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ON THE THURINGIAN AGE OF THE UPPER PALAEOZOIC SEDIMENTARY AND VOLCANIC DEPOSITS OF THE ESTÉREL (SOUTHERN FRANCE)

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SUMMARY

The recognition of both Thuringian macroscopic plant remains (*Ullmannia bronni*, *Ullmannia frumentaria*, *Quadrocladus orobiformis*, etc.) and miospores (*Lueckisporites virkkiae*, *Nuskoisporites dulhuntyi*, *Falcisporites zapfei*, *Klausipollenites schaubergeri*, etc.) in the Upper Palaeozoic deposits of the Estérel evidences the presence of Upper Permian sediments as well as an important centre of Late Permian volcanic activity in southern France.

INTRODUCTION

In order to cut down the possibility of interpreting palaeomagnetic data erroneously, accurate age determinations of the formations studied are required. With special regard to the programme of investigations on Permian palaeomagnetism carried out in Utrecht, the author has proposed a liaison between the disciplines of palaeomagnetism and palynology (VISSCHER, 1967).

The present paper deals with a palaeobotanical age determination of the Upper Palaeozoic red beds and volcanic deposits of the Estérel in southern France, which have been palaeomagnetically investigated by J. D. A. Zijderveld (thesis, in preparation). The few plant remains which have been found in the past and the general stratigraphic position (unconformably resting on Stephanian and older formations, unconformably covered by Triassic formations) were taken to indicate a Permian age for this formation (usually referred to the Autunian and/or "Saxonian").

The geological history of the Estérel is described by BORDET (1951, 1966); for a summary of the tectonical relations in southern France one is referred to AUBOUIN and MENNESSIER (1963).

The present study has been carried out at the Department of Palaeobotany

of the Botanical Museum and Herbarium, Utrecht, under the direction of Prof. Dr. F. P. Jonker.

SITES OF ORIGIN, AND COMPOSITION OF THE ASSEMBLAGES

The present material (macroscopic plant remains and miospores) originates from quarries near Agay and Le Muy (Département Var). Samples of grey pelites have also been collected from field outcrops in the vicinity of Agay; these beds, however, did not yield recognizable pollen.

Agay

As early as 1877, plant remains were reported from sediments intercalated in the volcanic series in the vicinity of Agay. "Schistes à *Walchia*" were described by POTIER (1877): dark shales containing numerous fragments of *Walchia* and remains of other plants determined by GRAND'EURY (1877) as *Cordaites*, *Callipteris sphenopteroides*, cf. *Hymenophyllites weissii*, and a wood fragment resembling *Arthropitys*. BORDET (1966) mentions the small quarry in the valley of the Agay River; he reports an abundance of foliage-shoots of *Walchia*.

The fossiliferous lacustrine beds of Agay, mainly consisting of alternating greyish flaggy arkoses and pelites, are intercalated between two volcanic flows (according to BORDET, 1951, 1966, between the "basalte de Gondin" (D_2) and the "dolérite d'Agay" (D_3) of his stratigraphic column); they may belong to Bordet's sedimentary formation *i*.

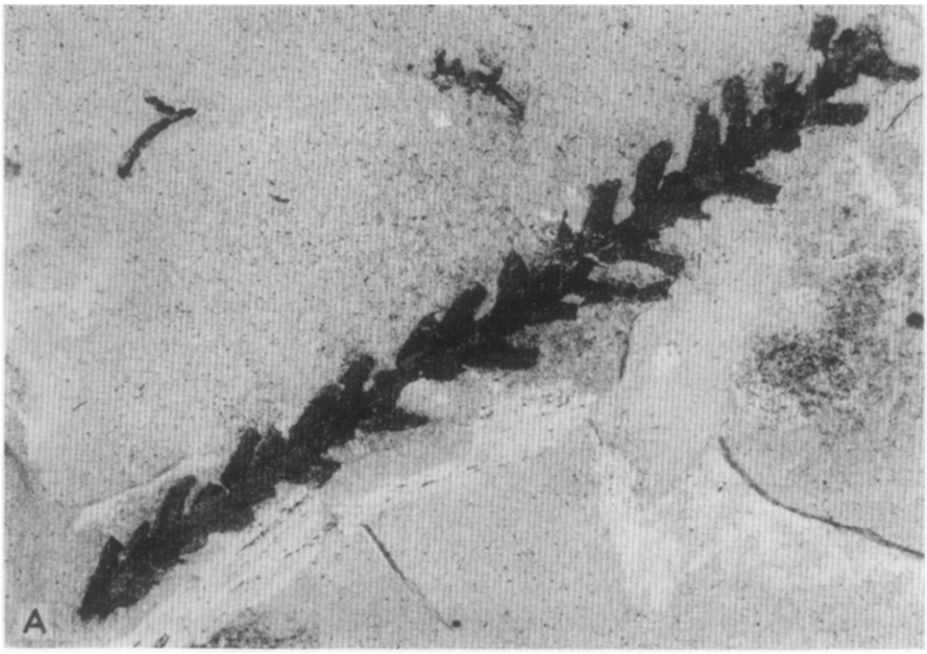
A determination of the numerous plant remains collected by J. D. A. Zijderveld and the author in the above-mentioned quarry (situated northwest of Agay along the road to Valescure) gives a completely new insight into the flora of Agay. The following assemblage has been recognized:

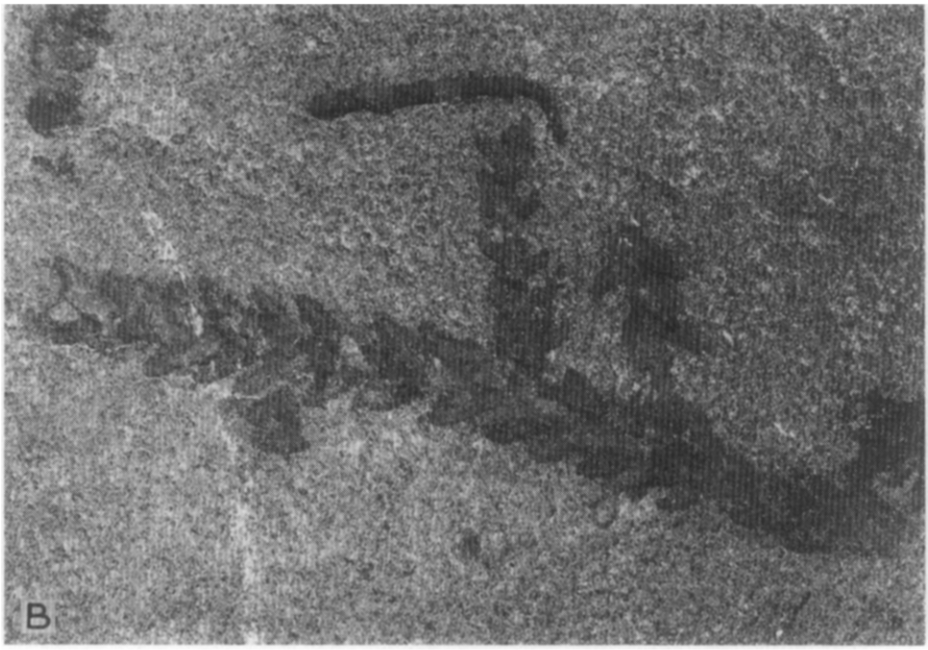
cf. *Sphenopteris kukukiana* GOTHAN et NAGALHARD (Plate II-C)
cf. *Pseudoctenis middridgensis* STONELEY (Plate II-A)
Ullmannia bronni GÖPPERT (Plate I-A,B)
Ullmannia frumentaria (SCHLOTHEIM) GÖPPERT
Quadrocladus orobiformis (SCHLOTHEIM) SCHWEITZER
cf. *Quadrocladus solmsi* (GOTHAN et NAGALHARD) SCHWEITZER (Plate II-B)
cf. *Culmitzchia florini* ULLRICH
(?) *Pseudovoltzia* sp.
cf. *Sphenobaiera* sp.

Furthermore at least two undescribed plant species are present.

Quantitatively, fragments of foliage of *Ullmannia bronni* are extremely abundant. *Ullmannia frumentaria* is uncommon; besides rare foliage-shoots some male cones and cone scales might be assignable to this species. All other species

PLATE I





A, B. *Ullmannia bronni* GÖPPERT; ×2.

are rare, especially the non-coniferous species. Of cf. *Sphenopteris kukukiana*, for example, only one small fragment has been found.

Palynologically the plant-bearing beds of Agay yielded an abundance of saccate pollen grains, which unfortunately appeared to be very badly preserved. Only two species have been identified, viz. *Lueckisporites virkkiae* POTONIÉ et KLAUS, and *Nuskoisporites dulhuntyi* POTONIÉ et KLAUS.

Le Muy

In general the lithology of the fossiliferous facies of Le Muy consists of greenish pelites, more or less coarse greenish arkoses, and conglomerates; intercalations of dark grey micaceous pelites are relatively rare. According to BORDET (1951) these lacustrine sediments belong in all probability to his sedimentary formation *g*.

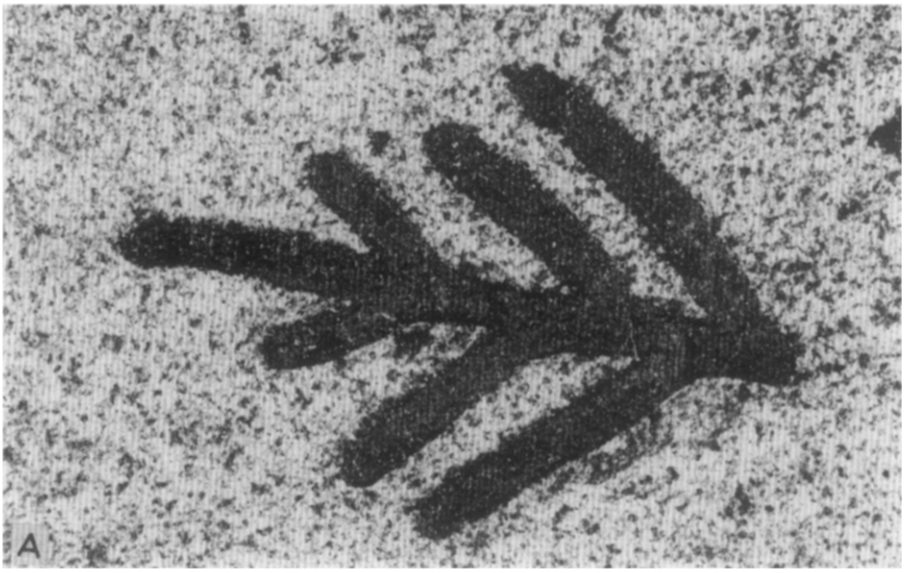
BORDET (1951, 1966) mentions the badly preserved plant remains from the quarry situated east of Le Muy along the N7 highway; the following species were recognized: *Calamites* sp. cf. *C. leioderma* GUTBIER, *Cordaites* sp., *Ullmannia* cf. *lycopodioides* GÖPPERT, *Annularia* sp., *Lepidostrobus* sp., *Cardiocarpus* cf. *orbicularis* ETTINGHAUSEN, and *Anthodiopsis* sp. Determinations of these species seem to be rather tentative and do not provide a definite age determination. Only *Ullmannia* cf. *lycopodioides* might indicate a Late Permian age.

The presence of very well-preserved fossil coniferous wood in a nearby locality is reported by BOUREAU (1949). Structurally this wood seems to be comparable with fossil wood from German Zechstein deposits (cf. SCHWEITZER, 1960); in both cases the arrangement of bordered pits shows modern (non-araucarian) affinities.

No new information on the megaflora of Le Muy can be given. A palynological investigation of the grey pelites found in the above-mentioned quarry, however, provided the following assemblage:

Nuskoisporites dulhuntyi POTONIÉ et KLAUS (Plate III-B)
cf. *Endosporites hexareticulatus* KLAUS
cf. *Perisaccus granulatus* KLAUS (Plate III-A)
Jugasporites delasaucei (POTONIÉ et KLAUS) LESCHIK (Plate IV-G)
Vitreisporites sp. (Plate IV-F)
Limitisporites (sensu KLAUS, 1963) n. sp. (Plate III-F)
Labiisporites granulatus LESCHIK (Plate III-C)
Gigantosporites hallstattensis KLAUS (Plate III-G)
Gardenasporites oberrauchi KLAUS
Lueckisporites virkkiae POTONIÉ et KLAUS (Plate IV-H,J)
Taeniaesporites sp.
Strotersporites richteri (KLAUS) WILSON, ex KLAUS, 1963 (Plate IV-A)
Strotersporites jansonii KLAUS

PLATE II



A. cf. *Pseudoctenis middridgensis* STONELEY; ×4.5.
B. cf. *Quadrocladus solmsi* (GOTHAN et NAGALHARD) SCHWEITZER; ×8.
C. cf. *Sphenopteris kukukiana* GOTHAN et NAGALHARD; ×8.

Striatites sp.
Paravesicaspora splendens (LESCHIK) KLAUS (Plate IV-C)
Falcisporites zapfei (POTONIÉ et KLAUS) LESCHIK (Plate IV-D)
Klausipollenites schaubergeri (POTONIÉ et KLAUS) JANSONIUS (Plate IV-E)
cf. *Protopodocarpus alatus* (LUBER), as figured by SAMOILOVICH, 1953, plate VII-3c (Plate IV-B)
Platysaccus papilionis POTONIÉ et KLAUS
Vittatina costabilis WILSON (Plate III-D)
Vittatina ovalis KLAUS (Plate III-E)
Vittatina sp.

In order to avoid detailed taxonomic comments this enumeration is mainly based on the taxonomic concepts of KLAUS (1963). A few of Klaus' species, however, are lumped together; the most important example is *Lueckisporites microgranulatus* KLAUS, which is considered to be a synonym of *Lueckisporites virkkiae*.

The saccate pollen is often badly preserved and consequently a quantitative analysis of the present assemblage remains rather subjective. The main trend is a dominance of *Lueckisporites virkkiae*. *Nuskoisporites dulhuntyi*, *Limitisporites* n. sp., and *Falcisporites zapfei* are common elements; all other species seem to occur in minor percentages. The scarceness of *Jugasporites delasaucei* is in accordance with the scarceness of *Ullmannia frumentaria* in the assemblage of Agay since *J. delasaucei* is proven to be the pollen of *U. frumentaria* (GREBE and SCHWEITZER, 1962).

Representatives of the Sporites are extremely rare.

AGE DETERMINATION

For the purpose of age determination the most significant features of the assemblages found are the following:

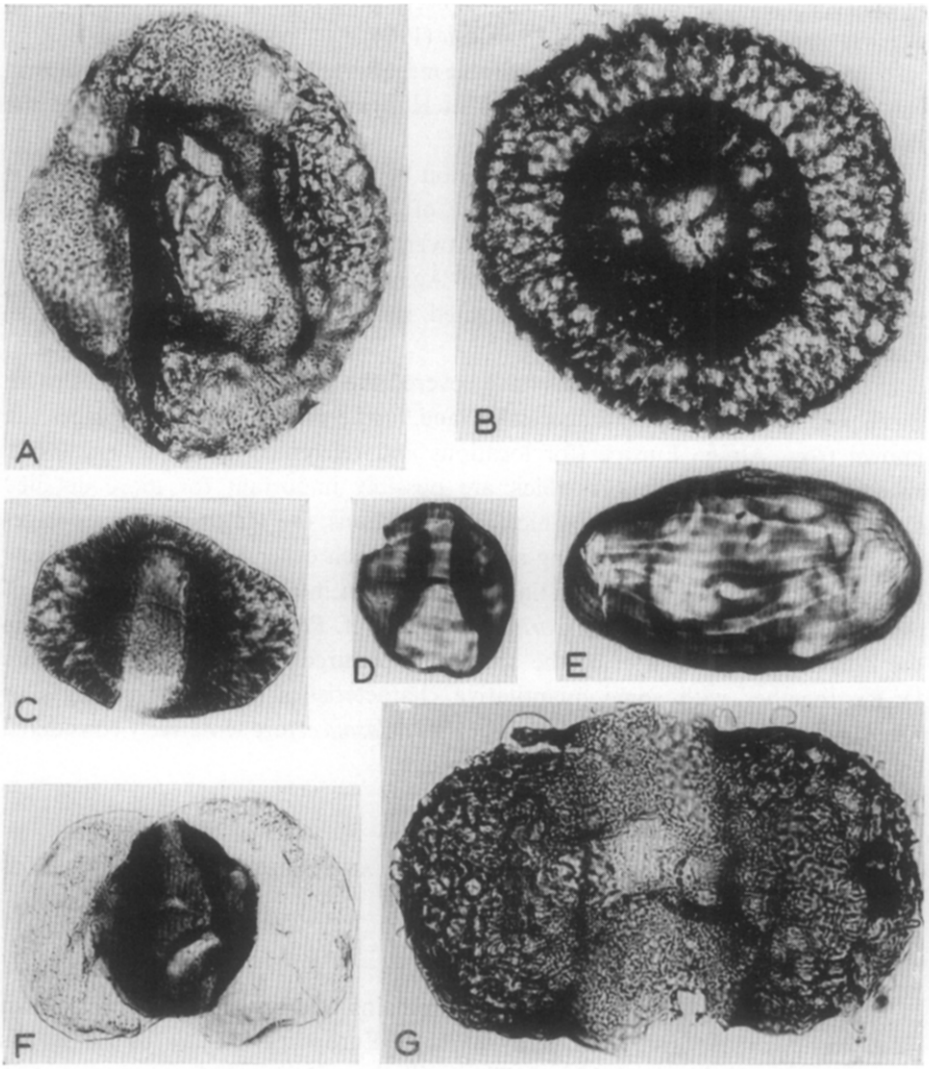
(*1*) The presence of macroscopic plant remains assignable to such taxa as *Quadrocladus* and *Ullmannia frumentaria*, in combination with a high percentage of foliage belonging to *Ullmannia bronni*.

(*2*) The presence of such miospore species as *Nuskoisporites dulhuntyi*, *Jugasporites delasaucei*, *Labiisporites granulatus*, *Klausipollenites schaubergeri*, *Strotersporites richteri*, *Paravesicaspora splendens*, and *Falcisporites zapfei*, in combination with high percentages of *Lueckisporites virkkiae*.

These features conform in general with those reported from Thuringian (Late Permian) assemblages encountered in the deposits of the Zechstein Basin and their Alpine equivalents.

Thuringian megafloras from the Zechstein deposits have been intensively studied since the second part of the nineteenth century (among others by H. B.

PLATE III



A. cf. *Perisaccus granulatus* KLAUS; ×540.
B. *Nuskoisporites dulhuntyi* POTONIÉ et KLAUS; ×340.
C. *Labiisporites granulatus* LESCHIK; ×540.
D. *Vittatina costabilis* WILSON; ×540.
E. *Vittatina ovalis* KLAUS; ×540.
F. *Limitisporites* n.sp.; ×340.
G. *Gigantosporites hallstattensis* KLAUS; ×540.

Geinitz, W. Gothan, K. Nagalhard, H. Solms-Laubach, and WEIGELT, 1928); more recent studies and reviews have been published by STONELEY (1958), SCHWEITZER (1960, 1968), and ULLRICH (1964).

Also from Alpine Europe comparable megafloras have long since been known, viz. those from the Mecsec mountains in Hungary (HEER, 1876) and from the southern Alps (e.g., GÜMBEL, 1879).

Quantitative data on the composition of these Thuringian assemblages is scarce. In the German Zechstein foliage of *Ullmannia* (*U. frumentaria* and/or *U. bronni*) seems to be dominant (cf. SCHWEITZER, 1960, 1968).

With regard to the assemblage of Agay, the only important Thuringian species which has not been demonstrated is *Pseudovoltzia liebeana* (GEINITZ) FLORIN.

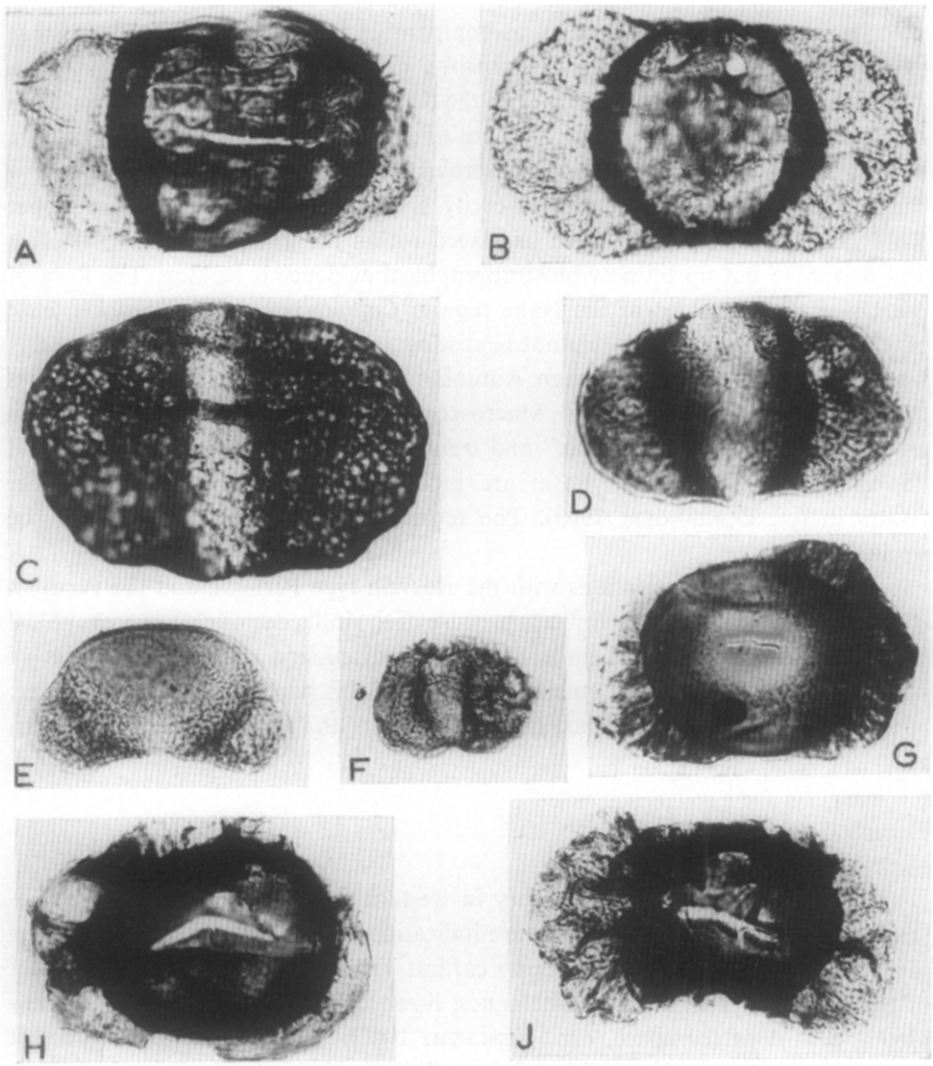
Palynological investigations have covered the greatest part of the Zechstein Basin and its stratigraphical succession and furthermore many assemblages are known from Alpine Europe (for locations and references see VISSCHER, 1967). In spite of some differences which are possibly important for more detailed stratigraphical and phytogeographical considerations, the Thuringian assemblages are characterized by their striking similarity to each other. At least qualitatively the assemblage of Le Muy is distinctly Thuringian in aspect. The occurrence of the large saccate species *Limitisporites* n. sp. and cf. *Protopodocarpus alatus* (note the different magnification of the specimens pictured in Plate III-F and Plate IV-B), together with some quantitative characteristics (minor percentages of *Klausipollenites schaubergeri* and *Jugasporites delasaucei*) are tentatively considered to be indicative for an Early Thuringian age.

COMPARATIVE NOTES ON AUTUNIAN, "SAXONIAN", AND EARLY TRIASSIC ASSEMBLAGES

Autunian

Assemblages of macroscopic plant remains and/or miospores are known from Autunian deposits from many parts of Europe. These are by no means related to Thuringian assemblages. They still show Palaeophytic characters and are highly comparable to Late Carboniferous assemblages (cf. DOUBINGER, 1956, 1962). The Autunian of the Lodève Basin (southeastern margin of the Central Massif in France), for example, is palynologically characterized by the predominance of Monoletes (*Laevigatosporites*, *Punctatosporites*, *Verrucososporites*, *Speciososporites*, etc.), Triletes (*Calamospora*, *Leiotriletes*, *Cyclogranisporites*, *Microreticulatisporites*, etc.), and/or Monosaccites (*Florinites*, *Wilsonites*, etc.) (cf. DOUBINGER, 1963). Rare specimens of *Nuskoisporites*, *Platysaccus*, and cf. *Lueckisporites* are also reported; it is, however, rather doubtful whether these forms are fully comparable with Late Permian species.

PLATE IV



A. *Strotersporites richteri* (KLAUS) WILSON, ex KLAUS; ×540.
B. cf. *Protopodocarpus alatus* (LUBER), ex SAMOILOVICH; ×340.
C. *Paravesicaspora splendens* (LESCHIK) KLAUS; ×540.
D. *Falcisporites zapfei* (POTONIÉ et KLAUS) LESCHIK; ×540.
E. *Klausipollenites schaubergeri* (POTONIÉ et KLAUS) JANSONIUS; ×540.
F. *Vitreisporites* sp.; ×540.
G. *Jugasporites delasaucei* (POTONIÉ et KLAUS) LESCHIK; ×540.
H, J. *Lueckisporites virkkiae* POTONIÉ et KLAUS; ×540.

"*Saxonian*"

If we consider the Autunian as comparable to the Russian Asselian Stage (following Soviet authors, e.g., NAOUMOVA and RAUSER-CHERNOUSOVA, 1964), and if we correlate the Thuringian with the Kazanian–Tatarian Stages (correlation based on faunal similarities), the presence of analogues of the Russian Sakmarian, Artinskian, and Kungurian remains unproved in western Europe and in southern Europe west of the line Carnian Alps–Sicily. Eventually part of the German Upper Rotliegendes ("Saxonian") might be placed within the interval between Asselian and Kazanian but up till now biostratigraphical evidence is lacking. The flora of the Upper Rotliegendes of the Nahe region (*Callipteris conferta*, *Walchia*, etc.; cf. GEIB, 1950), for example, cannot be distinguished from Autunian floras and is by no means transitional between Autunian and Thuringian. The same applies to the "Saxonian" of France. Macroscopic plant remains and spore-pollen assemblages from the "Saxonian" and transitional layers between Autunian and "Saxonian" of the Lodève Basin are indistinguishable from those from the Autunian (cf. DOUBINGER, 1963). The term "Saxonian" should, therefore, be avoided.

Palynological correlations with the Russian type Permian and the Permian of western Europe are rather difficult because of the influence of phytogeographical boundaries during Permian times. A detailed discussion of the possibilities of palynological correlations is outside the scope of this paper. There are, however, at the moment no reasons for assigning the flora of the Estérel to a pre-Kazanian age.

Triassic

The Permian–Triassic boundary in western Europe has not yet been biostratigraphically determined. There are indications that at least part of the Thuringian flora continued to exist during earliest Triassic times. The Upper Bunter of the Germanic Basin and its analogues, however, are characterized by a completely new flora (compare, e.g., VISSCHER, 1967). With regard to the present material it can be said that neither definite Triassic elements nor Triassic compositional characters have been demonstrated.

CONCLUSIONS

With regard to palaeogeographic relations in southern Europe, two conclusions can be drawn from the present investigation:

(*1*) *In the Estérel continental Thuringian sedimentation took place on a pre-Permian basement.*

The extension of this Thuringian realm in southern France remains uncertain. The "Néopermien" of French authors, which is distinguished in the Western Alps (Briançonnais zone, Belledonne massif, Argentéra–Mercantour massif, Dôme de Barrot) is sometimes lithostratigraphically correlated with the Permian of the Estérel, especially because of the locally important traces of volcanic activity; moreover the "Néopermien" rests unconformably on older formations. We ought to reckon with the possibility of a Thuringian (not "Saxonian") age. Biostratigraphical data from these areas, however, is still extremely meagre. It is mainly restricted to records of plant remains from the "Grès d'Allevard" of the Belledonne massif. This flora (*Calamites cisti*, *Cordaites*, and *Pseudovoltzia*) indicates, according to HADOUR and SARROT-REYNAULD (1964), a "Saxonian" age. *Pseudovoltzia*, however, might eventually evidence a Thuringian age.

(*2*) *In Thuringian times the Estérel formed an important centre of volcanic activity.*

Permian volcanism in western Europe is by no means contemporaneous and by no means restricted to Early Permian times. Late Permian volcanism may have had a wide extension especially in regions affected by the Alpine orogeny. Contrary to the palaeobotanically determined Early Permian volcanism of the Oslo and Nahe regions, so far four regions with intercalated volcanic deposits in palynologically determined Upper Permian sediments can be distinguished in western Europe:

(*a*) *western Czechoslowakia:* Upper Permian volcanic deposits of the Choč nappe (compare, e.g., ANDRUSOV, 1964) in the Little Karpathians (dated by ČORNÁ and ILAVSKÁ, 1962);

(*b*) *northern Austria:* a basaltic effusion with accompanying tuffites, contemporaneous with evaporite deposition, is known from the Alpine salt deposits of Hallstatt (cf. ZIRKL, 1949), which have been intensively investigated palynologically by W. Klaus (compare, e.g., KLAUS, 1963, 1965);

(*c*) *northern Italy:* Thuringian (not "Saxonian") volcanic deposits of the Vincentinian Alps (palynological data after J. Jansonius, in: DE BOER, 1963);

(*d*) *southern France:* Upper Permian volcanic deposits of the Estérel.

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REFERENCES

ANDRUSOV, D., 1964. *Geologie der tschechoslowakischen Karpaten*, 1. Akademie Verlag, Berlin, 263 pp.

AUBOUIN, J. et MENNESSIER, G., 1963. Essai sur la structure de la Provence. Dans: M. DURAND DELGA (Rédacteur), *Livre à la Mémoire du Professeur Paul Fallot*, 2. Soc. Géol. France, Paris, pp. 45–98.

BORDET, P., 1951. Étude géologique et pétrographique de l'Estérel. *Mém. Carte Géol. France*, 1951: 207 pp.

BORDET, P., 1966. *L'Estérel et le Massif de Tanneron. Histoire Géologique–Itinéraires Géologiques.* Hermann, Paris, 114 pp.

BOUREAU, E., 1949. Sur l'évolution de la ponctuation araucarienne dans les bois vivants et fossiles. *Bull. Soc. Botan. France*, 96: 94–97.

ČORNÁ, O. a ILAVSKÁ, Ž., 1962. Nález permských spóromorf v Malých Karpatoch. *Geol. Sb. (Bratislava)*, 13(2): 187–195.

DE BOER, J., 1963. The geology of the Vincentinian Alps (NE Italy). *Geol. Ultraiectina*, 11: 178 pp.

DOUBINGER, J., 1956. Contribution à l'étude des flores autuno-stéphaniennes. *Mém. Soc. Géol. France, Nouvelle Sér.*, 35(75): 180 pp.

DOUBINGER, J., 1962. Caractères palynologiques du Stéphanien et de l'Autunien. *Compt. Rend.*, 255: 2158–2160.

DOUBINGER, J., 1963. Notes palynologiques sur le Permien de Lodève (Hérault). *Compt. Rend. Soc. Géol. France*, 1963: 201–203.

GEIB, K. W., 1950. Über eine Pflanzenreste-führende Schichtfolge in den Waderner Schichten des Oberrotliegenden bei Sobernheim im Nahebergland. *Notizbl. Hess. Landesamtes Bodenforsch., Wiesbaden*, 6(1): 193–200.

GRAND'EURY, M., 1877. Sur des empreintes végétales trouvées dans l'Estérel (lettre à M. Potier). *Bull. Soc. Géol. France, 3e Sér.*, 5: 758–759.

GREBE, H. und SCHWEITZER, H. J., 1962. Die Sporae dispersae des niederrheinischen Zechsteins. *Fortschr. Geol. Rheinland Westfalen*, 12: 201–224.

GÜMBEL, C. W., 1879. Geognostische Mittheilungen aus den Alpen, 5. Die Pflanzenreste-führenden Sandsteinschichte von Recoaro. *Sitz. Ber. Königl. Bayer. Akad. Wiss. München, Math. Physik. Cl.*, 9: 33–85.

HADOUR, J. et SARROT-REYNAULD, J., 1964. Le Carbonifère des zones externes des Alpes françaises. *Congr. Avan. Études Stratigraph. Géol. Carbonifère, Compt. Rend., 5, Paris, 1963*, 1: 119–173.

HEER, O., 1876. Über permische Pflanzen von Fünfkirchen in Ungarn. *Mitt. Jahrb. Ungar. Geol. Reichsanstalt*, 5: 18 pp.

KLAUS, W., 1963. Sporen aus dem südalpinen Perm. *Jahrb. Geol. Bundesanstalt (Austria)*, 106: 229–363.

KLAUS, W., 1965. Zur Einstufung alpiner Salztone mittels Sporen. *Verhandl. Geol. Bundesanstalt (Austria), Sonderh.*, G: 288–292; *Z. Deut. Geol. Ges.*, 116(2): 544–548.

NAOUMOVA, S. et RAUSER-CHERNOUSOVA, D., 1964. Sur la position stratigraphique de l'Autunien et de ses analogues. *Congr. Avan. Études Stratigraph. Géol. Carbonifère, Compt. Rend., 5, Paris, 1963*, 3: 1215–1228.

POTIER, M., 1877. Compte rendu de la course de Saint-Raphaël et d'Agay. *Bull. Soc. Géol. France, 3e Sér.*, 5: 754–758.

SAMOILOVICH, S. R., 1953. Pollen and spores from the Permian deposits of the Cherdyn' and Aktyubinsk areas, Cis-Urals. *Tr. Vses. Nauchn. Issled. Geologorazved. Inst., Novaya Ser.*, 75: 5–91 (in Russian, English translation in: *Oklahoma Geol. Surv., Circ.*, 1961, 56: 103 pp.)

SCHWEITZER, H. J., 1960. Die Makroflora des niederrheinischen Zechsteins. *Fortschr. Geol. Rheinland Westfalen*, 6: 331–376.

SCHWEITZER, H. J., 1968. Die Flora des oberen Perm in Mitteleuropa. *Naturwiss. Rundschau*, 21 (3): 93–102.

STONELEY, H. M. M., 1958. The Upper Permian flora of England. *Bull. Brit. Museum, Geol.*, 3(9): 293–337.

ULLRICH, H., 1964. Zur Stratigraphie und Paläontologie der marin beeinflussten Randfazies des Zechsteinbeckens in Ostthüringen und Sachsen. *Freiberger Forschungsh., C.*, 169: 163 pp.

VISSCHER, H., 1967. Permian and Triassic palynology and the concept of "Tethys twist". *Palaeogeography, Palaeoclimatol., Palaeoecol.*, 3(1): 151–166.

WEIGELT, J., 1928. Die Pflanzenreste des mitteldeutschen Kupferschiefers und ihre Einschaltung ins Sediment. *Fortschr. Geol. Palaeontol.*, 6(19): 395–592.

ZIRKL, E. J., 1949. Die Melaphyreruption im Hallstätter Salzberg. *Berg- Hüttenmänn. Monatsh. Montan. Hochschule Leoben*, 94(3): 1–4.