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Palynology

1958

POLLEN ANALYSIS CIRCULAR no. 8

October 28, 1944

Edited by Paul B. Sears, Department of Botany
Oberlin College, Oberlin, Ohio

THIS ISSUE is being printed and distributed by Dr. S. A. Cain of the University of Tennessee who did the same for the last issue. Professor E. C. Cocke of Wake Forest College, North Carolina, has generously offered to sponsor two issues and Professor C. A. Arnold of the University of Michigan at Ann Arbor has written that he will be glad to help in the distribution of the circular at any future date if needed.

OFF SCHEDULE. - For the fact that this issue is more than a month late, the editor is solely responsible. In extenuation he can only blame the most serious of war-time shortages—that of leisure time. Important material, notably a review of Dr. Cain's remarkable new book (Foundations of Plant Geography) will have to be held over for the next issue.

CLEVELAND CONFERENCE. - Under the auspices of the Ecological Society of America, our conference enjoyed the following announcement:

Wednesday Afternoon Session (September 13, 1944)

Section 1. Conference on Pollen Analysis and Related Bog Problems. 1 p.m., Room 34, Adelbert Hall, Western Reserve University. L. R. Wilson, Coe College, Chairman.

PANEL DISCUSSION

Pierre Dansereau, University of Montreal
John E. Potzger, Butler University
Chester A. Arnold, University of Michigan

Dr. Arnold was unable to be present. The meeting was quite informal. Particular attention was given to the problems of identification, to important relicts in southeastern Canada, and to the unpublished striking profiles which Dr. L. R. Wilson has completed. These last extend northward from southern Ohio well into Canada. Dr. Ira T. Wilson also had on exhibit his sampling device for the study of deep-lake sediments.

Drs. Potzger and Cain gave papers at the Thursday afternoon joint session of the ESA and Botanical Society of America—the report of Dr. Potzger being on bogs within the New Jersey Pine Barrens, that of Dr. Cain (and Louise G. Cain) being a study of size-frequency in Pinus echinata pollen.

Several members of the conference attended the Thursday morning session of the geologists, to hear Dr. Ira T. Wilson report on laminated sediments and while there made a valued contact with Dr. George M. Stanley of the University of Michigan, whose work on glacial features of the Great Lakes region will afford useful correlations with pollen analysis data.

Particularly welcome to those present in Cleveland was the presence of Prof. Pierre Dansereau of Montreal, and his charming wife.

TO BE OR NOT TO BE. - The Cleveland Conference considered the question of organization and decided by a margin of one vote not to organize at this time. The responsible vote was cast—a bit sheepishly—by your editor who confesses to a phobia towards organizations which outlive enthusiasm and justification. However, much interesting discussion has come in on this subject and will be found below.

Subsequently, a letter from the National Research Council (printed below) was received, containing the interesting suggestion that it might arrange for a special committee dealing with the subject of our mutual interest. Comments on this letter will be extremely helpful.

CONCERNING ORGANIZATION. - Of the 10 ballots returned, 9 favored informal organization and 8 the title POLLEN AND SPORE SCIENCE CIRCULAR for our publication. The following comments were made:

"Since a title above all should be brief and is not expected to mention everything, it does not seem necessary or desirable to include 'spore,' 'miscellaneous identifiable plant fragments,' or such. The word 'Circular' has been good so far. In the future 'Bulletin' might be better. Dues should be set in relation to cost, but perhaps with maximum of \$2.00. I prefer the following title, for issues beginning in 1945 (?): POLLEN SCIENCE CIRCULAR (to correspond to POLLEN SCIENCE SOCIETY). The title should perhaps be changed directly upon the formation of the society, and new numbering - Vol. 1, no. 1, started." (Ernst Antevs)

"Society for the Study of Pollen and Spores. Dues \$5.00 per annum. Separates of articles on pertinent subjects to be furnished to members, as a return on dues. Formal Organization: President, Vice-president, Secretary-Treasurer. Committee to select articles for which separates are to be ordered. I prefer the following title for issues beginning in 1945: Circular of Micro-paleobotany." (Kirk Bryan)

"A multiplicity of formal organizations is undesirable but the 'Pollen Analysis Circular' and organization of a pollen program at the AAAS meetings are both sufficiently excellent things to deserve perpetuation. To the extent that organization and dues are necessary to continue and promote these functions, one would expect universal cooperation within the group. The Ecological Society really ought to be interested in fostering this development. Certainly a pollen program at the meetings should be in their program." (M.L. Buell)

"I prefer POLLEN AND SPORE SCIENCE CIRCULAR as a title, since this includes without doubt workers on Palaeozoic spores. Such work is gaining importance in Great Britain, especially in connection with correlation of coals." (Elizabeth M. Knox, Edinburgh)

"Dues should be low (say 50 cents per year) in order to encourage membership on the part of those who (like myself) are not particularly engaged in pollen work. Suggestions as to the type of

organization, I leave to those closer to the work and likely to attend meetings." (E. H. Moss)

"I have the following suggestions to offer regarding name, dues and type of organization: MICROFOSSIL SOCIETY. If the organization will include workers in pollen from the hayfever angle, we should, perhaps, call it POLLEN AND SPORE INVESTIGATORS. An organization without persons who are responsible for necessary obligations, will hardly survive, so I suggest that we have the customary official family. If we plan to have the mimeographed Circular to continue, dues of \$1.50 should be sufficient." (J. E. Potzger)

"I have the following suggestions to offer regarding name, dues, and type of organization: POLLEN AND SPORE SCIENCE ASSOCIATION. Dues restricted to actual cost of mimeographing circular, i.e., \$1.00 or less. Probably many libraries would become 'associate members' paying cost of subscription of publication, possibly at a slightly higher rate." (Horace G. Richards)

"Name - Society of Pollen and Spore Science.

"Dues - One dollar every two years.

"Type of organization - Informal as possible - a steering committee - with a chairman, secretary-treasurer, editor." (L.R. Wilson)

"Instead of returning the ballot included in the recent Pollen Analysis Circular, I thought a letter might express my views a little better.

"The fact is that study of fossil spores and pollen—that is, plant microfossils—is not in itself a qualified 'field' of scientific study. The microfossil studies are pertinent to several different fields. On the one hand they may apply to paleobotany in its various geological and stratigraphical aspects and on the other to relatively recent aspects of plant sociology. Study from the standpoint primarily of coal constitution may also become more prevalent later. Students in these different fields all expect to call on the microfossil material to serve their rather different purposes. The inherent tendencies implicit in this situation affect the type of organization that is possible, and suggest that it will have limitations. I believe that some type of organization could serve a useful purpose. Any significant advance in microfossil technology has significance for others working on this type of material regardless of their main purposes of study.

"I have no particular preference about an organizational name. From my remarks above, you may infer that to me the type of organization deserves greatest consideration and that this may best be judged in accordance with the service such an organization may legitimately perform.

"It does not seem to me that the proposed organization should attempt independent formal meetings. At present the Ecological Society and the Paleobotanical Section of the Botanical Society sponsor meetings which accord with both diverse interests inherent in the group. If the organization desires to participate in scientific meetings, it would seem to me a more effective arrangement

to propose collaboration with these pre-existing organizations in their normal annual programs. So far as the Paleobotanical Section is concerned, I have every reason to think such collaboration would be welcomed.

"The main function of the new organization I believe should be crystallized around the technologic aspects of microfossil work inasmuch as that is the common point of interest. The interpretation of pollen and spore morphology and variation and a proper terminology to express microfossil characteristics would be pertinent, as well as the manipulative aspects.

"As to general organization, I think the pattern that has been followed by the American Society of Plant Taxonomists most nearly approaches what is feasible for the plant micropaleontologists. (This obviously is too polysyllabic for a name.) Their membership is not restricted. The dues are very modest. A mimeographed circular, chiefly a current literature check list and commentary, is distributed which is very helpful. It seems to me all these features can be incorporated into the proposed organization with advantages.

✓ "I do not care to suggest a title for a circular either. Obviously it should be short and informative of the objectives of the circulation. I am glad to see that 'spores' are included in the title suggested for the 1945 circular inasmuch as that implies recognition and inclusion of work by 'antediluvian' workers like myself. A thing, perhaps of minor consequence but nevertheless factually correct, which bothers me is that a spore really is a single-celled reproductive body. A pollen grain is properly the name for the dispersal stage of the one or few celled male gametophyte and the androspore stage is antecedent to the pollen stage in seed plants. Probably every botanist appreciates this, but it is a most confusing thing to explain to nonbotanists. The fact remains that there is no simple and correct designation for the dispersal stage of gametophytes of cryptogamic forms, despite the popular appellation of ✓ the bodies as 'spores.' Either 'spore' should be redefined with the active support of an organization, such as the proposed one bids to be; or else a new and appropriate term should be utilized—though this problem has been in my mind for several years, I have no practical suggestion to offer." (James M. Schopf)

✓ "The problem of determining the correct amount of dues is a difficult one. I would judge that the purpose of dues was to make a certain amount of publication possible. From my experience with several young societies it is wise to establish the dues at a figure which will be quite close to its maximum. I have found that it is extremely difficult to raise the dues once a society has been established. Thus if this organization is looking forward to the publication of 500-1000 copies of an annual volume having 400-500 pages the annual income will have to be between \$1500 and \$2000. This means that dues should be at least \$4.00 and probably more. With dues at a figure established in this way the securing of members will at first be difficult for they will not consider that they get "enough for their money." However, as the journal improves the number of members increases and the organization develops on a very firm foundation." (Frederick Johnson)

SEPARATES OR A JOURNAL? - "I still feel that it might be better for the proposed society to circulate separates of articles published in other journals than to start a journal, although, of course, such a journal might have pretty good support. I can believe that many of you in the biological sciences hesitate about starting another organization as you already have a great many. I feel, however, that it is only fair that those of us who are interested, but hardly workers in the field, should have an opportunity of making a definite contribution and at the same time of having an opportunity of keeping up with the progress of the work." (Kirk Bryan)

PALEOBOTANISTS ENCOURAGE. - "Paleobotanical research as we formerly knew it has been seriously curtailed during the war but some aspects are still receiving considerable attention. These relate to the study of coal and peat deposits. There is a need for information that will assist in detailed geological correlation of coal beds and for the accurate comparison of varieties of coal based on botanical origin. The latter has significant bearing on many coal utilization characteristics. Peat studies contribute greatly to our understanding of coal origin and in some localities may be called on for use as a substitute fuel when coal is difficult to obtain." (James M. Schopf, Chairman, Henry M. Andrews, Jr., Secretary, Paleobotanical Section, The Botanical Society of America. May 15, 1944)

INTEREST EXPRESSED BY NATIONAL RESEARCH COUNCIL. - "I wish to thank you for your kindness in sending copies of Pollen Analysis Circular, Nos. 1-7 to the Division of Geology and Geography of the National Research Council. I am, of course, a rank outsider and a mere layman in this borderline subject. However, you may recall from the Soil Conservation Service field conference at Spartanburg several years ago that I am much interested in the geochronologic results being obtained by those of you who are working in this field. I have read these circulars with great interest, and I wish to compliment your group on what is being accomplished by means of them.

"Having made so good a start in these difficult times, it seems unlikely that your group will need much encouragement from outsiders like myself in order to keep going from now on. Nevertheless, I should like to be of assistance if there is some way in which the Division of Geology and Geography can appropriately do so. I doubt that the Division can demonstrate its interest in the field of 'pollen science' by offering to print and distribute one or more issues of your Circular, partly because our stenographic and duplicating facilities are somewhat limited these days and partly because it might open the way to embarrassing requests for similar help from other informal organizations. However, it might possibly be arranged if you think it worthwhile.

"I also doubt that at this relatively late date in its development 'pollen science' has need for the type of encouragement sometimes afforded to new scientific fields by the establishment of an NRC committee on the subject. If such a committee were to be considered at this time, I think that it should mean the selection of a relatively small number of the most active research workers in the field. But from the number of workers listed in various numbers of the Circular, I surmise that such a selection might possibly run

"However, there may be other ways in which the Division could be of assistance and I should be very glad to have any suggestions that you might care to offer." (William W. Rubey, Chairman, Division of Geology and Geography, National Research Council, August 30, 1944)

THE RIGHT WORD. - "The question raised by Dr. Antevs: 'Is pollen analysis the proper name for the study of pollen and its applications?' and his suggestion to replace it by 'pollen science' interest us very much. We entirely agree that a new term is needed but in view of the fact that pollen analysts normally include in their counts the spores of such plants as ferns and mosses we think that some word carrying a wider connotation than pollen seems to be called for. We would therefore suggest palynology, (from Greek $\pi\alpha\lambda\acute{\upsilon}\nu\omega$ (paluno), to strew or sprinkle; cf. $\pi\alpha\lambda\acute{\eta}$ (palē), fine meal; cognate with Latin pollen, flour, dust): the study of pollen and other spores and their dispersal, and applications thereof. We venture to hope that the sequence of consonants p-l-n, (suggesting pollen, but with a difference) and the general euphony of the new word may commend it to our fellow workers in this field. We have been assisted in the coining of this new word by Mr. L. J. D. Richardson, M.A., University College, Cardiff." (H.A. Hyde and D. A. Williams, July 15, 1944. Wales)

"I have been toying with the idea of 'micro-paleobotany' as including most of the work on pollen and spores and also all minor constituents of peat and humus layers of vegetative remains which have to be identified by microscopic work. We have a micro-paleontology, and this term is now current. It is not a perfect term, as the interest of the society is in the paleontology of microscopic animals. Hence micro-paleontology is badly constructed. Micro-paleobotany would have the same objection. It is also true that some of these people who are interested in pollen from the standpoint of human allergies might not take kindly to the name which implies that the principle objectives have to do with past events. Naturally the geological adherents are primarily interested from the point of view of the past, and have only nominal interest in methods of detecting different types of pollen, etc. We, of course, realize that in order for the paleobotanists' conclusions to be valid, identification must be absolute, but obviously we cannot retain too much interest in the methods by which absolute identification is achieved." (Kirk Bryan)

POLLEN ANALYSIS IN THE PACIFIC NORTHWEST. - Professor Henry P. Hansen of Oregon State College has in preparation for publication a paper "discussing the pollen analysis of about 70 sedimentary columns from this part of the country." This paper embodies work done on a Guggenheim fellowship. The editor has had the privilege of examining it in manuscript, and has been struck with its workmanlike quality and its strong confirmation of general results obtained in eastern North America.

A GEOLOGICAL PAPER OF INTEREST TO POLLEN ANALYSTS. - In 1942 a series of studies by W. H. Bradley and others was completed on the geology and biology of North Atlantic deep-sea cores (Bradley, W.H., et al. 1942. Geology and Biology of North Atlantic Deep-Sea Cores between Newfoundland and Ireland. U.S.G.S., Prof. Paper 190: 1-163 (Parts 1-9, Feb. 1941-June 1942). 23 plates, 30 figs., 36 tables.) that is

worthy of the study of pollen analysts and investigators of Pleistocene and postglacial climatic history. No review of this important paper will be attempted here, but certain of the findings and interpretations will be mentioned.

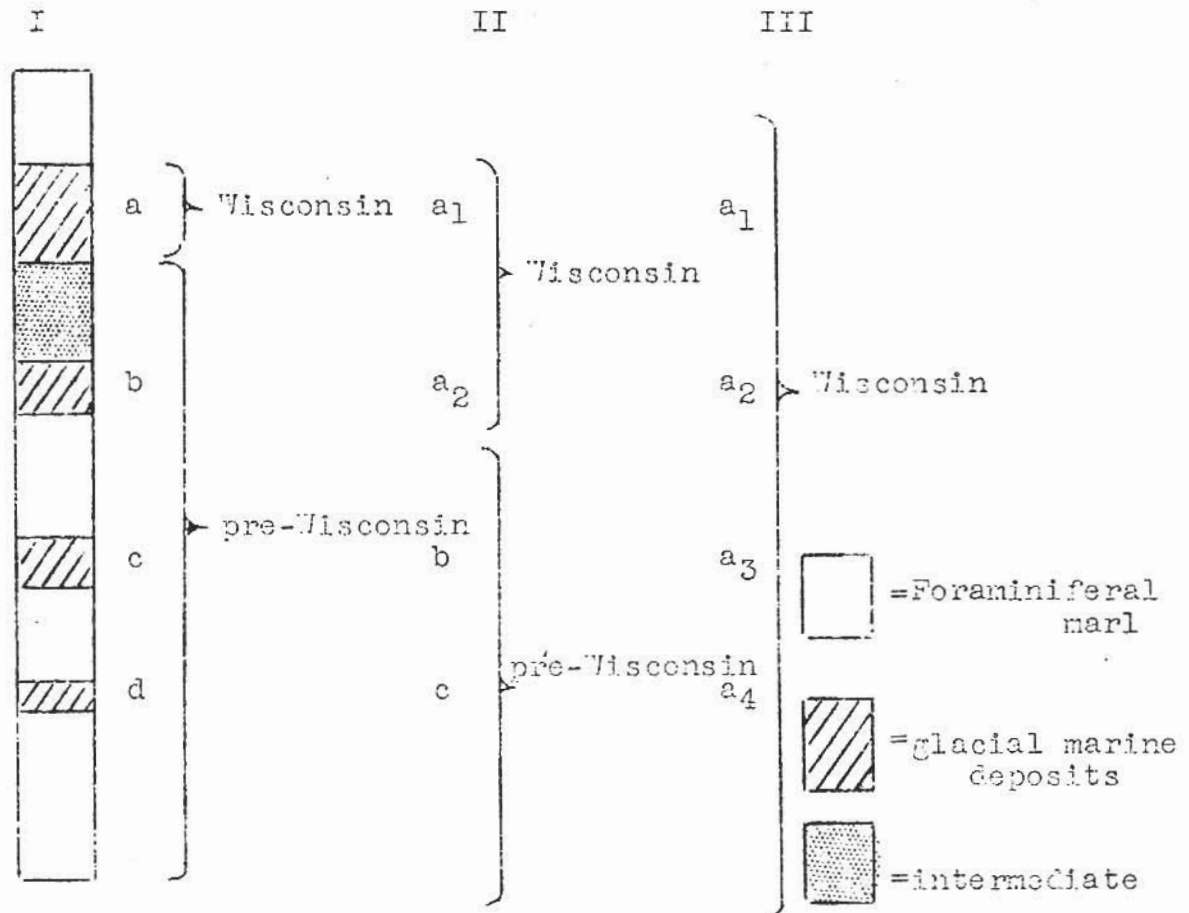
Of all the studies of the cores those on lithology and Foraminifera were most suggestive. Lithologic correlations were possible on a basis of alkalic volcanic glass shards (an upper zone all across the Atlantic, at about lat. 50°N ., and a lower zone west of the Faraday Hills portion of the Atlantic Ridge, at about long. 30°W .), glacial marine sediments, and foraminiferal marl. The foraminiferal facies (especially pelagic species) that are characteristic of cold and warm climates correlate with the alternating glacial marine and warm-water sediments indicated by the lithology.

"...Cores 4, 5, 6, and 7 [western Atlantic] contain two ash zones and have the same sequence of glacial marine deposits between the ash zones. Below the lower ash zone in each core there is another glacial marine zone, which is underlain by foraminiferal marl similar to that found today at the surface of the ocean floor. The sequence of zones in these four cores agrees so well that their correlation seems well established in this area... The correlation of strata in the cores is...less satisfactory from core 8 [on the Atlantic Ridge] eastward [cores 9-13] than it is west of the mid-Atlantic ridge, but the consistent relation between an upper ash zone and the uppermost glacial marine zone appears to be a reliable basis for tying together all cores except 3 [near the Newfoundland Bank] and 11 [when hard volcanic rock was struck and only a shallow sample obtained]."

The evidence from lithologic and foraminiferal data permit three interpretations (I, II, III of the accompanying diagram). The authors favor interpretation III, and I quote the following interesting paragraph.

"The third possible interpretation is that all four glacial marine zones represent only substages of the Wisconsin stage..., though the latest two substages are not separated by a clearly defined non-glacial substage. For the greater part of the Wisconsin stage this interpretation apparently implies a greater latitudinal range of glacial phenomena both in the North Atlantic ocean and in eastern North America than is evident in the record of continental glaciation. It implies that for periods of time measured in thousands of years the North Atlantic at approximately 50°N . alternately contained an abundance of drift ice and then again for thousands of years was nearly or quite free of ice. This seems to indicate that, except in the intervals between the latest two glacial marine zones, the continental ice sheet not only withdrew from the coast but probably retreated well back toward its centers of dispersal so that the marine climate of the western North Atlantic was not greatly different from what it now is."

From the upper portions of the cores above the most recent glacial marine sediment there is a strong indication from the Foraminifera that "during roughly the middle part of the post-glacial interval the surface-water temperature in those areas in the North Atlantic was somewhat higher than prevails there today."



✓ This suggests the three-phase postglacial climatic history as known from some pollen studies, with a middle warm (? xerothermic) period and a third-period reversion.

Undoubtedly the future will see further deep-sea sediment analyses which would seem to offer the soundest possible trans-Atlantic correlation of late Pleistocene and Recent climates, especially with samples south of the Atlantic Ridge, more numerous in the Eastern Atlantic, and along a meridional line. Without some such information the evidence from pollen analysis on the two sides of the Atlantic will remain more in the nature of analogy than correlation.

✓ Although the authors make no effort to estimate the extent of the probable temperature changes in degrees, the indications are that considerable refrigeration and warming occurred. Students of terrestrial conditions (such as the modern anomalous areas of species and communities: warm and cold relics) may be encouraged in hypothesizing the necessary past temperatures to explain present aereographical patterns. In this connection I can not refrain from one further quotation, "the most reliable source of information on the ecology of foraminiferal faunas is still the known distribution of the species composing the faunas," which can be extended to ecological-geographical problems in general.---Stanley A. Cain.

FROM NEW ZEALAND.--"Dr. Allan has kindly lent me two copies of your Pollen Analysis Circular (Nos. 6 and 7), and I feel that pollen workers are much indebted to the sponsors for this very readable publication.

"I am just picking up the threads again after a period of war work and hope to continue the work on New Zealand Pollens launched by Miss L. M. Cranwell, now Mrs. S. Watson Smith, who has recently joined you in America.

"Altogether we have some 400,000 acres of peat lands, about a quarter of which has been brought into cultivation. In certain areas, where swamp land has been converted to pasture, stock is not doing well and evidence has been obtained, in some instances, of copper deficiency. We are taking up the comparative study of selected peat deposits to see whether any botanical factors may be found which might be correlated with the incidence of these troubles. Pollen and fern spores are being taken into account, and it is hoped that the data so obtained may be useful for future studies. In this connection, attention is being given to the dispersal of pollen and spores, as preliminary work suggests that, under New Zealand conditions, the effect of long distance transport is not conspicuous or, at any rate, is largely confined to certain species." (W. F. Harris, Plant Research Bureau, Wellington, N.Z., Sept. 6, 1944)

KEY TO THE GENERA OF PALEOZOIC SPORES AND POLLEN

- I. Fossils unicentric, no special axis of symmetry, suture absent
 - A. Spherical or subspherical, disc shaped when compressed; wall minutely perforate, surface otherwise smooth.....Tasmanites
 - A. Irregular or lobate masses; wall alveolate openings outward; surface irregular, coarsely dentate."Boghead algae"
- II. Fossils with bilateral or triradial symmetry; sutures monolete; trilete or absent
 - A. Fossils bilaterally symmetric; sutures monolete, trilete or absent
 - B. Vesicular (bladder) appendages lacking
 - C. Fossils 100-500 μ . through long axis; monolete suture with median angular deflection; distal groove often present; translucent to opaque...Dolerospora
 - C. Fossils 20-130 μ . through long axis; monolete suture without medial deflection; distal grooves absent; usually transparent; often bean-shaped.....Laevigato-sporites
 - B. Vesicular (bladder) appendage, one or two
 - C. Vesicular appendages two, opposite or sub-opposite on the central cell

- D. Bladders inclined distally; central cell thickened on proximal side.....Pityosporites
- D. Bladders not distally inclined; central cell not differentially thickened
 - E. Bladders oppositely attached on central cell; suture absent.....Alisporites
 - E. Bladders sub-oppositely attached on central cell; suture functionally monolete with slight medial deflection and shorter suture simulating an assymetrical trilete suture pattern.....Parasporites
- C. Vesicular (bladder) appendage annulate; fossils elliptical
 - D. Relatively large, 200-300 mu.....Zonalosporites
 - D. Smaller, 50-195 mu.....Florinites
- A. Fossils with triradial symmetry; sutures trilete or obscure
 - B. Fossils usually compressed, sack-like, 4-10 mm. or more in length; wall composed of intermeshed fibrils; 3 diminutive aborted spores sometimes also present.....Cystosporites
 - B. Fossils not sack-like; less than 4 mm. in size; walls not as above; when in tetrads, usually no spores are diminutive
 - C. one or more vesicular appendages present
 - D. Vesicular appendage single.....Endosporites
 - D. Vesicular appendages trimerous.....Alati-sporites
 - C. Vesicular appendages not present
 - D. Fossils 0.4-3 mm. or more in diameter; walls relatively thick; opaque or poorly translucent; surface often highly ornamented
 - E. Axis (of uncompressed spore) shorter than radial diameter
 - F. Trilete rays not reaching the equator; appendages, if present, not confined to equator; ornamentation apiculate or lacking; diameter usually more than 1 mm.....Triletes, sect. Aphanozonati
 - F. Trilete rays extending to or nearly to the equator; appendages on the equator flange-like, auriculate, apiculate, or absent; ornamentation various

- G. Fossils triangular in equatorial view
 - H. Auriculae present on equator.....Triletes, sect. Auriculati
 - H. Auriculae not present on equator.....Triletes, sect. Triangulati
 - G. Fossils round in equatorial view.....Triletes, sect. undifferentiated

- E. Axis (of uncompressed spore) equal to or longer than equatorial diameter
 - F. Not spherical; ornamentation various.....Triletes, sect. Lagenicula
 - F. Spherical; ornamentation absent.....Calamospora

- D. Fossils less than .4 mm. in diameter
 - E. Uncompressed spores spherical, ornamentation absent; transparent to opaque
 - F. Fossils usually collapsed and much folded, elaters absent.....Calamospora
 - F. Fossils usually not collapsed or much folded, circinately coiled elaters present.Elaterites
 - E. Uncompressed spores not spherical, or if spherical ornamentation present, folding infrequent; transparent to opaque
 - F. Fossils triangular in equatorial view
 - G. Equatorial region fimbriate, flanged, thickened, or auriculate
 - H. Auriculate thickenings at radial angles.....Triquitrites
 - H. Auriculate thickenings absent at radial angles
 - I. Fimbriate flange or equatorial apiculae present; elements of flange longer between radii than at radial angles.....Reinschospora
 - I. Flange not as above
 - J. Equatorial region of spore wall thickened, frequently opaque.....Denso-sporites
 - J. Equatorial region not thickened, highly translucent
 - K. Flange broad, membranous, slightly striate, usually serrulate, wider at radial angles.....Cirratriradites
 - K. Flange narrow or obscure, ridge-like, of uniform width.....Lycospora

- G. Equatorial region without flange
- H. Prominent reticulate wall thickenings on at least half of spore surface. Reticulate-sporites
- H. No reticulate wall thickenings
- I. Ornamentation of blunt or partate spines.....Raistrickia
- I. Ornamentation not as above
- J. Equatorial ridge or thickenings absent.....Granulate-sporites
- J. Simple equatorial ridge present; with uniform.....Lycospora
- F. Fossils round in equatorial view
- G. Equatorial region flanged or thickened
- H. Equatorial region thickened, frequently opaque; flange may be present...Denso-sporites
- H. Equatorial region not appreciably thickened
- I. Flange membranous.....Cirratriradites
- I. Flange narrow and ridge-like.....Lycospora
- G. Equatorial region neither flanged nor visibly thickened
- H. Ornamentation of blunt or partate spines.....Raistrickia
- H. Ornamentation not as above
- I. Equatorial ridge or thickenings absent.....Punctatisporites
- I. Equatorial ridge or thickenings present
- J. Equatorial ridge simple, width uniform.....Lycospora
- J. Equatorial thickenings irregular, with not uniform.....Reticulatisporites

ADDRESSES OF WORKERS:

- Cain, Louise Gilbert, 13 Highland Hills Drive, Knoxville 16, Tenn.
 Harris, Mr. W. F., 8 The Terrace, Wellington, C. 1, New Zealand.
 Parker, Dorothy, Dept. of Biology, University of Notre Dame, Notre
 Dame, Indiana
 Stanley, Dr. George M., Dept. of Geology, University of Michigan,
 Ann Arbor, Michigan.
 Verdoorn, Dr. Frans, CHRONICA BOTANICA, Waltham, Mass.

NEW ADDRESSES:

- Dewey, E. R., Director of Foundation for the Study of Cycles,
 274 Madison Ave., New York 16, N. Y.
 Hamp, F. A., 2332 E. 65th St., Indianapolis, Indiana.
 Howell, J. W., 2316 Ralston Road, Bellview Village, Sacramento, Calif.
 Otto, J. H., 5114 Kingsley Drive, Indianapolis, Ind.
 Schrock, Alta, Dept. of Biology, American University, Washington, D.C.
 ✓ Smith, Mrs. S. Watson (Lucy Cranwell, of Auckland, N.Z.), Orange
 Court Hotel, Orlando, Florida.

ADDRESSES NEEDED: (mail has been returned unclaimed)

- Benninghoff, W. S. (formerly at Harvard)
 Truman, H. V. (formerly at Havre, Montana)

DECEASED:

- Kay, G. F., Dept. of Geology, State University of Iowa, Iowa City
 Rosendahl, C. O., Univ. of Minnesota, Minneapolis

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