953) 50 µm × 50 µm
Outline subcircular to subtriangular. Trilete with three protruding laesura. Exine is intectate and echinate (1.25µm length) (apiculate).

Fig. 3
? Stereisporites antiquasporites, Wilson and Webster (1946), Dettmann (1963) 17.5 µm × 17.5 µm
Outline subtriangular, with convex sides. Trilete, with wide opening laesura. Exine is etectate and psilate (laevigate).

Fig. 4
Unkown-2, 24 µm × 24 µm
Outline triangular, with three concave apexas (the end of three laesura) and a concave center. Trilete, with three protruding laesura connecting to each other at one point and located on the same surface and contact each other. Exine is etectate.

Fig. 5, 6
Unkown-3, 27 µm × 26 µm
Outline circular, with a chain-like outer frame. Trilete, with three laesura connecting to each other at one point. Exine is intectate and verrucate (2 µm width).

Fig. 7
Unknown-4, 23 µm × 23 µm
Outline circular. Trilete, with three wide opening laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 8
Unknown-5, 22.5 µm × 17.5 µm
Outline elliptical, with hairy structure on the surface. Exine is intectate and echinate (spinose).

Fig. 9, 10
Unknown-6, 30 µm × 30 µm
Outline subtriangular, with round apexes and concave sides. Trilete, with three protruding laesura connecting to each other at one point and extending to the equator. Exine is tectate and reticulate.

Fig. 11, 12
Unkown-7, 27 µm × 21 µm
Outline circular, with radial wall pattern. Trilete, with three wide opening laesura connecting to each other at one point and extending to the equator. Exine is intectate and striate (0.1µm).

Fig. 13
Unknown-8, 60 µm × 60 µm
Outline subcircular to subtriangular, with round apexes and convex sides. Trilete, with three laesura connecting to each other at one point and extending to the equator. Exine is etectate and psilate (laevigate). Wall is thick (3.3 µm).

Fig. 14
Unknown-9, 26.7 µm × 18.3 µm
Outline elliptical, with one concave side. Monolete, with one laesura aligned along the long axis. Exine is etectate and psilate (laevigate).

Fig. 15
Unknown-10, 38.3 µm × 38.3 µm
Outline subtriangular, with convex sides. Trilete, with three protruding laesura. Exine is intectate and striate.

Fig. 16
Unknown-11, 60 µm × 60 µm
Outline subcircular to subtriangular, with one sharp and folded apex. Trilete, with three laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 17
Unknown-12, 26.7 µm × 26.7 µm
Outline elliptical to circular. Trilete, three laesura connecting to each other at one point. Exine is etectate and psilate (laevigate). Inxine is concave at the three points connecting to laesura.

Fig. 18
Unknown-13, 36.7 µm × 36.7 µm
Outline triangular. Trilete, with three laesura connecting to each other and extending to the equator. Exine is etectate and psilate (laevigate).

Fig. 19, 20
Unknown-14, 37.5 µm × 37.5 µm
Outline subtriangular, with round apexes and concave sides. Trilete, with triangular broken shape. Exine is etectate and psilate (laevigate). Wall is thick (2.5 µm).

Plate 4 Spore Types
Fig. 1, 2, 3
Unknown-15, 33.3 µm × 33.3 µm
Outline subtriangular, with round apexes and concave sides. Trilete, with three laesura connecting to each other at one point. Exine is tectate and verrucate to baculate.

Fig. 4
Unknown-16, 40 µm × 27.5 µm
Outline subelliptical. Trilete, with three laesura connecting to each other at one point and extending to the equator. Exine is etectate and psilate (laevigate). Outer part surrounded by wrinkled structure.

Fig. 5
Unknown-17, 32.5 µm × 32.5 µm
Outline subtriangular. No laesura. Three protruding elongated parts connecting to each other as a triangular shape. Exine is etectate and psilate (laevigate).

Plate 5 Dinoflagellate, Microforaminifera
Fig. 1, 2, 3
Diconodinium, Helby and McMinn (1992) 80 µm × 42.5 µm
Outline fusiform and biconical. Unilayered cyst with two horns-one apical, the other antapical. The antapical horn close to the longitidinal axis and is spinelike. Cingulum wide and located in the middle of the cyst.

Fig. 4, 5
Unknown-17 (dinoflagellate),
Outline elliptical. Bilayered cyst with no clear horns. Aperture located on the   part. Cingulum aligned along the short axis.

Fig. 6
Unknown-18 (microforaminifera)
Outline whorl and staphylococcus-like. Seven linked spheral chambers, with broken thin walls.

Fig. 7
Unknown-19 (microforaminifera)
Outline subcircular. Six chambers. Five of them linked together and surround one chamber in the center. Wall thick.

Fig. 8
Unknown-20 (microforaminifera)
Outline whorl ellipses. More than eleven chambers, with sequentially small to big size from center to outer part. Biggest chamber is subtriangular, with convex sides and cracks on the wall. Wall thick.

Fig. 9
Unknown-21 (microforaminifera)
Outline subcircular. More than nine linked chambers, with subtriangular plate-like shapes. Wall thick.

Fig. 10
Unknown-22 (microforaminifera)
Outline whorl ellipses. More than ten chambers, with sequentially small to big size from center to outer part. The wall of biggest chamber is thinner than other chambers.

Fig. 11, 12
Unknown-23 (microforaminifera)
Outline chain-like. Five chambers linked together Hole in the center. Wall thin.

Fig. 13, 14
Unknown-24 (microforaminifera)
Outline chain-like. Five chambers linked together Hole in the center. Elongate structure at the end and outer side. Wall thin.

Fig. 15
Unknown-25 (microforaminifera)
Outline chain-like. Five chambers linked together Hole in the center. Elongate structure at the end and outer side. Wall thin.

Fig. 16, 17, 18
Unknown-26 (microforaminifera)
Outline chain-like. Five chambers linked together Hole in the center. Elongate structure at the end and outer side. Wall thin.

Fig. 19
Unknown-27 (fragment of microforaminifera)
Outline subtriangular. Two linked chambers. Cracks on walls. Triangular pattern on the lateral sides. Wall thick.

Plate 6 Leiosphere
Fig. 1, 2
Unknown-28, 65 µm × 55 µm
Outline circular to subcircular. Thin. Bilayered wall (3.75µm), without pylome. Center

lain by irregularly ridged, without a definite ridge pattern.

Fig. 3
Unknown-29, 92.5 µm × 87.5 µm
Outline circular to subcircular. Thin. Bilayered wall (<3.75µm), without pylome. Center folded.

Fig. 4
Unknown-30, 87.5 µm × 82.5 µm
Outline circular to subcircular. Thick. Bilayered wall (10µm), with concave center.

Fig. 5
Unknown-31, 70 µm × 70 µm
Outline circular. Thick. Bilayered wall (7.5µm).Center with one convex ridge aligning along central axis.

Fig. 6
Unknown-32, 70 µm × 70 µm
Outline circular. Thin. Bilayered wall (1.25µm), with two or more pylomes. Inner layer irregularly ridged, without a definite ridge pattern. excystment is by mean of a rounded pylome, bordered with an elevated rim.

Fig. 7
Unknown-33, 70 µm × 55 µm
Outline subelliptical. Thin. Bilayered wall (1.25µm), with one pylomes. Inner layer irregularly ridged, without a definite ridge pattern. Excystment is by means of a rounded pylome.

Fig. 8
Unknown-34, 40 µm × 40 µm
Outline subcircular. Thin. Monolayered wall, without pylome, with two protruding crescent.

Fig. 9
Unknown-35, 125 µm × 110 µm
Outline subelliptical. Thin. Bilayered wall (1.25µm), without pylome. Outer layer folded. Inner layer irregularly ridged, without a definite ridge pattern.

Fig. 10
Unknown-36, 77.5 µm × 77.5 µm
Outline circular. Thin. Bilayered wall (1.25µm), without pylome. Rough surface, with spots. Layer irregularly ridged, without a definite ridge pattern.

Fig. 11
Unknown-37, 85 µm × 65 µm
Outline subelliptical. Thin. Bilayered wall (2.5µm), with one pylome. Excystment is by means of an irregular pylome.

Fig. 12
Unknown-38, 65 µm × 65 µm
Outline circular. Thin. Bilayered wall (5µm). Layer irregularly ridged, without a definite ridge pattern. Outer layer broken in the center.

Fig. 13
Unknown-39, 50 µm × 50 µm
Outline circular. Thin. Monolayered wall (1.25µm), without Pylome. Layer irregularly ridged, without a definite ridge pattern.

Fig. 14
Unknown-40, 87.5 µm × 65 µm
Outline circular. Thin. Bilayered wall (<1.25µm), without Pylome. Layer irregularly ridged, without a definite ridge pattern.

Plate 7 Palynomorphs from Leg 129 Site 802 (Ogg, 1992)
Fig. 1, 2
Callialasporites trilobatus, Balme (1957); Dev (1961) 45 µm × 35 µm (Fig. 1); 37.5 µm × 47.5 µm (Fig. 2)
Outline subcircular, with inner subcircle to subtriangular. Trisaccate, without apertures and colpi. Exine is etectate (psilate) or intectate (granulate).

Fig. 3
Cyathidites minor, Couper (1953) 40 µm × 40 µm
Outline subtriangular with round apexes and concave sides. Trilete, with three wide opening laesura connecting to each other at one point. Exine is etectate and psilate (laevigate).

Fig. 4, 5
Cicatricosisporites australiensis, Cookson (1953); Potonié (1956) 35 µm × 32.5 µm
Outline circular, with reticulate pattern. Trilete, with three laesura. Exine is intectate and striate.

Fig. 6
Gleicheniidites spp., 22.5 µm × 22.5 µm
Outline subtriangular, with concave sides and laterally expanded apices. Tetrahedral trilete, with three protruding laesura connecting to each other at one point and extending to the equator. Exine is etectate and psilate (laevigate).

Fig. 7
Concavissimisporites punctatus, Delcourt and Sprumont (1955); Brenner (1963), 42.5 µm × 42.5 µm
Outline subtriangular with round apexes and concave sides. Center concave. Trilete, with three wide opening laesura connecting to each other at one point. Exine is intectate and verrucate.

Fig. 8
?Foraminisporis asymmetricus, Cookson and Dettmann (1958); Dettmann (1963), 45 µm × 45 µm
Outline subtriangular with round apexes and concave sides. Trilete, with three laesura connecting to each other at one point and located on the same surface.The edge of laesura thick protuding. Exine is intectate and verrucate to baculate.

CHAPTER IV

DISCUSSION

Evidence for Freshwater Plants on Allison Guyot in the Albian

The presence of *in-situ* roots and traces of lignite in Allison Guyot cores indicates

the presence of land plants growing on Allison Guyot in the Early Albian. In the

Cretaceous, the closest emergent land to Allison Guyot was probably Resolution Guyot

(Site 866), which lay approximately 675 km to the north (Koppers et al., 1998; Winterer

and Sager, 1995). Since the direction of prevailing winds would have been from the

south and east, Resolution Guyot probably did not contribute terrestrial palynomorphs to

Allison Guyot sediments due (Fig. 5).

Both distance from shore and the prevailing wind and current direction influence

the distribution of terrestrial palynomorphs in marine sediments (Muller, 1959;

Koreneva, 1968; Farley, 1987). Koreneva (1968) found a high diversity and great

abundance (> 400 grains/ 10 g sediment) of terrestrial palynomorphs in marine

sediments off shore from the southeast coast of New Zealand, in the downwind direction.

She found very few terrestrial palynomorphs to the northwest of New Zealand, in the

upwind direction. Farley (1987) reported that the direction of prevailing currents (wind

and water) influenced the diversity and abundance of terrestrial palynomorphs in marine

sediments in the Caribbean Basin.

Terrestrial palynomorphs rarely occur in marine sediments far from continents

and islands. Koreneva (1968) found almost no pollen in sediments from the ocean floor

which lay north of New Zealand between Vanuatu and the Fiji Islands. Sample 3848,

the single exception was core, which lay approximately 300 km from Vanuatu and approximately 600 km from the Fiji Islands (Fig. 1). This core contained almost 100 terrestrial palynomorphs per 10 g of sediment. The source of these palynomorphs may have been the Fiji Islands, which lay to the east of the core, such that prevailing winds could have transported palynomorphs from Fiji to the core site. However, Koreneva's core 3852, which appears to lie in the path of prevailaing winds from the northern large Fiji Island, Vanua Levu, contains no terrestrial palynomorphs. Although Koreneva (1968) contains a comprehensive discussion of terrestrial palynomorphs in open ocean sediments, she did not report the latitudinal coordinates of her samples and cores, and the map of sampling localities included in the translation of her paper is schematic, which makes detailed interpretation of her results difficult.

In contrast to the low concentration of pollen and spores in the open ocean sediments in Koreneva's research, the concentration of terrestrial pollen and spores in samples from Allison Guyot was higher than 30 grains per 10g, indicating that this palynomorph assemblage derived from plants growing on Allison Guyot. Due to the long distance between Allison Guyot and other continents and islands (more than 675 km), it seems unlikely that Allison Guyot palynomorphs were transported from other land masses. Tropical heavy, and often daily, rainfall tends to wash the air clear of dust and pollen, restricting the long-distance transport of terrestrial palynomorphs, especially in the rainy season (Muller, 1959).

The terrestrial palynomorph assemblage of Allison Guyot consists of tree ferns (Cyatheaceae), forked ferns (Gleicheniaceae), club mosses (Lycopodiaceae) and

gymnosperm shrubs (Ephedra), and probably represents a fresh water plant community (Table 2). These four families are the most abundant spores and pollen in Allison Guyot samples and specimens from one of these four groups occur in almost all of the samples.

Ogg (1992) reported a similar assemblage from ODP Leg 129, Site 802 near the western Mid-Pacific mountains (Plate 7 and Table 4). This site is located in the Mariana Basin and the sediments consist of shallow water carbonates and woody fragments derived from nearby seamounts (approximate 300 km from Site 802). Core intervals 129-802-56 and 129-802-56 -57 were dated as late Aptian to Albian. This core interval consisted of 1) brown claystone, calcareous claystone, radiolarian limestone; and 2) volcaniclastic turbidites with wood fragments (Shipboard Scientific Party, 1990). Both of these facies are similar to facies encountered at Allison Guyot. Pollen and spores from Aspleniaceae, Araucariaceae, Cyatheaceae, Gleicheniaceae, Lycopodiaceae, Schizaeaceae, and Selaginellaceae, which occur in samples from Allison Guyot, also occured in Albian sediments from Leg 129 Site 802. Ogg (1992) suggested that the abundance of terrestrial palynomorphs and woody materials from Leg 129 Site 802 (Albian) represented vegetation growing on exposed land masses, which were nearby seamounts. Comparing with Leg 129 Site 802, the similar terrestrial palynomorphs appeared at Allison Guyot and the similar carbonate facies at Allison Guyot may also reflected an existence of an island during the Early Albian. Both the diversity and the abundance of spores and pollen in sediments from Allison Guyot and Leg 129, Site 802 argue for the presence of islands with freshwater vegetation.

Pollen in Allison Guyot Samples

Ninety percent of the terrestrial palynomorphs from Allison Guyot were spores. Allison Guyot samples did not yield Cretaceous angiosperm pollen. The remaining palynomorphs were gymnosperm pollen belonging to *Ephedra*, *Callialasporites*, and *Podocarpus*. Modern *Ephedra* is a gymnosperm shrub belonging to the Gnetopsida; most species grow in arid and semi-arid regions in the temperate zone, and are wind pollinated (Yang, et al., 2005). Hooghiemstra et al. (1986) argued that distribution patterns of two *Ephedra* pollen types, *E. fragilis* and *E. distachya*, in marine surface sediments closely matched the average wind flow pattern of the trade winds. Ancient *Ephedra* pollen first appears in the Triassic and is widespread in Lower Cretaceous palynomorph assemblages (Crepet, 1991). *Ephedra* pollen occurs 15 samples from Allison Guyot, and the quantity of *Ephedra* pollen is more than 10 grains per 10 g in some samples, suggesting that this species grew on Allison Guyot.

Callialasporites and *Podocarpus* pollen derived from gymnosperm trees belong to the Pinopsida; the parent plant of *Callialasporites* is extinct. Ogg (1992) also found *Callialasporites*, and *Podocarpus* at ODP Leg 129, Site 802, which is close to the western Mid-Pacific Mountains. Although saccate pollen such as *Callialasporites*, which is monosaccate in Allison Guyot samples, and *Podocarpus*, which is bisaccate in Allison Guyot samples, could have been transported from a far distant location by wind or water, the presence of these two pollen genera at both Allison Guyot and ODP Leg 129, Site 802, suggests that their parent trees were part of the mid-Pacific island flora of the Cretaceous.

Most reviews of Early Cretaceous phytogeography focus primarily on the distribution of pollen (Srivastava, 1981; Herngreen and Jimenez, 1990; Herngreen et al., 1996). For example, Herngreen et al. (1996) outlined 4 palynofloral provinces for the Early Cretaceous: a North Polar *Cerebropollenites* province; an Equatorial Elaterates province consisting of equatorial South America, Africa, and the middle East; an eastern Equatorial Schizaeoisporites province in Central and East Asia, which was apparently more arid than the Elaterates province; and a South Polar Trisaccates province which included Antarctica, Australia, New Zealand, India, as well as the tip of South America and the tip of Africa. Because most of the palynomorphs that distinguish these provinces are pollen, it is difficult to assign the Early Cretaceous spore-dominated floras of the mid-Pacific to a particular floral province.

Three pollen genera occur in mid-Cretaceous sediments from Allison Guyot: *Ephedra*, a gnetalean gymnosperm shrub; the conifer *Podocarpus,* which belongs to Podocarpaceae; and *Callialasporites*, an extinct member of Araucariaceae. *Ephedra* was globally distributed in the Albian, as were the Podocarpaceae (Herngreen and Jimenez, 1990; Jameossanai and Lindsley-Griffi, 1993; Dettmann, 1994; Mildenhall, 1994; Ravn, 1995; Coa, 1999).

However, *Callialasporities* may provide evidence for a Southern Hemisphere derivation of the Albian flora of Allison Guyot. The Early Cretaceous of New Zealand has two species of *Callialasporites*, *C. dampieri* and *C. seqmentatus*, both of which occur at Allison Guyot. In addition, *Callialasporites* pollen occurs in the Une Formation in Colombia, South America. In the Early Cretaceous, Colombia lay at approximately 1°

N in the Equatorial Elaterates province of Herngreen et al. (1996). Otherwise, *Callialasporites* occurs in the Klamath River Conglomerate and unnamed conglomerates at Pythian Cave, in California, western North America, in allocthonous terranes from the Paleo-Pacific Ocean (Jameossanai and Lindsley-Griffi, 1993).

Instead of pollen, I used the spores present in Early Cretaceous palynofloral provinces to determine the phytogeographic affiliation of mid-Pacific terrestrial pollen assemblages. In comparison with palynomorphs from Albian formations in North America, Africa, southeastern China, Europe, New Zealand, and Australia, the assemblage at Allison Guyot appears most similar to the palynomorph assemblage in New Zealand and Australia (Herngreen and Jimenez, 1990; Jameossanai and Lindsley-Griffi, 1993; Dettmann, 1994; Mao el at., 2006; Mildenhall, 1994; Ravn, 1995; Coa, 1999).

Depending on the microfossil records in Australia (Dettmann, 1994), there are seven similar groups in the records and in our samples. These groups are Podocarpaceae, Schizaecea, Gleicheniaceae, Osmundaceae, Araucariaceae, Lycopodiaceae, and *Stereisporites*. The pollen and spore types in the Albian formation, the Une Formation in Colombia, South America, include four groups, *Impardecispora, Leptolepidites, Callialasporites dampieri, Cyathidite*s, which are the same as the groups in our samples from Allison Guyot. Gymnospermous pollens (*Callialasporites*) were common in Colombia in Albian (Herngreen and Jimenez, 1990). We found fewer than 10 grains of *Callialasporites,* which is a monosaccate pollen, in our samples. Monosaccate pollen may be transported great distances by wind or water currents, and *Callialasporites* might

have been transported by wind or water to Allison Guyot. However, Ogg (1992) interpreted *Callailasporites* in marine turbidites from ODP leg 129, Site 802 as having grown with the other plants represented in her palynomorph assemblage. Likewise, *Callailasporites* may have been growing on Allison Guyot in the Albian. In Zhejiang Formation (Mid-eastern China, Albian) (Cao, 1999), only two pollen and spore groups, Selaginellites and Araucariaceae, are similar to our samples. The Albian Dakota Formation in northeastern Nebraska, USA, contains only one fern family, Schizaeceae (*Cicatricosisporites venustus*) (Ravn, 1995), which occurs in our samples. In comparison the Albian palynomorph assemblages from around the globe, the palynomorph assemblage of Allison Guyot is closest to that of New Zealand and Australia.

CHAPTER V

CONCLUSIONS

The resource of pollen and spores in marine sediments usually comes from plants on continents or islands, which are close to those marine terrains. The concentration of pollen and spores is related to the distance between the parent plants and depositional locations. Therefore, terrestrial palynomorphs are abundant near the shore, but rare in open ocean sediments; unless there is a large island or continent nearby. The abundance of palynomorphs in marine sediments decreases with increasing distance from islands and continents. And the distribution of terrestrial palynomorphs in marine sediments is influenced by both distance from shore and the prevailing wind and current direction.

There were many terrestrial palynomorphs reported from IODP, ODP, and DSPS cores. Samples in this research were from ODP cores (Leg 143 Site 865), Allison Guyot. Twenty two samples contain terrestrial palynomorphs, but 1 sample which was close to an intrusive basalt contains no palynomorphs. Thirteen pollen types, 28 spore types, 2 dinoflagellates, and leiospheres were found in Allison Guyot samples. The palynomorphs can be related to plant taxa: Bryophyta; Filicopsida, including Cyatheaceae, Dicksoniaceae, Schizaeaceae, Osmundaceae, Gleicheniaceae, Hymenophyllaceae, and Aspleniaceae; Lycopsida including Lycopodiaceae and Selaginellaceae; and gymnosperms, including Ephedraceae and Araucariaceae, and possibly Podocarpaceae. The most common spore type is *Cyathidites minor* (Cyatheaceae). The second abundant spore type is *Gleicheniidites senonicus* (Gleicheniaceae). Both the diversity and the abundance of spores and pollen in Allison

Guyot sediments argue for the presence of an island with a freshwater table. The high quantity (more than 30 grains per 10 g) and continuity of appearance (presented almost in all samples) of these four families indicate endemic vegetation at Allison Guyot. Marine turbidites from Leg 129 Site 802, contain a terrestrial palynomorph assemblages similar to that of Allison Guyot. Both the diversity and the abundance of spores and pollen in sediments from Allison Guyot and Leg 129, Site 802 argue for the presence of mid-Pacific islands with freshwater vegetation.

The terrestrial palynomorph assemblage of Allison Guyot consists of tree ferns (Cyatheaceae), forked ferns (Gleicheniaceae), club mosses (Lycopodiaceae) and gymnosperm shrubs (Ephedra), and probably represents a fresh water plant community. The vegetational assemblage on Allison Guyot was similar to the vegetation of New Zealand and Australia in the Albian, and shares few plant groups with palynomorph assemblages in Albian sediments from North America, South America, eastern Asia, Africa, Australia, and New Zealand. These terrestrial palynomorphs from Allison Guyot derived from vegetation growing on an exposed island.

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APPENDIX A

TABLES

Table 1. Depth and lithology of samples from Allison Guyot

Core	Section	Interval	Interval	weight (g)	Label	Major lithology
74	1	109	111	10.08	2-1	wackestone with some dark gray clay seams, stylolites, compacted burrows, leached zones infilled by probable dolomite.
78	1	52	54	10.36	2-2	mudstone and wackestone with clayey sediment, foraminifers (miliolids) and gastropods, burrows infilled with rhombic crystals of dolomite, common stylolites
81	1	21	23	10.17	2-3	packstone and wackestone with foraminiferal and other molds, some dolomite, disseminated organic matter, mm-cm-size black pebbles, and black clayey seams with pyrite
81	2	30	32	10.5	2-4	packstone and wackestone with foraminiferal and other molds, some dolomite, disseminated organic matter, mm-cm-size black pebbles, and black clayey seams with pyrite
85	1	117	120	10.16	2-5	clayey limestone with appearance of peloids, foraminifers, and replaced gastropod shells, some with dolomite
86	3	36	40	10.5	2-6	white to gray clayey limestone (Packstone) with foraminifers, bivalves, and gastropods
86	3	65	68	10.21	2-7	white to gray clayey limestone (Packstone) with foraminifers, bivalves, and gastropods
87	1	113	115	10.89	2-8	gray to white intensively bioturbated, laminated clayey limestone with benthic foraminifers
87	2	67	69	10.27	2-9	gray to white intensively bioturbated, laminated clayey limestone with benthic foraminifers
88	1	47	49	10.19	2-10	bioturbated clayey limestone (packstone), white to gray, with benthic foramminifers, gastropods, bivalves, ostracods, and sponge spicules, intercalated with thin, dark clayey layers
88	2	36	38	10.26	2-11	bioturbated clayey limestone (packstone), white to gray, with benthic foramminifers, gastropods, bivalves, ostracods, and sponge spicules, intercalated with thin, dark clayey layers
89	1	20	23	10.41	2-12	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
89	3	36	38	10.71	2-13	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
89	2	7	11	17	1-1	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
89	5	64	66	18.55	1-2	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
89	5	66	69	18.56	1-3	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
89	6	13	15	16.82	1-4	parallel to wavy laminated clayey limestone, very dark grayish brown to light gray, with peloids, foraminifers, gastropods, bivalve fragments (mostly oyster), arthopods (rare), volcanic clasts, and coal layers
90	1	109	111	20.82	1-5	clayey limestone (packstone), large gastropods, peloids, foraminifers, abundant sponge spicules, and finely disseminated organic matter and pyrite
90	3	37	41	20.61	1-6	clayey limestone (packstone), large gastropods, peloids, foraminifers, abundant sponge spicules, and finely disseminated organic matter and pyrite
90	3	98	99	19.4	1-7	clayey limestone (packstone), large gastropods, peloids, foraminifers, abundant sponge spicules, and finely disseminated organic matter and pyrite

Table 1. Continued

Core	Section	Interval	Interval	weight (g)	Label	Major lithology
90	3	130	132	20.19	1-8	clayey limestone (packstone), large gastropods, peloids, foraminifers, abundant sponge spicules, and finely disseminated organic matter and pyrite
92	2	43	44	20.02	1-9	black claystone, pyritic and locally green and laminated on a mm scale
94	3	70	73	20.4	1-10	bioturbated clayey limestone, abundant carbonaceous particles, numerous gastropods, bivalves, some woody pieces replaced by pyrite, and few benthic foraminifers

Table 2. Taxa and affinity of terrestrial palynomorphs from Allison Guyot

Pollen or Spore type	Affinity	Homosporous/ Heterosporous	Distribution in core
Callialasporites dampieri	Araucariaceae	Gymnosperm	143-865-87-2
Callialasporites segmentatus	Araucariaceae	Gymnosperm	143-865-78-1, 86-3, 88-2, 89-2
Ephedra	Ephedraceae	Gymnosperm	143-865-78-1, 81-1, 86-3, 87-1, 88-2, 89-1, 89-3-2, 89-3, 89-5, 89-6, 90-1, 90-3, 92-2, 94-3
Podocarpus sp.	Podocarpus	Gymnosperm	143-865-81-2, 85-1, 86-3, 87-2, 88-2, 94-3
Baculatisporites comaumensis	Osmundaceae	Homosporous	143-865-81-2, 86-3, 89-1
? Biretisporites potoniaei	Hymenophyllaceae	Homosporous	143-865-81-2
Ceratosporites equalis	Selaginellaceae	Heterosporous	143-865-88-2, 89-1, 89-3
Cicatricosisporites hughesii	Schizaeacea	Homosporous	143-865-89-5
Cicatricosisporites sp.	Schizaeacea	Homosporous	143-865-85-1, 89-5
Cyathidites minor	Cyatheaceae or Dicksoniaceae	Homosporous	143-865-74-1, 78-1, 81-1, 81-2, 85-1, 86-3, 87-1, 87-2, 88-2, 89-1, 89-2, 89-3, 89-5, 89-6, 90-1, 90-3, 92-2, 94-3
? Foveosporites canalis	Lycopodiaceae	Homosporous	143-865-85-1, 89-2, 90-3
Gleicheniidites senonicus	Gleicheniaceae	Homosporous	143-865-74-1, 85-1, 86-3, 88-2, 89-1, 89-2, 89-3, 89-5, 89-

			6, 90-1, 92-2, 94-3
Impardecispora excavate	Unkown	Unkown	143-865-89-5
Laevigatosporites ovatus	Aspleniaceae	Homosporous	143-865-78-1, 89-3, 89-5, 89-6, 90-1, 90-3, 92-2
Leptolepidites verrucatus	Pteridaceae	Homosporous	143-865-89-1, 90-3
Lycopodiacidites dettmannae	Lycopodiaceae	Homosporous	143-865-74-1, 78-1, 86-3, 88-2, 89-1, 89-2, 89-5, 89-6, 90-1, 94-3
Retitriletes circolumenus	Lycopodiaceae	Homosporous	143-865-86-3, 87-2, 88-2, 89-2, 89-5, 89-6
Ruffordiaspora australiensis	Schizaeacea	Homosporous	143-865-78-1, 81-2, 86-3, 88-2, 89-5, 89-6, 92-2
Osmundacidites wellmanii	Osmundaceae	Homosporous	143-865-85-1, 87-2, 88-2, 89-1, 89-3, 94-3
? Stereisporites antiquasporites	Sphagnaceae	Bryophyta	143-865-88-2

Table 3. A list of taxa of terrestrial palynomorphs from Allison Guyot

Core	Section	Interval	Interval	weight (g)	Label	Lycopodiacidites dettmannae	Cyathidites minor	Gleicheniidites senonicus	Retitriletes circolumenus	Ruffordiaspora australiensis	Laevigatosporites avatus	Callialasporites dampieri	Podocarpus sp.	Osmundacidites wellmanii	Ceratosporites equalis	Basculatisporites comaumensis
74	1	109	111	10.08	2-1	1	16	1	0	0	0	0	0	0	0	0
78	1	52	54	10.36	2-2	3	14	0	0	1	1	0	0	0	0	0
81	1	21	23	10.17	2-3	0	5	0	0	0	0	0	0	0	0	0
81	2	30	32	10.5	2-4	0	14	0	0	2	0	0	1	0	0	1
85	1	117	120	10.16	2-5	0	5	1	0	0	0	0	5	1	0	0
86	3	36	40	10.5	2-6	0	6	4	0	0	0	0	1	0	0	0
86	3	65	68	10.21	2-7	2	10	2	1	3	0	0		0	0	2
87	1	113	115	10.89	2-8	0	4	0	0	0	0	0	0	0	0	0
87	2	67	69	10.27	2-9	0	6	0	2	0	0	1	2	1	0	0
88	1	47	49	10.19	2-10	0	0	0	0	0	0	0	0	0	0	0
88	2	36	38	10.26	2-11	30	24	7	1	3	0	0	1	11	3	0
89	1	20	23	10.41	2-12	9	35	6	0	0	0	0	0	5	1	2
89	3	36	38	10.71	2-13	0	10	2	0	0	2	0	0	2	2	0
89	2	7	11	17	1-1	6	17	18	1	0	0	0	0	0	0	0
89	5	64	66	18.55	1-2	2	56	33	0	13	0	0	0	0	0	0
89	5	66	69	18.56	1-3	1	55	12	2	11	1	0	0	0	0	0
89	6	13	15	16.82	1-4	7	24	21	2	4	5	0	0	0	0	0
90	1	109	111	20.82	1-5	1	8	1	0	0	1	0	0	0	0	0
90	3	37	41	20.61	1-6	2	38	27	0	0	6	0	0	0	0	0
90	3	98	99	19.4	1-7	5	28	10	0	0	27	0	0	0	0	0
90	3	130	132	20.19	1-8	0	0	0	0	0	0	0	0	0	0	0
92	2	43	44	20.02	1-9	0	15	14	0	2	3	0	0	0	0	0
94	3	70	73	20.4	1-10	2	19	3	0	0	0	0	1	5	0	0

Table 3. Continued

Cicatricosisporites hughesii	Cicatricosisporites sp.	Impardecispora excavate	Leptolepidites verrucatus	Ephedra	?Foveneosporites canalis	Callialasporites segmentatus	?Stereisporites antiquasporites	?Biretisporites potoniaei	Unknown spores and pollen	Leiosphere	Summary
0	0	0	0	0	0	0	0	0	1	2	21
0	0	0	0	9	0	1	0	0	18	2	49
0	0	0	0	3	0	0	0	0	0	5	8
0	0	0	0	0	0	0	0	3	1	51	22
0	1	0	0	0	1	0	0	0	2	2	16
0	0	0	0	0	0	0	0	0	2	5	13
0	0	0	0	3	0	1	0	0	6	1	31
0	0	0	0	1	0	0	0	0	1	1	7
0	0	0	0	0	0	0	0	0	4	26	16
0	0	0	0	0	0	0	0	0	2	2	4
0	0	0	0	2	0	2	1	0	2	1	96
0	0	0	2	4	0	0	0	0	3	5	72
0	0	0	0	1	0	0	0	0	0	3	22
0	0	0	0	3	2	2	0	0	2	1	52
0	1	1	0	4	0	0	0	0	0	2	112
1	0	0	0	2	0	0	0	0	0	14	99
0	0	0	0	12	0	0	0	0	17	21	92
0	0	0	0	8	0	0	0	0	0	7	19
0	0	0	5	18	1	0	0	0	0	1	98
0	0	0	0	3	10	0	0	0	0	1	84
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2	0	0	0	0	0	0	36
0	0	0	0	0	0	1	0	0	0	0	31

Table 4. Comparison of terrestrial palynomorphs from Allison Guyot and Leg 129 Site 802

Pollen or Spore type from Allison Guyot	Pollen or Spore type from Leg 129 Site 802 (Ogg, 1992)
Callialasporites dampieri	*Alisporites* sp.
Callialasporites segmentatus	*Araucariacites australis*
Ephedra	*Callialasporites dampieri*
Podocarpus sp.	*Callialasporites trilobatus*
Baculatisporites comaumensis	*Ceratosporites equalis*
? Biretisporites potoniaei	*Cicatricosisporites australiensis*
Ceratosporites equalis	*Cicatricosisporites minor*
Cicatricosisporites hughesii	*Concavissimisporites pulcher*
Cicatricosisporites sp.	*Concavissimisporites punctatus*
Cyathidites minor	*Crybelosporites* sp.
? Foveosporites canalis	*Cyathidites australis*
Gleicheniidites senonicus	*Cyathidites minor*
Impardecispora excavate	*Dictyophyllidites* sp.
Laevigatosporites ovatus	*Foraminisporis asymmetricus*
Leptolepidites verrucatus	*Foveosporites canalis*
Lycopodiacidites dettmannae	*Gleicheniidites* spp.
Retitriletes circolumenus	*Klukisporites* sp.
Ruffordiaspora australiensis	*Laevigatosporites ovatus*
Osmundacidites wellmanii	*Lycopodiumsporites* sp.
? Stereisporites antiquasporites	*Osmundacidites wellmanii*
	Podocarpidites sp.
	Staplinisporites sp.

APPENDIX B

FIGURES
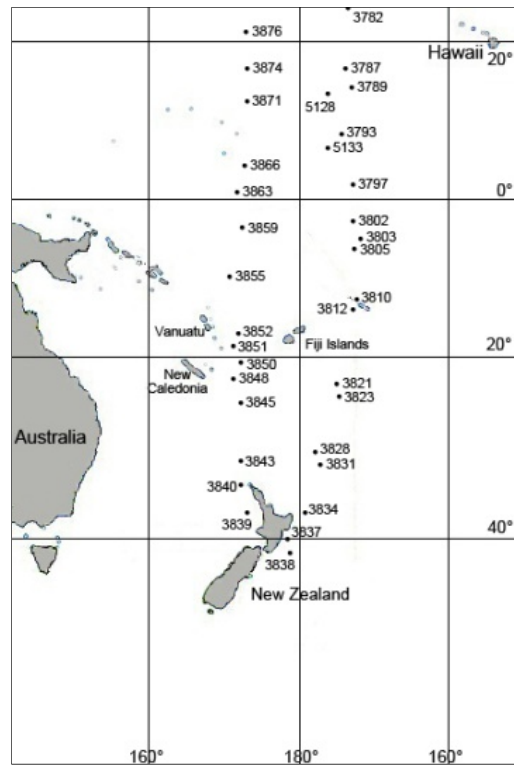
Figure 1. Map of the distribution of sediments sampled during the 26th voyage of the Vityaz. (Koreneva, 1968; Modified by Hsiung, 2011)
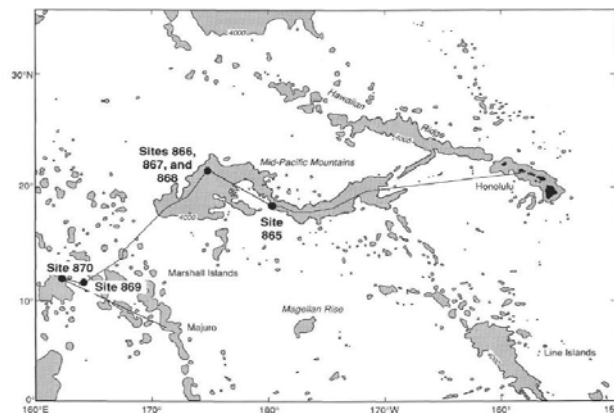
Figure 2. Location of Leg 143 drill sites (Sager, Winterer, Firth, 1993). Samples used in this study came from Site 865.
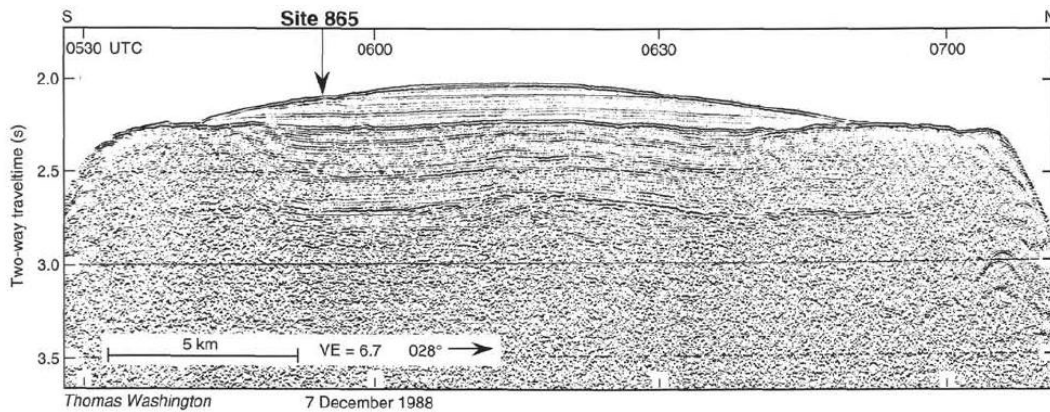
Figure 3. Single-channel seismic profile over the summit of Allison Guyot (Sager, Winterer, Firth, 1993).
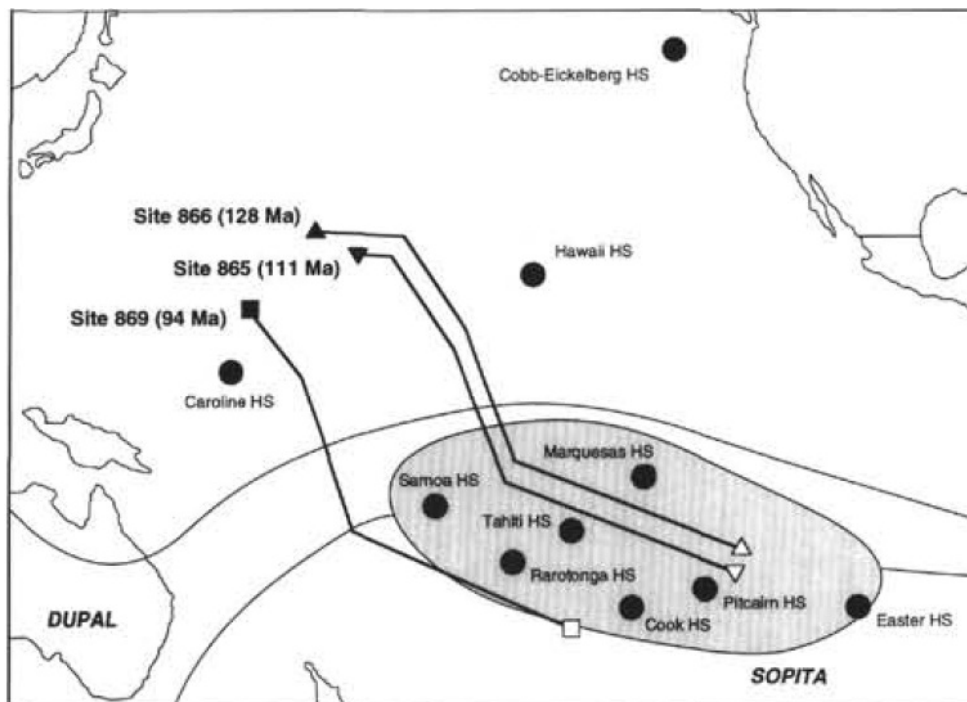
Figure 4. Present-day (inverted triangle) and original (open inverted triangle) of Sites 865 calculated by backtracking using the model of Duncan and Clague (1985) of Pacific Plate motion relative to the hotspots (Winterer and Sager, 1995).
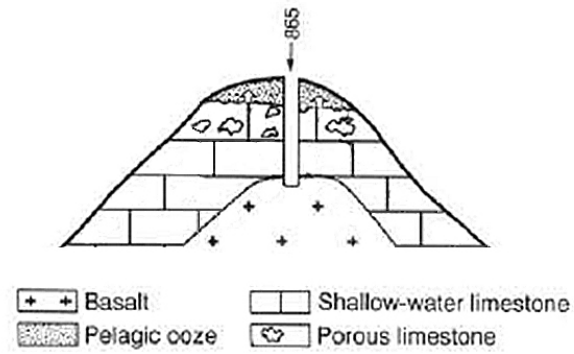
Figure 5. Schematic cross section showing the location of boreholes drilled at Allison (ODP Site 865) (Winterer et al., 1995)

APPENDIX C

PLATES

Plate 1 Pollen Types
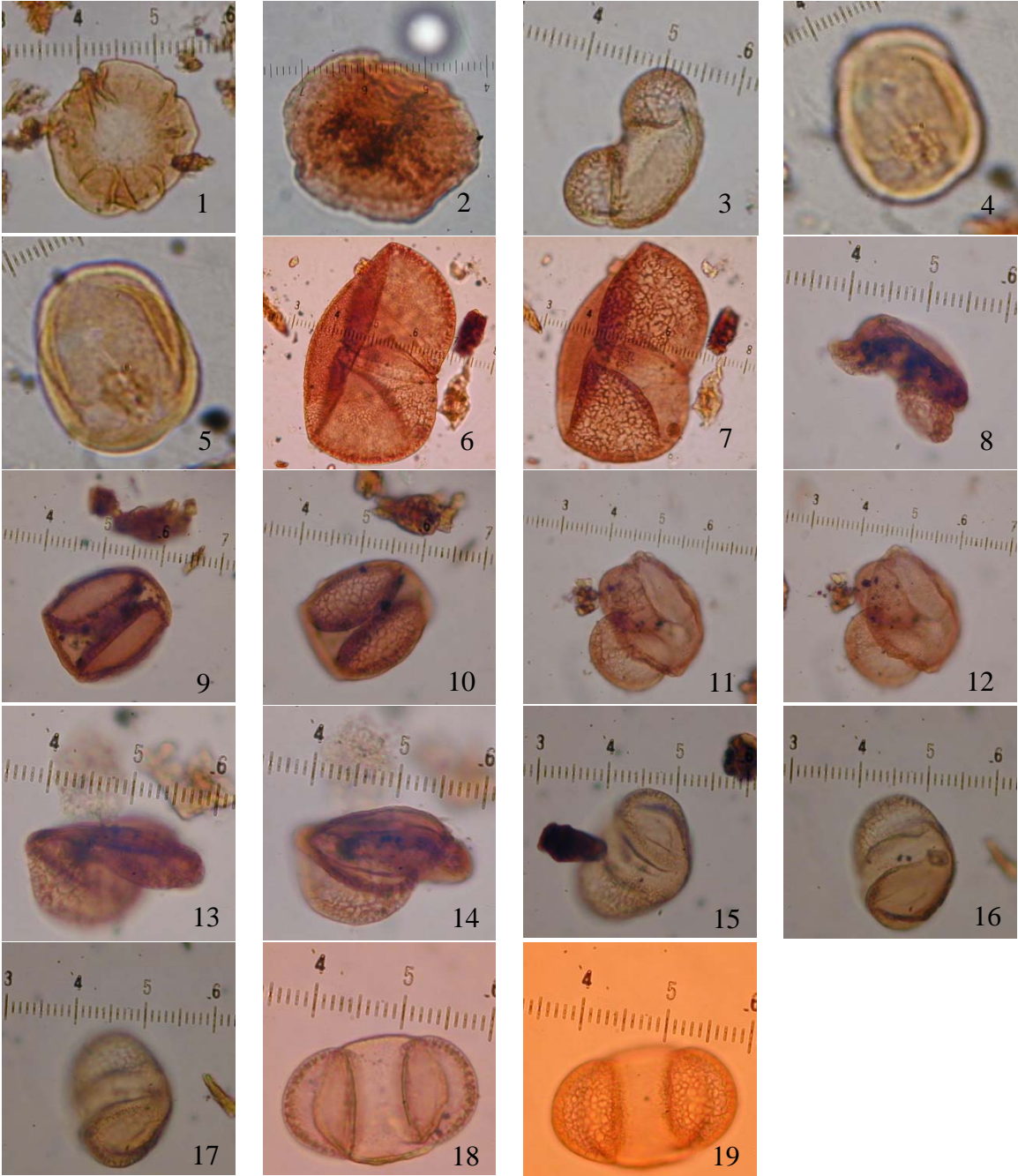
Plate 2 Spore Types
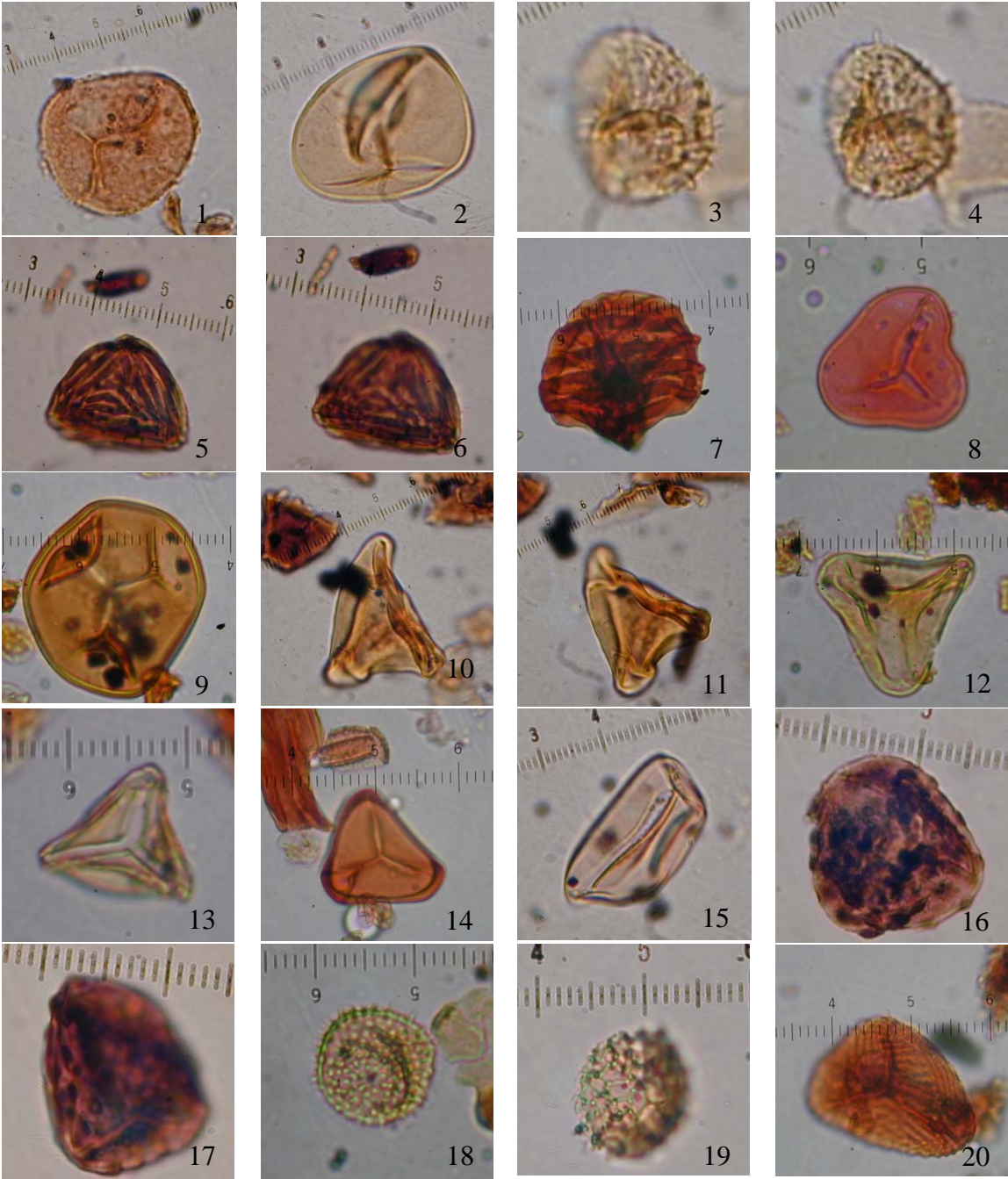
Plate 3 Spore Types
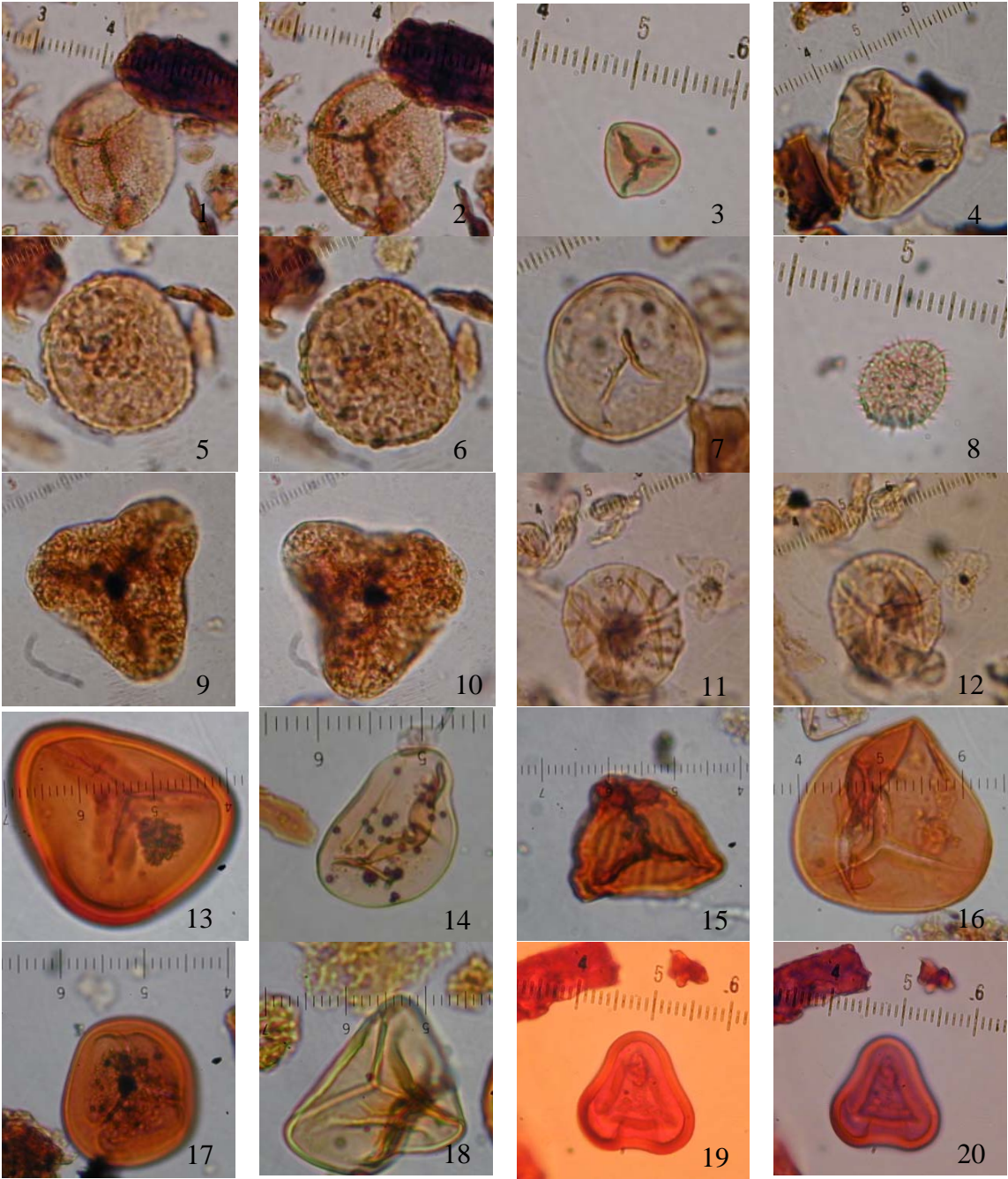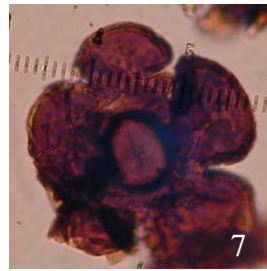
Plate 4 Spore Types
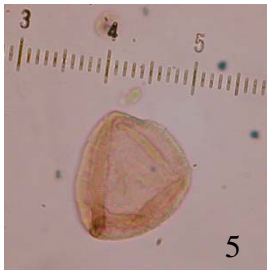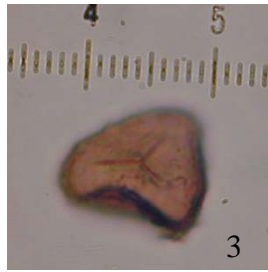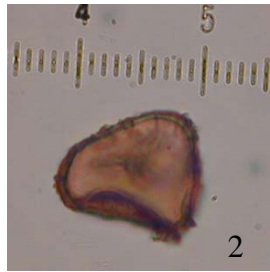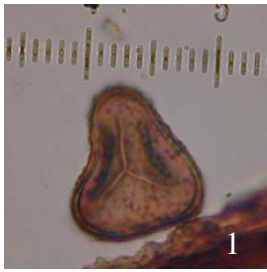
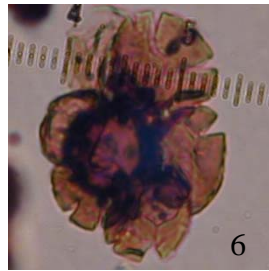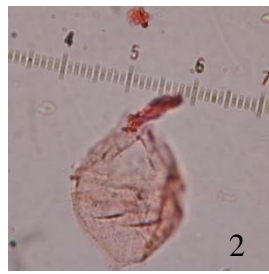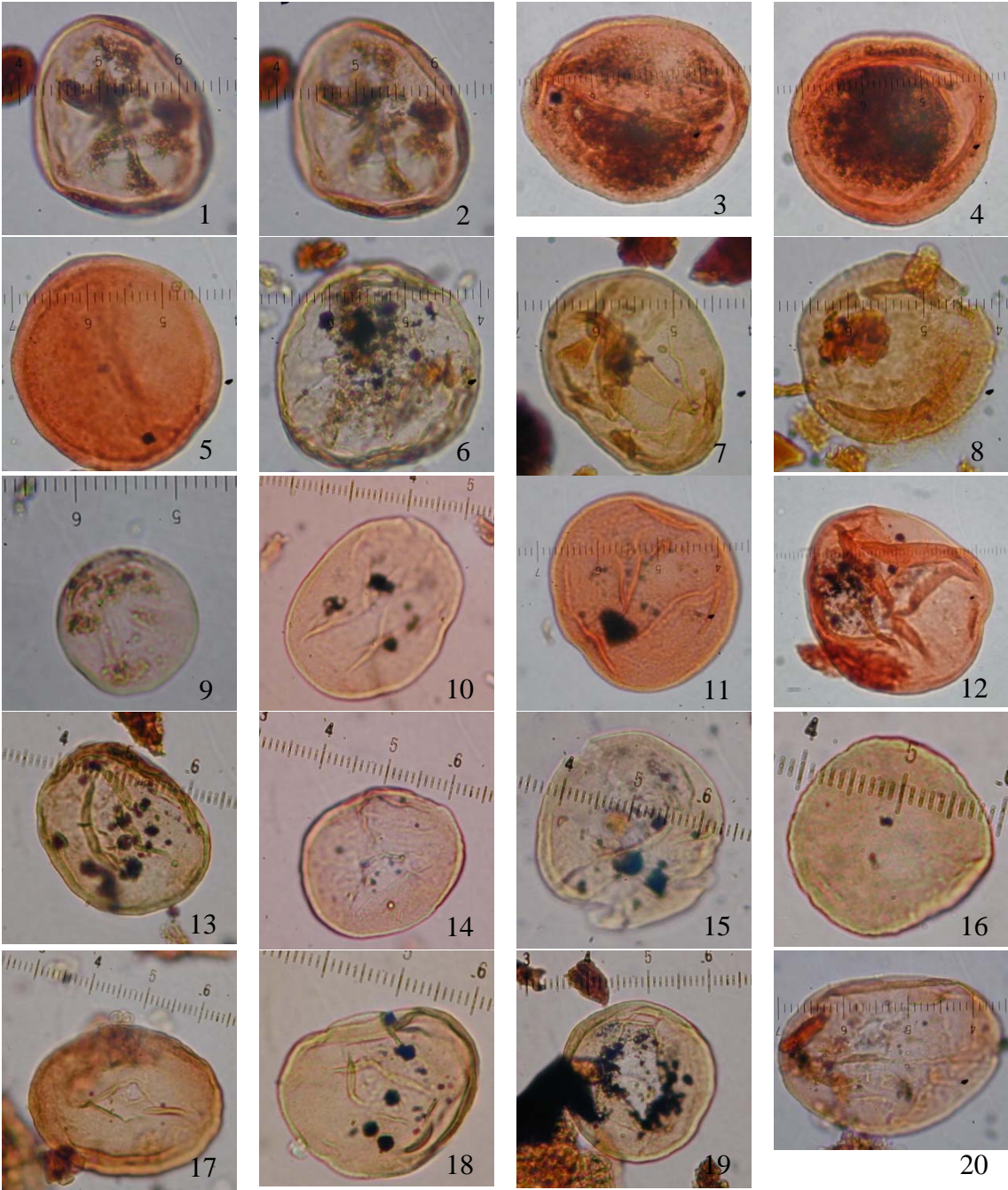Plate 5 Dinoflagellate, Microforaminifera
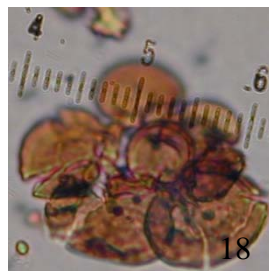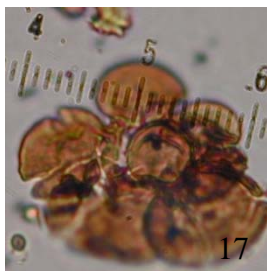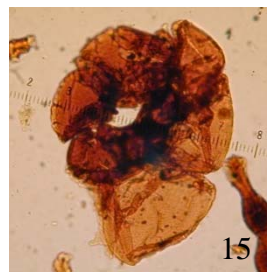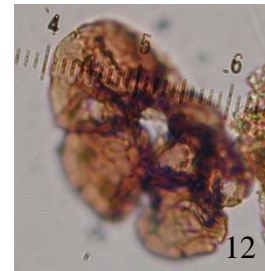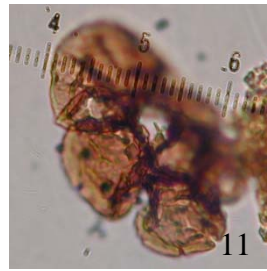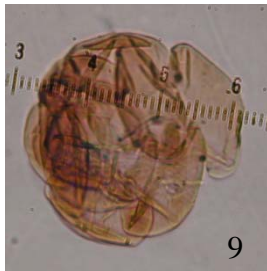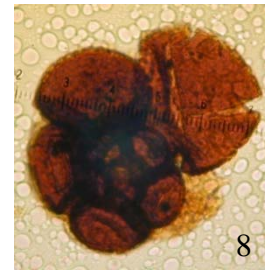
Plate 6 Leiosphere

Plate 7 Palynomorphs from Leg 129 Site 802 (Ogg, 1992)

VITA

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Shih-Yi received her Bachelor of Science degree in earth science from National Taiwan Normal University in June 2005. After graduation, Shih-Yi completed a one year teaching intern at Taipei Municipal Yang Ming Senior High School and became a certified Junior and Senior High School Teacher in Taiwan. During this year, she won Award of Excellence and Honorable Mention in Basic Earth Science Teaching Materials Design Competition, Award of Excellence in Research in Specialized Creativity and Behavior in Education for "Designing Creative Teaching Activities", and Honorable Mention in Research in Specialized Creativity and Behavior in Education for "Sharing Professional Teaching Experience".

She was a research assistant at National Taiwan Normal University Science Education Center in 2007. Then, she went abroad to study Instructional Technology at New York Institute of Technology and Geology at Texas A&M University, College Station.

Her research interests include modern mangrove communities and using ancient terrestrial palynomorphs to investigate the response of plant communities to ecological and climatic changes.

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