The ORE BIN
Vol. 29, No. 9
September 1967

Palynology and its Paleoecological Application in the Coos Bay Area, Oregon

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Introduction

In recent years the study of fossil plant spores and pollen has become a rapidly growing field of endeavor. From mid-Paleozoic to the present time, terrestrial plants have been abundant and diversified, covering most of the land areas of the world. Plants produce enormous quantities of spores and pollen and with the coming of each flowering season these are widely dispersed by wind, water, insects, birds, and occasionally mammals. Coupled with the tremendous production of spores and pollen is the fact that most are incredibly resistant to destruction. A hard, cutinous coating aids in their preservation under a variety of depositional environments, and permits them to survive the rather rigorous treatment they undergo during maceration. Furthermore, a wide diversity in morphology including size, shape, and ornamentation makes many of them readily identifiable. These three factors then, abundance, resistance to destruction, and morphologic diversity, make spores and pollen very valuable for studying and reinterpreting the past record of plant life.

Most continental, and many marine, sediments contain fossil pollen and spores, a partial record of the flora extant at the time of deposition. From spores, pollen, and other plant microfossils various data can be derived, such as information on the environment of deposition, suggestions as to plant evolution, genetic relationships, and the age of the enclosing rock. And finally, correlations of time-equivalent sedimentary rocks are frequently possible, depending on the number of microfossils present and their degree of preservation.

Recently I have had the opportunity to examine a number of rock samples from the Coos Bay area of southwest Oregon. The three formations with which I was concerned are the Coaledo (upper Eocene), Bastendorff (upper Eocene-lower Oligocene), and Tunnel Point (middle Oligocene). This paper presents some of the results of this investigation.

Geology

The geology of the Coos Bay area has been described by a number of investigators over a period of many years, so I will not attempt a detailed synthesis here. The two most recent works are by Ehlen (1967) who provides an interesting account of the

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geology of the Cape Arago area, and by Baldwin (1966) who revises some of the earlier interpretations. Dott (1966) discusses the Eocene sedimentation in the Coos Bay area in considerable detail. A popular discussion of Oregon geology, including the Coos Bay area, appears in Baldwin (1964). A brief, but readable, geologic history of western Oregon and Washington is given by Snavely and Wagner (1963). Youngquist (1961) briefly discusses the individual Tertiary formations of western Oregon and Washington. The general relationship of the Coos Bay Tertiary rocks to other Tertiary sedimentary rocks of the Pacific Coast is presented in tabular form by Weaver and others (1944). Useful and up-to-date geologic maps are contained in Ehlen (1967) (see page 173 of this report), Baldwin (1966), and Dott (1966). The Geologic Map of Oregon West of the 121st Meridian (1961) shows the regional relationships of the coastal Tertiary rocks in Oregon.

The following paragraphs present only a very brief summary on the stratigraphy of the three formations dealt with in this paper. For the reader wishing a more complete discussion of Coos Bay geology I suggest examination of the above-mentioned publications and the numerous references contained in them.

The Coaledo Formation is 5840 feet thick and subdivided into three members whose approximate thicknesses are, from bottom to top, 1600 feet, 2525 feet, and 1715 feet. The formation is essentially clastic, composed largely of sandstone, siltstone, and minor shale. Some coal is present in both the lower and upper members. According to Baldwin (1966, p. 195) "...the formation was laid down as deltaic shallow-water sediments with swampy margins and interfingering continental beds in which primary sedimentary features such as cross-bedding, scour and fill channeling, and slump structures occurred."

The Bastendorff Formation is a marine shale, conformably overlying the Coaledo Formation. Its thickness is variously given as 1500 feet (Weaver and others, 1944), 2300 feet (Allen and Baldwin, 1944), and 2900 feet (Baldwin, 1966). Schenck (1928, p. 18) states that these sediments were deposited "...in quiet waters where only weak currents and no strong wave action prevailed; it resembles a histogram of silt deposited in harbors." Baldwin (1964) suggests that the "lower third of the type section is late Eocene and the upper two-thirds is early Oligocene."

The Tunnel Point Formation is a tuffaceous sandstone unit approximately 800 feet thick, which conformably overlies the Bastendorff Formation. Invertebrate fossil remains indicate a middle Oligocene age and a marine origin for this unit.

All three formations appear to have been deposited in brackish to marine waters with marine conditions predominating. Evidently the Coos Bay area was close to the strand line during the upper Eocene to middle Oligocene interval.

Palynology

General remarks

The basic principles behind the use of palynology in Tertiary stratigraphic studies are two assumptions: 1) That plants evolve, and 2) that floras migrate in time and space under the influence of environmental change. The evolution of plants affects not only their extreme gross form but also the microscopic reproductive parts.

Briefly speaking, spores and pollen are reproductive units of plants. The spores are produced by the "lower" land and aquatic plants such as fungi, algae, bryophytes, and ferns. They are produced in special organs of the plants and at an appropriate time are disseminated by wind, water, insects, or birds. If they land in a favorable site they will eventually develop into a form of living tissue known as a gametophyte. With further lengthy and complicated development a complete plant will eventually result.

Pollen, on the other hand, are an elaboration of spores and are produced by the "higher" plants, that is, the flowering plants and conifers. They are the male part of a flower, and by wind, water, insect, or bird transport they are carried to the same or different flower, where the female element, the egg, is fertilized. Development of this egg leads eventually to a viable seed. Reference to any good elementary botany textbook will provide more information on the purely biologic aspects of pollen and spores. We are not concerned with that aspect here.

As mentioned in the Introduction, pollen and spores are produced in tremendous quantity, and only a minute percentage ever fulfills nature's purpose of reproduction. Many of the remainder, because of their toughness and resistance, are transported to favorable sedimentary environments where they are incorporated into accumulating sediments. Unless these are later destroyed by some geologic or biologic process, a permanent record of the flora is preserved.

Because the evolution of plants is reflected in the morphology of the pollen and spores, and because during the Tertiary wholesale plant migration occurred, we have a record of these plant changes, a record based on the microscopic parts known as spores and pollen.

Sampling

In general, fine-grained clastic rocks of clay size and carbonaceous sediments, especially coal, are the most productive of plant microfossils (pollen and spores). In most cases, siltstone or sandstone yield no plant microfossils; if they were ever present, physical damage or corrosion has made them unrecognizable. As a general rule, the depositional environment of sand is one of considerable turbulence which almost always results in physical abrasion, destruction, or washing out of any contained microfossils. Furthermore, the higher permeability of sandstone, as contrasted with shale, permits the entrance of atmospheric oxygen into the sands, with the concomitant growth of destructive fungi and bacteria. Although a number of silty and sandy shale samples were prepared for examination, virtually all of the material on which floral conclusions are based was derived from shales and coals.

The collecting of the Coos Bay samples was done during the summer of 1965. The distribution of the palynologically analyzed samples is as follows: two from the Tunnel Point Formation, 35 from the Bastendorff Formation, and 27 from the three members of the Coaledo Formation. All of the samples were taken in stratigraphic succession from beach exposures between Cape Arago and Coos Head. (See map p. 173.)

Maceration procedure

The extraction of plant microfossils from a rock and the preparation for examination is a process known as maceration. The basic procedure is standard, although minor variations are introduced to suit specific cases.

Six to 10 grams of sample are crushed so that the maximum particle size is about 3 mm. This crushed sample is placed in dilute hydrochloric acid for as much as 24 hours to remove any carbonate present. Following this treatment the sample is washed using distilled water and centrifuge, then placed in dilute hydrofluoric acid to remove the silicate minerals. This particular operation takes from one to three days. At this stage little remains of the original rock but the contained organic material which includes the spores and pollen.

Usually the plant microfossils are coated with carbonaceous material which must be removed by oxidation. This is done with nitric acid, and the residue of this operation is cleared up by the use of very dilute potassium carbonate. The remaining spores and pollen are then dyed with a chemical stain (usually safranin), and then mounted permanently on glass slides using a clear plastic cement. They are then ready for microscopic examination.

Taxonomy

The identification and classification of the pollen and spores is known as taxonomy. The system which I have used here is the so-called "natural classification," in which the pollen grains are assigned to existing natural plant groups. This procedure is possible only with Upper Cretaceous and Tertiary microfossils, because during this period of time most of the extant plant genera made their first appearance. Throughout the Tertiary the floras of the world were taking on an ever more modern aspect with most, if not all, of the modern genera appearing before the end of the Pliocene. By comparison with both the literature and modern reference material, many Tertiary pollen and spores can be assigned to modern genera.

Fossil species are a more difficult problem and for the most part are created on the basis of minor morphological variations within microfossils of the established genus. These may or may not represent true species in the botanical sense, and in most cases probably do not. Some palynologists have assigned modern specific names to microfossils as old as the Miocene (for example, Macko, 1957, 1959), but for several reasons this is a dubious procedure. In the first place, it seems unlikely that a species would survive for 25 or more millions of years without change, especially during the Tertiary with its world-wide climatic changes and constant tectonic instability. In the second place, pollen grains are seldom so perfectly preserved that they can be compared in every respect with modern material. In late Pliocene or Pleistocene rocks, assignment of modern specific names is often possible and desirable, but in rocks older than Pliocene this is not valid. For rocks older than Upper Cretaceous, identification of spores or pollen is tenuous, assignment to modern genera is usually not possible, and the usage of some "artificial" system becomes mandatory.

For grains which cannot be assigned to modern extant genera I have used the form generic names which have been assigned by various other investigators. In this paper I restrict myself to natural generic names only, because for a discussion of ecology the artificial specific name has little value.

Discussion of results

In the study of these three formations, a total of 77 distinctive pollen and spore types was encountered. In this group are about 34 natural genera which can be used to give us some idea as to the flora present during the late Eocene-middle Oligocene. The remaining plant microfossils are assigned to form genera which are useful to stratigraphic correlation, such as an oil company might do in correlating offshore wells with surface exposures on the mainland. However, form genera are of little value to ecological interpretations unless their botanical relationships are known. In this particular paper I shall discuss only those forms which can be assigned to natural genera.

These are listed on table 1 along with their common names. Most of the identified genera occur in the Bastendorff Formation, a somewhat smaller number in the Coaledo, and the smallest number in the Tunnel Point Formation. This distribution is not surprising considering the lithologies involved and the number of samples taken.

The Tunnel Point is largely a sandstone unit with only a few thin shale zones and did not provide the distinct microfloral variation of the Bastendorff and Coaledo. Generally speaking, however, I believe it probable that the total flora was similar throughout all three formations, but because of geologic conditions during Tunnel Point time the preservation here was not good. All the evidence to date, both floral and faunal as well as geologic, indicates that the Tertiary generally was a period of cooling, with occasional temporary reversals but with the world-wide climate becoming colder. However, the interval of time between late Eocene and middle Oligocene was too short, and the cooling not sufficient, to make major changes in the local floral picture. By the Miocene, changes are reflected in the fossil pollen and spores indicating major climatic changes, but this is not evidenced in the much shorter interval of time with which we are concerned here. As a result, I shall discuss the floras of these three formations as a unit and attempt to draw some general conclusions.

Table 1. Natural genera present in Coaledo, Bastendorff, and Tunnel Point Formations

Genus*	Common Name**
Alnus	alder
Betula	birch
Bombacaceae	tropical trees
Carpinus	blue-beech
Carya	hickory
Castanea	chestnut
Cicatricosisporites	fern
Corylus	hazel
Ephedra	gymnosperm
Fagus	beech
Glyptostrobus	cantonwater pine
Ilex	holly
Juniperus	juniper
Liliaceae	lily family
Liquidambar	sweet gum
Lycopodium	club moss
Magnoliaceae	magnolia family
Metasequoia	dawn redwood
Myrica	wax-myrtle, bayberry
Osmunda	fern

* Because of similarity between pollen of various genera, identification is only to family level in several cases.

** In some cases there is no common name, in which case only a general designation is given, for example, "fern."

Table 1. Continued.

Genus	Common Name
Picea	spruce
Pinus	pine
Platycarya	angiosperm, tree
Podocarpus	conifer
Polypodiaceae	fern
Proteaceae	angiosperm, tree
Pterocarya	angiosperm, tree
Quercus	oak
Salix	willow
Sparganium	aquatic herb
Taxodium	swamp cypress
Tilia	basswood
Typha	cattail
Ulmus	elm

Paleoecological Interpretations

General

Ideally, plants are the most sensitive of the terrestrial ecological indicators. Animals can roam and move about if climatic conditions become unfavorable, but plants are rooted to one spot and must tolerate the environment in which they grow. Furthermore, their tolerance of environmental changes is less than that of most animals. Because the most critical stage in a plant's entire growth cycle is at germination, a changing environment will allow survival of the reproductive propagules only if they fall in a favorable site. Because of this, a changing climate can markedly alter the flora in a comparatively few years. As a consequence, analysis of fossil floras should provide data on climatic conditions at the time of growth.

And indeed they do, but several problems loom large. In palynology, as in all paleontology, a generally accepted truism is the old saw, "The present is the key to the past." In paleoecological interpretations one must assume that organisms, whether plant or animal, reacted to a given environment in much the same way as their modern counterparts. In other words, an alder or elm would have had the same ecological requirements in the Miocene as it does today. The difficulty of applying this assumption is that we are not really familiar with the complete ecological requirements and the range of tolerance of most genera and species of plants. This is true with temperate species, and is even more so for tropical and subtropical species. Furthermore, within any given genus the range of variability may be (and usually is) high, with each species requiring slightly different conditions. However, in virtually all studies where plant microfossils are used to interpret paleoecology we are not dealing with a natural species but only with natural genera. Palynologists usually take the total range of variables within a genus, and utilize as many genera as possible to interpret paleoecology. Thus a large microfossil assemblage should give a qualitative estimate of the climatic conditions at the site of deposition while the particular flora was in existence.

The other problem is whether or not a given sample is truly representative of the extant flora at the time of deposition. As pointed out previously, differential preservation is always a factor -- some pollen grains survive bacterial and fungal attack, oxidation hydrolysis, and rock diagenesis more readily than others. Furthermore, pollen and spores are produced in vastly different quantities in different genera. For example, a 10-year-old branch system of beech has been estimated to produce 28 million pollen grains per year, while an equivalent branch system of pine may produce 350 million grains (Faegri and Iverson, 1964). This difference will obviously be reflected in the quantities of pollen grains obtained from maceration of rock samples used in slide counts.

The method of pollen dispersal also reflects relative quantities. Wind-pollinated species (for example, Pinus) which usually produce pollen in enormous quantities will be abundant in the fossil record, whereas insect-pollinated plants (for example, Acer) produce relatively few pollen grains. As a result, Acer may be underrepresented in a microfossil spectrum and its importance in the assemblage will be underrated. In the case of Acer (maple), a pollen grain which is also easily destroyed, the combination of low relative productivity and comparative fragility may result in its absence entirely from the pollen record.

Factors such as these undoubtedly lead to complications of interpretation and must always be borne in mind when arriving at ecological conclusions. Provided enough samples are collected, both laterally and vertically, in a formation, a fairly satisfactory interpretation of some aspects of ecology should be possible. However, when using samples which are taken only at arbitrarily selected stratigraphic intervals, any conclusions of paleoecology must be regarded as tentative and can be presented only in general qualitative terms. This is what I have done in the following section, with brief interpretations of the over-all floral picture from late Eocene to middle Oligocene. Reference can be made to table 2, where generalized statements are made on both habitat and climatic requirements of the more common genera.

Interpretation

Definite statements about climate 45 million years ago based on 34 modern natural genera require that one tread cautiously. However, as the data in themselves are of no value without interpretation, we shall see where the available information leads.

Reference to table 2, under the climatic column, shows that most of the genera indicated range in climatic requirements from temperate to subtropical and most appear to be warm temperate. Interestingly enough, only one family appears to be exclusively tropical, and that is Bombacaceae. In fact, this family appears almost anomalous in this generic list, and perhaps can be accounted for only by assuming that all of these genera were living at the warm end of the warm temperate category. Bombacaceae is an omnipresent element of Eocene floras in both western Oregon and Washington, and even if not a dominant element of the Eocene flora, it was at least widespread.

Several other genera appear somewhat anomalous in this flora. Ephedra, which is a peculiar little shrub distantly related to the gymnosperms (such as conifers, cycads, ginkgo) is a xerophytic plant which grows in rocky or sandy soil in areas where there is little precipitation. This is not in keeping with the climate indicated by most of the other genera, and so it is possible this is one genus which has changed its ecological requirements through time, and that it has not always been xerophytic. Although never common, it is virtually always present in Eocene-Oligocene floras of the northwestern United States. Also surprising, from an ecological point of view, is the presence of the family Proteaceae, most of whose modern genera are xerophytic. Possibly the same explanation applies here as to Ephedra. The remainder of the microfossils, however, fit together nicely and give us an admittedly incomplete but at least consistent picture of the late Eocene-middle Oligocene flora.

The bulk of the flora from these three formations is composed of genera whose modern counterparts are warm temperate to subtropical. Most of the genera such as Taxodium, Glyptostrobus, Salix, Alnus, Ilex, and Typha are characteristic of a low, moist, and poorly drained coastal area.

The abundance of Taxodium and Glyptostrobus is an indication of large bodies of standing water in a warm temperate to subtropical climate. These two genera fill identical ecological niches, but at the present time Glyptostrobus is restricted to China, whereas Taxodium is found only in the southeastern United States and northeastern Mexico. During the Tertiary, both of these genera were widespread over North America. At present, these genera require 50 to 60 inches of precipitation yearly and a temperature that rarely falls below 32° F. The abundance of Sparganium attests to the apparently rather extensive bodies of standing water. Typha and Ilex, both abundant in warm swampy environments, also inhabited these lowlands.

On slightly higher uplands, behind the low coastal plain, stood a hardwood forest much like that currently present in parts of the eastern United States and eastern Asia. Typical trees in this association were Tilia, Castanea, Ulmus, Carpinus, Myrica, Liquidambar, and Quercus. Such trees have a modern distribution in moderately well drained sites where the annual precipitation is 40 to 60 inches (Chaney, 1940) with both winter and summer rains.

Other plants are present which suggest a more upland habitat. These include Fagus, Pinus, Picea, Podocarpus, Carya, and Corylus. How far these trees were growing from the site of deposition is uncertain, but their low frequency of occurrence would suggest it was some distance away. Pinus, whose pollen is produced in prolific amounts, is a moderately common microfossil in the Coos Bay rocks. However, the bladdered conifer grains are seldom well preserved and are often physically broken and almost inevitably corroded. The implication is that their habitat was a considerable distance away, probably to the east and south, and if Dott's (1966) paleogeographic interpretations are correct, possibly on volcanic islands to the west. Transport to the depositional site was probably largely by streams to the marine waters, followed by gradual settling in the basin of deposition. This long history of transport probably accounts for the poor physical preservation of the pollen grains. Although we do not know the prevailing wind directions during the early Tertiary, they probably ranged from northwest to southwest, as at present. This would substantially reduce the number of pollen grains transported from the highlands to the east and southeast.

Still farther back from the coastal plain were more pronounced uplands, probably mountains, that supported at least some coniferous genera such as Pinus and Picea. Abies has not been found in the Eocene-Oligocene rocks, so presumably any site of growth during this time was well removed from the coast. In modern floras, Abies generally grows at a considerably higher elevation than Picea, so probably no highlands of sufficient height existed to support Abies.

In summary, the Eocene-Oligocene in the area of Coos Bay, Oregon appears to have been warmer and more humid than at present, probably subtropical, but certainly not tropical. Highlands must have surrounded the basin of deposition, but relief was far less than at present. Precipitation was probably 50 to 60 inches annually and was more or less uniformly distributed throughout the year.

Table 2. Range and ecological requirements of modern genera which have been identified from the upper Eocene-middle Oligocene of the Coos Bay area, Oregon.*

Genus (or family)	Habitat and geographic range	Climate
Polypodiaceae	Moist areas, cosmopolitan	Variable
Lycopodium	Most are mesophytic, cosmopolitan	Temperate to tropical
Osmunda	Swamps, shaded moist woodlands, mainly northern hemisphere	Temperate to tropical
Picea	Moist soils, mainly northern hemisphere	Cool temperate, generally high altitude
Pinus	Swamps to rocky highlands, predominantly dry sites, northern hemisphere	Variable
Glyptostrobus	Associated with evergreen oak forest, generally moist to swampy habitats, southeast China	Warm temperate to subtropical, 50-60° precipitation
Metasequoia	Well-drained slopes in damp climates, China	Temperate to warm temperate
Taxodium	Swamps and flood plains of southeastern United States and Mexico	Warm temperate to subtropical, 50-60° precipitation
Podocarpus	Moist woodlands and mountains of the southern hemisphere, Caribbean, and South America	Warm temperate
Ephedra	Xerophytic, rocky, sandy sites; shrub, North and South America, Eurasia	Warm temperate
Magnoliaceae	Trees and shrubs, some climbing, cosmopolitan	Warm temperate to tropical
Liquidambar	Tree, component of oak-hickory forest, northern hemisphere	Warm temperate
Salix	Damp thickets, swamps, cool woods, cosmopolitan	Variable

* Modified after Rouse (1962) and Hills (1965), with additions from Bailey (1949), Lawrence (1951), Graham (1965), Smiley (1966), and Willis (1966).

Table 2, Continued.

Genus (or family)	Habitat and geographic range	Climate
Fagus	Often forms homogeneous forests, northern hemisphere	Temperate
Myrica	Almost cosmopolitan	Cool temperate to warm temperate
Alnus	Swamps, wet woods, stream margins, cosmopolitan	Variable
Betula	Uplands to bog and wooded swamp, northern hemisphere	Cool temperate
Carpinus	Upland woodlands to coastal swamps, northern hemisphere	Cool temperate
Bombacaceae	Mainly western hemisphere	Tropical
Ulmus	Lowlands, river valleys, northern hemisphere	Temperate
Corylus	Thickets, woodlands, northern hemisphere	Temperate
Castanea	Dry woods, thickets, northern hemisphere	Cool to warm temperate
Quercus	Wide range of habitats, northern hemisphere, mountains of tropics	Variable
Carya	Variable habitats, China, Southeast Asia, eastern North America	Cool temperate to subtropical
Platycarya	Japan and northern China	Warm temperate
Pterocarya	Northern hemisphere of Old World	Temperate
Tilia	Low slopes and along streams, northern hemisphere	Temperate
Ilex	Bogs, moist depressions, cosmopolitan	Warm temperate to subtropical
Proteaceae	Mostly xerophytic, restricted to southern hemisphere	Most indicate long annual dry season
Liliaceae	Cosmopolitan	Variable

Table 2, Continued.

Genus (or family)	Habitat and geographic range	Climate
Typha	Marshes, along river banks, cosmopolitan except south of equator in Africa	Temperate to tropical
Sparganium	Aquatic herb, northern hemisphere, Australia, New Zealand	Temperate

This picture of early Tertiary floras and geography, determined independently on the basis of fossil spores and pollen, agrees with Dott's (1966) interpretation of the geologic picture during the late Eocene-early Oligocene. He has concluded (1966, p. 373) that "Eocene sedimentation occurred in an open embayment of the Pacific....Minor volcanic islands existed near the present northern Oregon coast. The embayment lay adjacent to a low, swampy subtropical coastal plain, beyond that lay forested uplands with volcanoes."

Filling of this off-shore embayment apparently took from the late Eocene until the middle Oligocene, with the rocks now exposed locally, and known as the Coaledo, Bastendorff, and Tunnel Point Formations. Many of the plants growing on the coastal lowland are represented by pollen which became incorporated in this offshore fill. The palynological evidence supports the conclusions of Chaney (1948) that this lowland climate was humid and supported a lush subtropical vegetation.

Farther to the east and southeast on the hills comprising what is now known as the Klamath uplands grew the more temperate vegetation including Tilia, Castanea, Ulmus, Carpinus, and Liquidambar, which suggests at most a warm temperate climate. Still farther back, possibly on the slopes of volcanoes, occurred the truly temperate Picea. A modern-day analogy might be on the west side of the island of Luzon in the Philippines, bordering Lingayen Gulf. A sea-level coastal plain supports a thick tropical flora including ferns, palms, and bananas. One-half mile to one mile inland mountains rise abruptly, culminating in peaks up to 6500 feet in elevation. A steady vertical change in flora occurs with various conifers and other cool, temperate forms making an appearance at the higher elevations. Although this area has not been examined palynologically, it is probable that a mixture of cool temperate to tropical pollen grains are accumulating in modern sediments immediately off the Luzon coast. Although the example cited here is somewhat more extreme, I believe a similar situation prevailed in the Coos Bay area during the early Tertiary.

Summary

Palynological evidence supports and adds to the total environmental picture evolving from geologic work and the study of plant microfossils. During upper Eocene-middle Oligocene time the Coos Bay area lay on or near a low, broad, swampy coastal plain in a subtropical climate and was covered with lush and dense vegetation. To the east, highlands supported a warm temperate vegetation not greatly unlike the hardwood forests of the eastern United States. The higher portions of the mountains, well away to the south and east and probably quite distant from the coast, were clothed in still more temperate genera.

Literature Cited

Allen, J. E., and Baldwin, E. M., 1944, Geology and coal resources of the Coos Bay quadrangle, Oregon: Oregon Dept. Geology and Mineral Industries Bull. 27, 157 p.

Bailey, L. H., 1949, Manual of cultivated plants: New York, The Macmillan Co., 9th ed., 1116 p.

Baldwin, E. M., 1964, Geology of Oregon: Eugene, Oregon, Univ. Oregon Book Store, 165 p.

__________, 1966, Some revisions of the geology of the Coos Bay area, Oregon: The ORE BIN, vol. 28, p. 189-203.

Chaney, R. W., 1940, Tertiary forests and continental history: Geol. Soc.America Bull., v. 51, p. 469-488.

__________, 1948, The ancient forests of Oregon: Eugene, Oregon, Oregon State System of Higher Education, Condon Lectures, 56 p.

Dott, R. H., 1966, Eocene deltaic sedimentation at Coos Bay, Oregon: Jour.Geol., v. 74, p. 373-420.

Ehlen, J., 1967, Geology of state parks near Cape Arago, Coos County, Oregon: The ORE BIN, v. 29, p. 61-82.

Faegri, K., and Iverson, Jr., 1964, Textbook of pollen analysis: New York, Hafner Publishing Co., 237 p.

Graham, A., 1965, The Sucker Creek and Trout Creek Miocene floras of southeastern Oregon: Kent State Univ. Bull., Research series 9, 147 p.

Hills, L. V., 1965, Palynology and age of early Tertiary basins, interior British Columbia: Edmonton, Alberta, Univ. Alberta Dept. Geol. doctoral dissertation, unpub., 192 p.

Lawrence, G. H. M., 1951, Taxonomy of vascular plants: New York, The Macmillan Co., 823 p.

Macko, Ṡ., 1957, Lower Miocene pollen flora from the valley of Klodnica near Gliwice (Upper Silesia): Traveaux de la Societe des Sciences et des Lettres de Wroclaw, seria B, nr. 88, p. 5-314.

__________, 1959, Pollen grains and spores from Miocene brown coals in Lower Silesia, 1: Traveaux de la Societe des Sciences and des Lettres de Wroclaw, seria B, nr. 96, p. 5-178.

Rouse, G. E., 1962, Plant microfossils from the Burrard Formation of western British Columbia: Micropaleontology, v. 8, p. 187-218.

Schenck, H. G., 1928, Stratigraphic relations of western Oregon Oligocene formations: Univ. Calif. Dept. Geol. Sci. Bull., v. 18, p. 1-50.

Snavely, P. D., and Wagner, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Div. Mines Rept. Inv. 22, 25 p.

Weaver, C. E., and others, 1944, Correlation of marine Cenozoic formations of western North America: Geol. Soc. America Bull., v. 55, p. 569-598.

Willis, J. C., 1966, A dictionary of the flowering plants and ferns: Cambridge Univ. Press, England, 7th ed., 1214 p.

Youngquist, W., 1961, Annotated lexicon of names applied to Tertiary stratigraphic units in Oregon and Washington west of the Cascade Mountains, with bibliography: Ann Arbor, Mich., Edwards Bros., Inc., 92 p.

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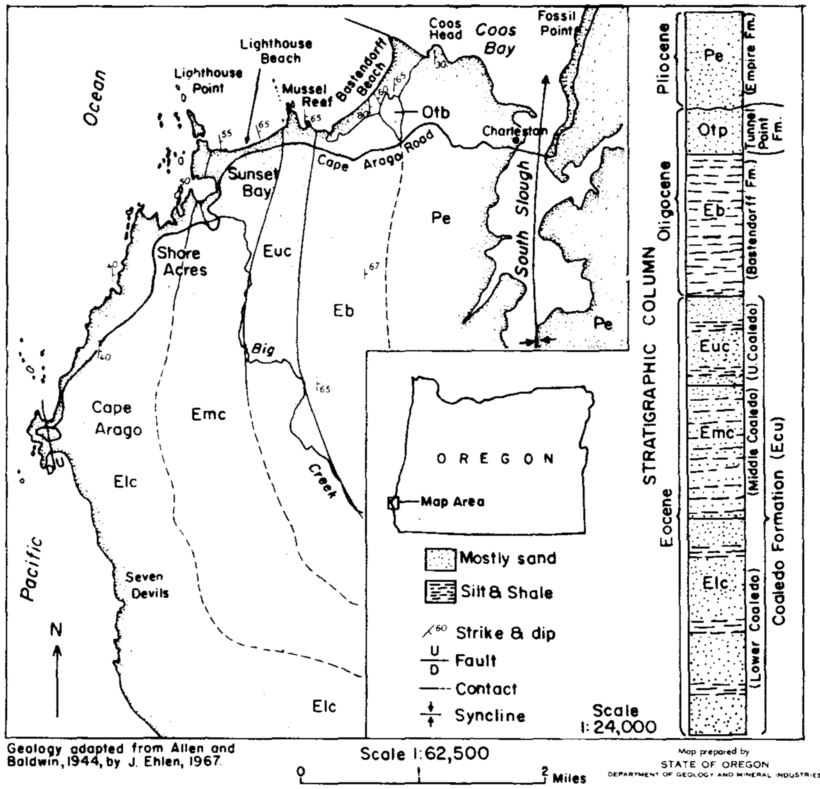


Plates

The following photographs are presented to show some of the ranges in size, variations in shape, and types of ornamentation of some common spore and pollen types found in the rocks of the Coos Bay area.

Plant pollen and spores are microscopic in size and are measured in microns (μ) which are units 0.001 millimeters (mm) in length. Most plant microfossils range in size from 15 to 130 μ or roughly 0.015 to 0.13 mm.

The photographs on the following pages were taken through a Leitz Ortholux Research microscope and printed at varying magnifications of 600 to 1100 times. On the plate explanation are given the generic name, the common name (see footnotes to table 1), and the maximum dimension in microns (μ) of the microfossil.

No attempt has been made to illustrate all the various spores and pollen grains found in these three formations. However, the illustrations include most of the morphological types, regardless of whether or not they can be assigned to modern genera.

PLATE 1

1. *Lycopodium*, club moss, 35 μ
2. *Osmunda*, fern, 40 μ
3. *Cicatricosisporites*, fern, 50 μ
4. Polypodiaceae, fern, 45 μ
5. Polypodiaceae, fern, 56 μ
6. *Laevigatosporites*, fern, 45 μ
7. *Pinus*, pine, 70 μ
8. *Picea*, spruce, 125 μ

PLATE I

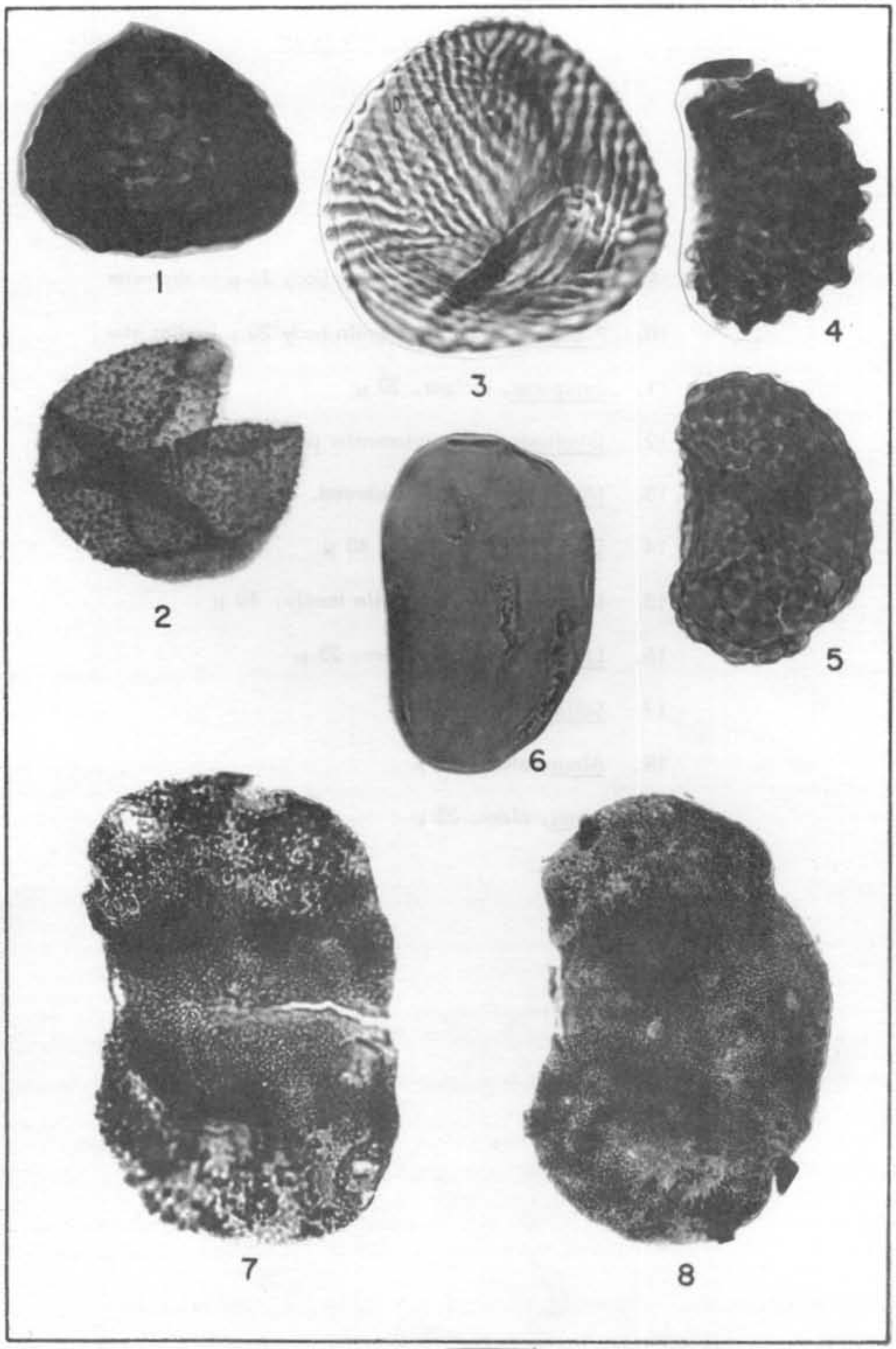


PLATE 2

9. *Podocarpus*, conifer, grain body 25 μ in diameter

10. *Podocarpus*, conifer, grain body 20 μ in diameter

11. *Juniperus*, juniper, 20 μ

12. *Glyptostrobus*, cantonwater pine, 28 μ

13. *Metasequoia*, dawn redwood, 24 μ

14. *Ephedra*, gymnosperm, 40 μ

15. Magnoliaceae, magnolia family, 40 μ

16. *Liquidambar*, sweet gum, 23 μ

17. *Salix*, willow, 34 μ

18. *Alnus*, alder, 19 μ

19. *Alnus*, alder, 23 μ

PLATE 2

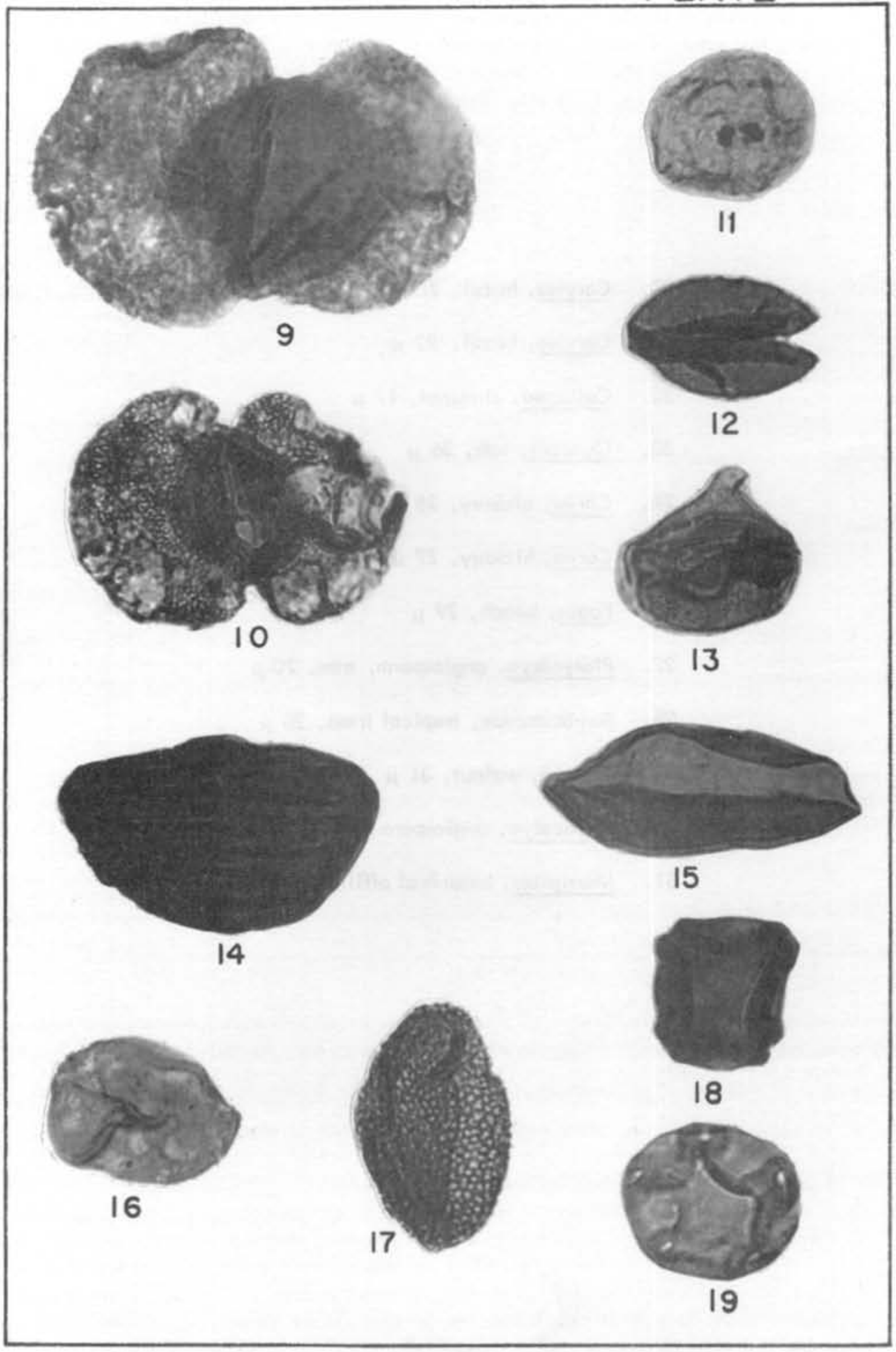


PLATE 3

20. *Corylus*, hazel, 27 μ

21. *Corylus*, hazel, 22 μ

22. *Castanea*, chestnut, 17 μ

23. *Quercus*, oak, 36 μ

24. *Carya*, hickory, 35 μ

25. *Carya*, hickory, 27 μ

26. *Fagus*, beech, 29 μ

27. *Platycarya*, angiosperm, tree, 20 μ

28. Bombacaceae, tropical trees, 28 μ

29. *Juglans*, walnut, 31 μ

30. *Pterocarya*, angiosperm, tree, 27 μ

31. *Momipites*, botanical affiliation unknown, 14 μ

PLATE 3

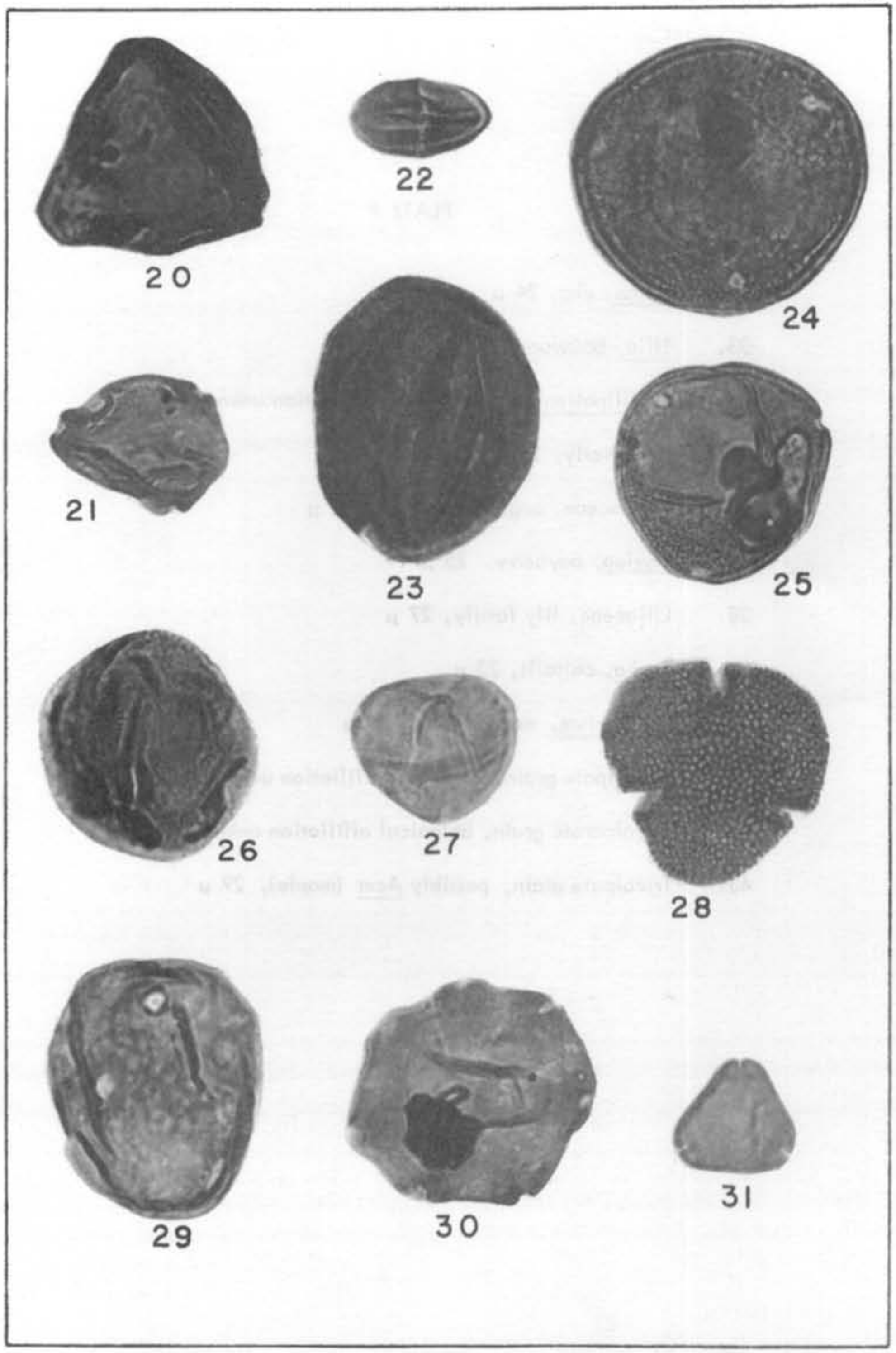


PLATE 4

32. *Ulmus*, elm, 24 μ

33. *Tilia*, basswood, 30 μ

34. *Pistillipollenites*, (botanical affiliation unknown), 22 μ

35. *Ilex*, holly, 24 μ

36. Proteaceae, angiosperm, tree, 22 μ

37. *Myrica*, bayberry, 25 μ

38. Liliaceae, lily family, 27 μ

39. *Typha*, cattails, 23 μ

40. *Sparganium*, aquatic herb, 29 μ

41. Syncolpate grain, botanical affiliation unknown, 27 μ

42. Tricolporate grain, botanical affiliation unknown, 25 μ

43. Tricolpate grain, possibly *Acer* (maple), 29 μ

PLATE 4

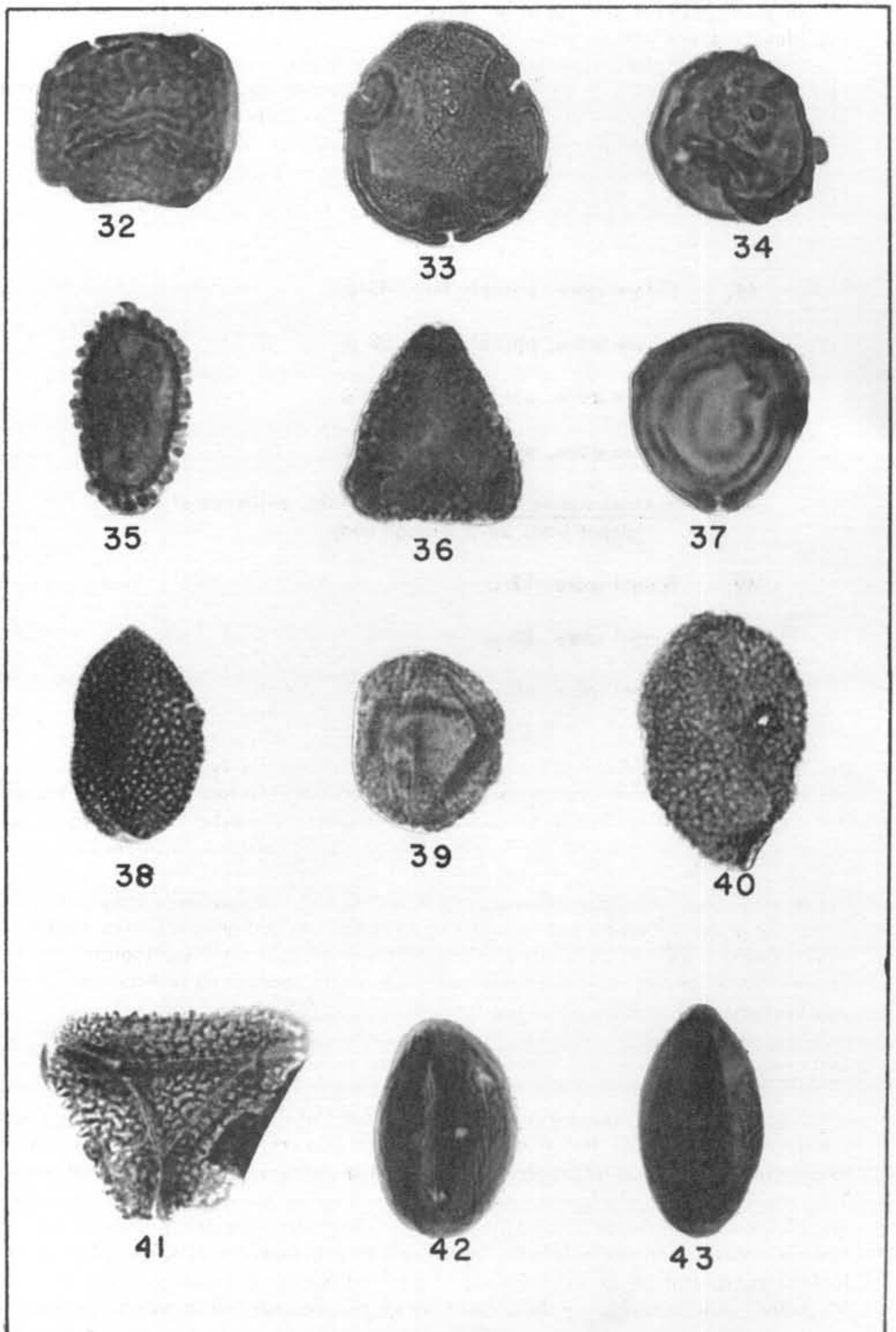


PLATE 5

44. Trilete spore, possibly fern, 45 μ

45. Trilete spore, possibly fern, 38 μ

46. Trilete spore, possibly fern, 40 μ

47. Trilete spore, possibly fern, 35 μ

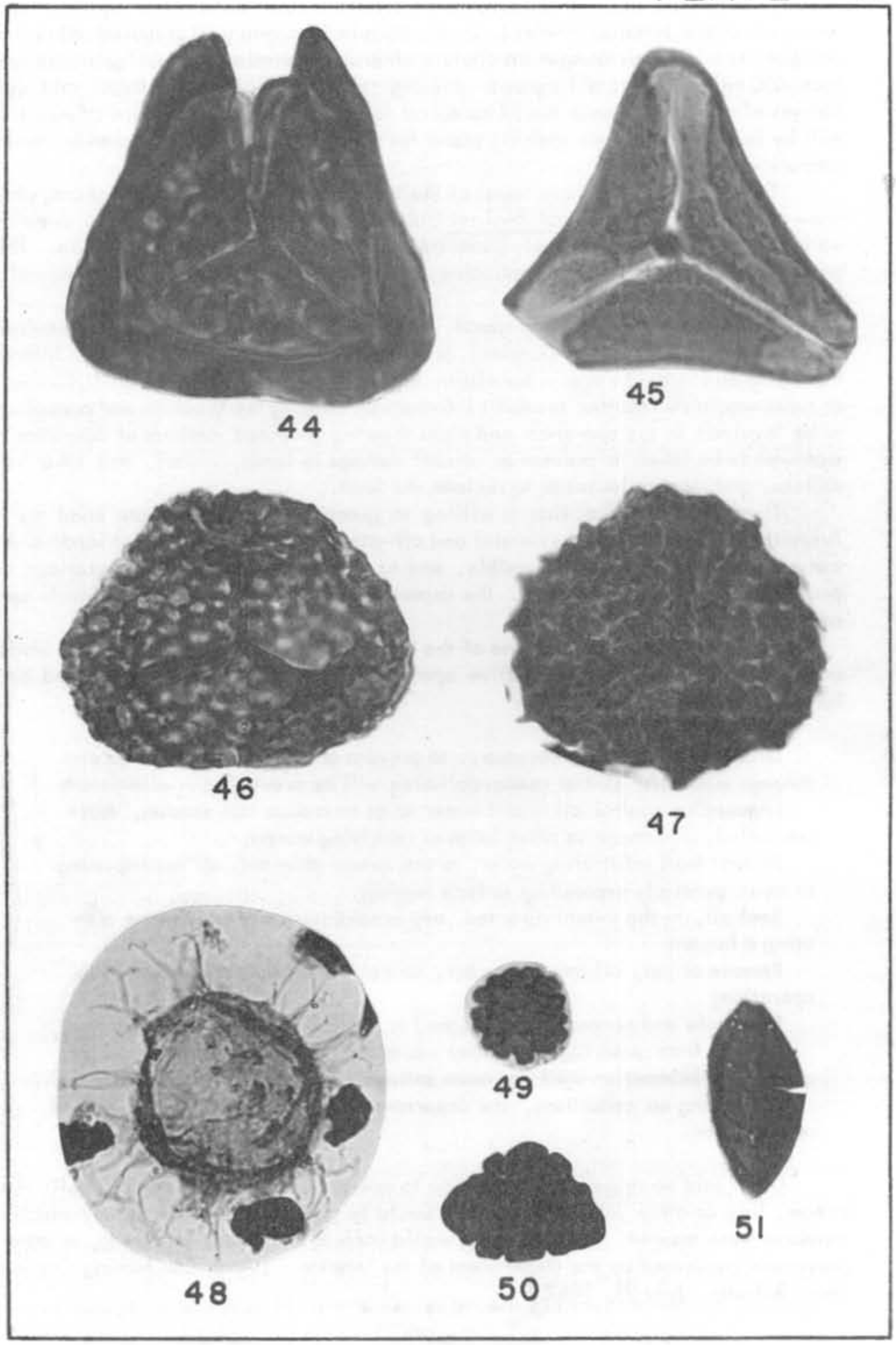
48. Hystrichosphaeridium, dinoflagellate, evidence of marine deposition, 22 μ through body

49. Fungal spore, 12 μ

50. Fungal spore, 20 μ

51. Fungal spore, 40 μ

PLATE 5



INTERIOR PROPOSES NEW RECLAMATION REGULATIONS

Secretary of the Interior Stewart L. Udall on July 17 announced proposed regulations designed to minimize damages from future mineral exploration and mining on the more than 500 million acres of land under his department's jurisdiction. Udall said that holders of permits or leases issued hereafter for exploration or extraction of minerals will be required to submit specific plans for restoring areas to be affected by their operations.

Covered under the Department of the Interior's proposed new regulations, which were published in The Federal Register July 20, are leasable minerals and common varieties of sand, stone, gravel, pumicite, cinders, clay, and petrified wood. The proposed regulations are not applicable to disposal of minerals under the general mining laws.

Under the department's proposal, "permission to operate" would be required before any exploration, development, or extraction operations could start on Interior-administered lands. To obtain permission to operate, the holder of a permit, license, or lease would be required to submit information showing the location and area of land to be involved in the operation and plans showing proposed methods of operation, measures to be taken to prevent or correct damage to lands, waters, and other resources, and steps to be taken to reclaim the land.

Unless the person or firm is willing to guarantee by performance bond the financial costs of minimizing on-site and off-site damages to the federal lands and waters for which they are responsible, and to reclaim the site of the operations in accordance with approved plans, the department would not grant permission to operate, Secretary Udall said.

Hereafter, the holder of one of the new permits, licenses, or leases -- while engaged in exploration or extractive operations on federal lands administered by Interior -- would be required to:

> Divert waters, where necessary, to prevent or reduce the flow into and through workings, so that stream pollution will be prevented or alleviated;
>
> Impound or control all runoff water so as to reduce soil erosion, sedimentation, or damage to other lands or receiving waters;
>
> Protect from infiltrating water, to the extent directed, all acid-forming or toxic materials exposed by surface mining;
>
> Seal off, to the extent directed, any breakthroughs of acid water creating a hazard;
>
> Remove or bury all metal, lumber, and other refuse resulting from the operation;
>
> Dismantle and remove all abandoned or useless structures and equipment;
>
> Refrain from removing equipment necessary to accomplish reclamation until such reclamation work has been satisfactorily completed and approved.
>
> Depending on conditions, the department would require backfilling and revegetation.

Udall said no request for permission to operate within 100 feet of a public road, stream, lake or other public installation would be granted unless adequate protective measures were assured. Such measures would include diversion, screening, or other provisions prescribed by the Department of the Interior. [American Mining Congress News Bulletin, July 21, 1967.]

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