PERMIAN AND TRIASSIC PALYNOLOGY AND THE CONCEPT OF "TETHYS TWIST"[1]

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SUMMARY

Both paleomagnetism and palynology may furnish useful diagnostic facts for recognizing long-distance movements of the earth's crust. With respect to the relative positions of North America and Eurasia, paleomagnetic and palynological data contribute evidence in support of the theory of continental drift. However, the conclusions based on paleomagnetic measurements sometimes disagree with palynological observations. Paleomagnetic data obtained in northeastern Italy, southern France and northern Spain differ considerably from those from Mesc-Europe. In recent geotectonical considerations this has been attributed to the so-called Tethys twist having effected a post-Carboniferous westward displacement of the structural units of Italy, southern France and Spain.

Palynology, however, reveals a highly uniform geological history of both Meso-Europe and a part of Alpine Europe during Permian and Triassic times. Biostratigraphical correlations between the two realms are possible by studying the palynological assemblages obtained from Permian and Triassic evaporites or associated sediments. Contemporaneous, short periods of evaporite deposition in both Meso-Europe and the Mediterranean region are suggested by the striking uniformities in Lower Mesophytic vegetations as reflected by sporae dispersae. There is every indication that there was a comparable evolution in the physiographical and climatological conditions which opposes the hypothesis of a mobile Tethys belt during Permian and Triassic times.

INTRODUCTION

Under the supervision of Prof. Dr. J. Veldkamp, Prof. Dr. M. G. Rutten, and Prof. Dr. R. W. van Bemmelen, students of the Geological Institute of the

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State University in Utrecht are carrying out investigations on Permian paleomagnetism in Europe. From their studies it is apparent that the direction of the Permian magnetic pole in regions subjected to the Alpine orogenic movements differs considerably from that of the relatively undisturbed regions of Europe. This fact has led to the revolutionary geotectonic concept of the so-called Tethys twist.

Having studied both tectonics and palynology, the present author has confidence in the possibility of a palynological approach to many geotectonic hypotheses, especially with regard to their paleogeographical aspects. In this paper, the author wants to discuss some preliminary results of a palynological approach to the problem of the Tethys twist. Palynological investigations were carried out at the Division of Paleobotany of the Botanical Museum and Herbarium in Utrecht, under the direction of Prof. Dr. F. P. Jonker.

PALEOMAGNETISM AND PALEOGEOGRAPHY

Measurements on orientated rock samples—both igneous and sedimentary—demonstrate the inclination and declination of remanent magnetism, formed at the time of formation of the rocks. Consequently information can be obtained about the position of the samples with respect to the then existing magnetic pole. A compilation of paleomagnetic data from all over the world has led to the following statements (VAN HILTEN, 1962):

(*1*) During geological time, the virtual pole positions for each continent seem to move along a rather well defined "polar-wandering path".

(*2*) These polar-wandering paths appear to meet at the present-day position of the earth's axis of rotation.

Since the polar-wandering paths for different continents frequently do not coincide, paleomagnetism contributes in a large measure to the old idea of continental drift as having effected the positions of the present continents; especially the position of North America relative to Europe. This is very well-illustrated in a comparison of the paleomagnetic maps as figured by VAN HILTEN (1962, 1964). These show the patterns of paleoisoclines—the course of which has also the significance of paleolatitudes—in different geological periods.

However, paleomagnetism not only confirms continental drift, is has also led to even more revolutionary geotectonical and paleogeographical assumptions such as the Tethys twist, the main subject of the present discussion.

The Tethys twist

Paleoinclinations and paleodeclinations derived from Alpine Europe show striking divergences, which do not support the "orthodox" paleogeographical reconstructions with respect to Europe. After paleomagnetical investigations were carried out in areas tectonically disturbed by the Alpine orogeny, very aberrant data became available, such as those published by DIETZEL (1960), VAN HILTEN (1960), DE BOER (1963), and GUICHERIT (1964) for the Italian Alps; by VAN DER LINGEN (1960) and SCHWARZ (1962) for the central Spanish Pyrenees; and by J.D.A. Zijderveld (thesis, in preparation) for the Estérel in southern France. A survey of the paleomagnetic data obtained in Alpine Europe is given by DE BOER (1965).

The paleoinclinations of Permian samples from the Vincentinian Alps, for

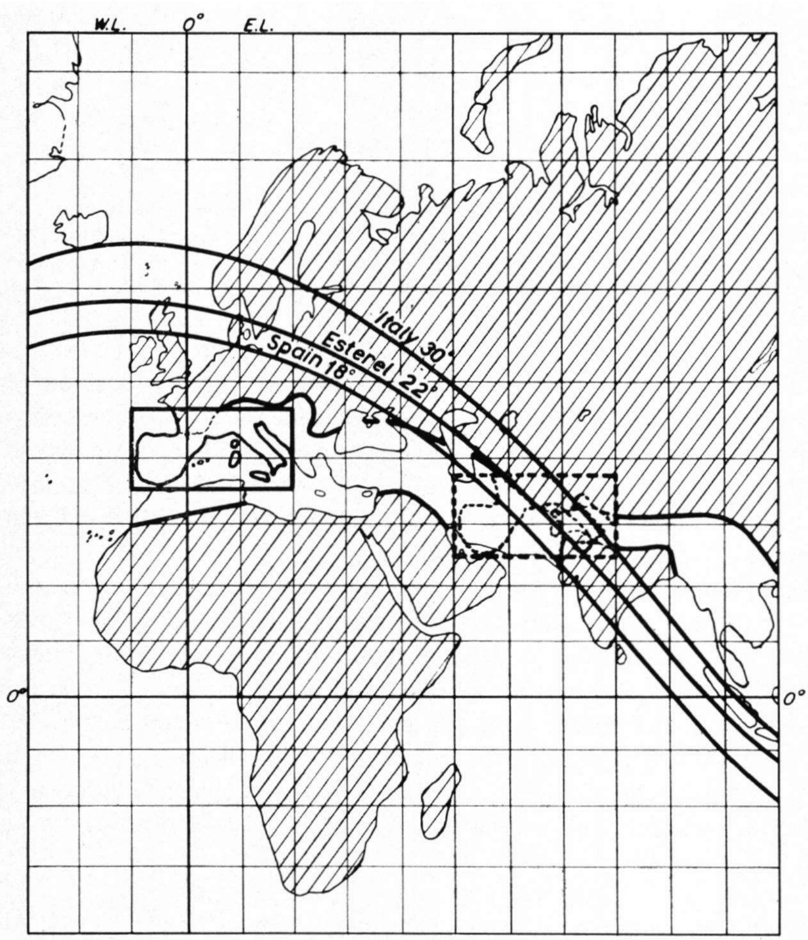


Fig.1. Reconstruction of the Permian position of Spain (Pyrenees), southern France (Estérel) and Italy (Vincentinian Alps) according to paleomagnetic data. Permian inclinations in these areas diverge from those expected in southern Europe; the corresponding isoclines cross Europe far north of the limit of Alpine Europe. As a position in the stable block of Eurasia has to be excluded, the nearest position possible is formed by the intersection of the isoclines concerned, with the Tethys belt. (After VAN BEMMELEN, 1964a.)

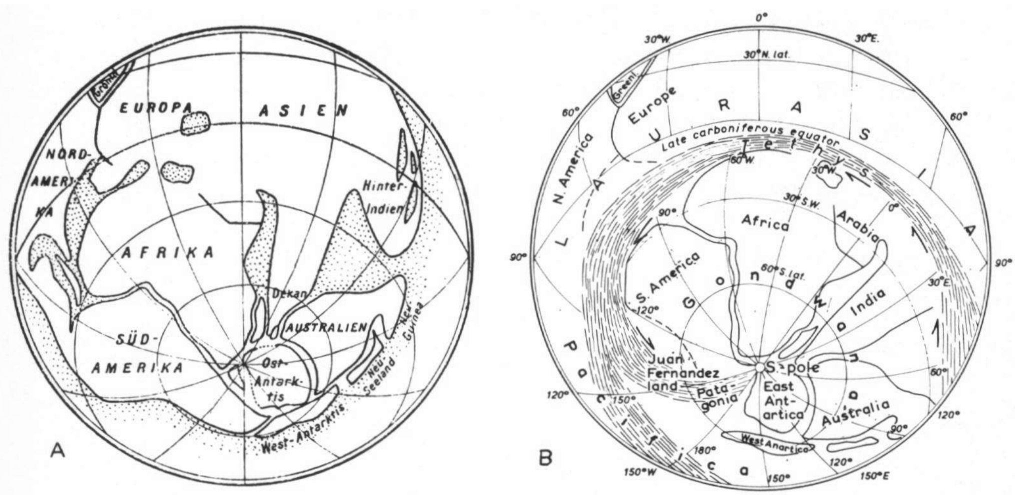


Fig.2. A. Reassembly of continents in Late Carboniferous times according to A. Wegener. B. The Tethys twist being applied to Wegener's reassembly. In this scheme the westward drift of the Vincentinian Alps—forming a part of Africa from Permian to Eocene times— is due to an anti-clockwise rotation of Africa at about 50° around the Late Paleozoic south pole. (After VAN BEMMELEN, 1966, fig.2.)

example, differed considerably from those expected. A probable position of northeastern Italy on the intersection of the −30° isocline and the Tethys zone was proposed by DE BOER (1963). As this point is the present position of the western Himalayas, a post-Carboniferous westward drift of about 5,000 km relative to the stable block of Meso-Europe has to be assumed (Fig.1). The data from Spain and France are in accordance with this assumption.

The translations of structural units are regarded as representing dextral transcurrent movements, which are integral in geotectonical considerations based on paleomagnetic evidence (e.g., VAN BEMMELEN, 1964a, b, 1965, 1966; VAN HILTEN, 1964; DE BOER, 1965). The existence of transcurrent movements in the Tethys zone is attributed to the westward movement of the Gondwana shields relative to Laurasia, forming a zone of torsion. This was called the Tethys twist by VAN HILTEN (1964). Fig.2 shows the Tethys twist as applied to Wegener's paleogeographic reassembly of continents, according to VAN BEMMELEN (1966).

LONG-DISTANCE CORRELATION BY MEANS OF PALYNOLOGY

Unlike many individual paleobotanical taxa, paleovegetations are limited both in time and space. This also applies to the palynological reflections of ancient phytogeographical units. The increasing number of investigations on spore-pollen assemblages provides us with a new resource for paleogeographical studies.

This is largely the result of the possibilities of long-distance correlation of stratigraphic successions.

With respect to the relative positions of North America and Eurasia, palynology, like paleomagnetism, supports the idea of continental drift, since many European assemblages of various ages are strikingly similar to the contemporaneous North American microfloras. The existence of any important barrier between the two continents seems very unlikely during the Upper Paleophytic and Mesophytic. Very convincing trans-Atlantic correlations have been made, e.g., by SULLIVAN (1965), who showed the presence of three different floral belts parallel to the Carboniferous paleoisoclines as figured by VAN HILTEN (1962); and by STOVER (1964), who found a striking similarity in the Lower Cretaceous microfloras from the eastern U.S.A. and Great Britain, in spite of their wide geographical separation.

As far as the problem of the post-Carboniferous Tethys twist is concerned, it is necessary to discuss some aspects of Permian and Triassic palynology in Europe. Correlations between Meso-Europe and Alpine Europe are facilitated by the common abundance of sporae dispersae in the various Upper Permian and Triassic evaporites or associated detritic sediments.

Permian

The Permian in "stable" Europe (Russia excluded) is usually subdivided into the Rotliegendes (Lower Permian) and Zechstein (Upper Permian). The Rotliegendes consists mainly of detritic sediments with, locally, a continuation of the Upper Carboniferous coal deposits. Unlike the Zechstein, the Lower Rotliegendes (Autunian) belongs paleobotanically to the Paleophytic. The chronostratigraphical position of the Upper Rotliegendes (Saxonian) remains uncertain.

The Zechstein (Thuringian) may represent—according to modern salt geology (compare, e.g., BORCHERT and MUIR, 1964)—a relatively short phase of dominantly chemically formed marine sedimentation during the uppermost Permian.

Both the continental Rotliegendes and the Zechstein evaporites have their equivalents in Alpine Europe. The evaporites appear to be particularly important; next to, for instance, the salt deposits in the Austrian Alps, borings in the Apennines and Dinarides have indicated the existence of very thick evaporite deposits in the subsoil of Italy and Yugoslavia (GORTANI, 1956; SIKOŠEK and MEDWENITSCH, 1965), probably representing the Upper Permian.

The abundance of sporae dispersae in evaporites or associated pelites, already discovered in 1913 by H. Lück, has appeared to be a useful tool in correlating Permian strata in Europe. Although Lower Permian evaporites, common in the U.S.S.R. and the U.S.A., probably exist in northern Germany, palynological data are lacking. The author, therefore, restricts himself to a discussion of palynological aspects of the European Upper Permian. So far as the coal-bearing Autunian is concerned, reference is made to the comparative studies by DOUBINGER (1962, 1965).

Upper Permian

The Zechstein Basin extends from Ireland to the Polish–Russian border (Fig.3). Deposition of the basal Zechstein conglomerate and the bituminous

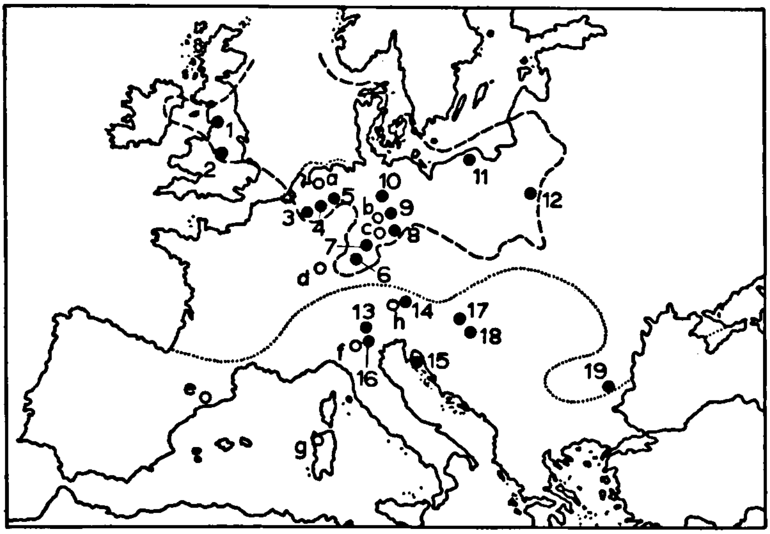


Fig.3. Locations of the Upper Permian and Lower and Middle Triassic palynological assemblages in Europe, referred to in the text.

Upper Permian (filled circles): (*1*) CLARKE (1956b); (*2*) CLARKE (1965b); (*3*) assemblage mentioned in the present paper; (*4*) GREBE (1957), GREBE and SCHWEITZER (1962); (*5*) KLAUS (1955); (*6*) SCHAARSCHMIDT (1963); (*7*) LESCHIK (1965b); (*8*) ULLRICH (1964); (*9*) LOFFLER and SCHULZE (1962); (*10*) KLAUS (1955); (*11*) KŁOSOWSKA and DOWGIAŁŁO (1964); (*12*) ORŁOWSKA-ZWOLIŃSKA (1962); (*13*) KLAUS (1963); (*14*) KLAUS (1953, 1963, 1965), POTONIÉ and KLAUS (1954), PLÖCHINGER et al. (1963); (*15*) SIKOŠEK and MEDWENITSCH (1965); (*16*) DE BOER (1963); (*17*) STUHL (1961); (*18*) DEÁK (1959); (*19*) SCHIRMER and KURZE (1960).

Lower and/or Middle Triassic (open circles): (*a*) FREUDENTHAL (1964), COMMISSARIS (1965), VISSCHER (1966); (*b*) MÄDLER (1964a); (*c*) KLAUS (1964), REINHARDT (1964a, b), REINHARDT and SCHMITZ (1965), SCHULZ (1964, 1965); (*d*) KLAUS (1964); (*e*) assemblage mentioned in the present paper; (*f*) KLAUS (1964); (*g*) assemblage mentioned in the present paper; (*h*) KLAUS (1964, 1965), SINGH (1965).

Recently detailed palynological charts from the German Upper Permian and Triassic have become available (SCHULZ, 1966). A new locality from which the characteristic European Upper Permian microflora has been studied—from core samples of the Zechstein border facies—occurs on the island of Rügen (west of locality *11*). An additional locality in Alpine Europe is found in the Upper Permian of the Little Carpathians (north of locality *17*) in Czechoslovakia (cf. PERŽEL, 1966).

- - - - - limit of Zechstein Basin; ... limit of Alpine Europe.

Kupferschiefer was followed by four evaporite cycles. Detailed palynological studies in the German Zechstein were started by KLAUS (1955), LESCHIK (1956b), and GREBE (1957); afterwards followed by GREBE and SCHWEITZER (1962), LOFFLER and SCHULZE (1962), SCHAARSCHMIDT (1963), and ULLRICH (1964). Investigations in Poland were carried out by ORŁOWSKA-ZWOLIŃSKA (1962) and by KŁOSOWSKA and DOWGIAŁŁO (1964). British palynological assemblages have been described recently by CLARKE (1965b).

The many assemblages known from these investigations—to which can be added the microflora obtained from the Dutch Zechstein—are characterized by their striking similarity to each other. As the investigations cover the greatest part of the Zechstein Basin (Fig.3) and its stratigraphical succession, these similarities suggest a highly uniform vegetation existing in this region during the uppermost Permian.

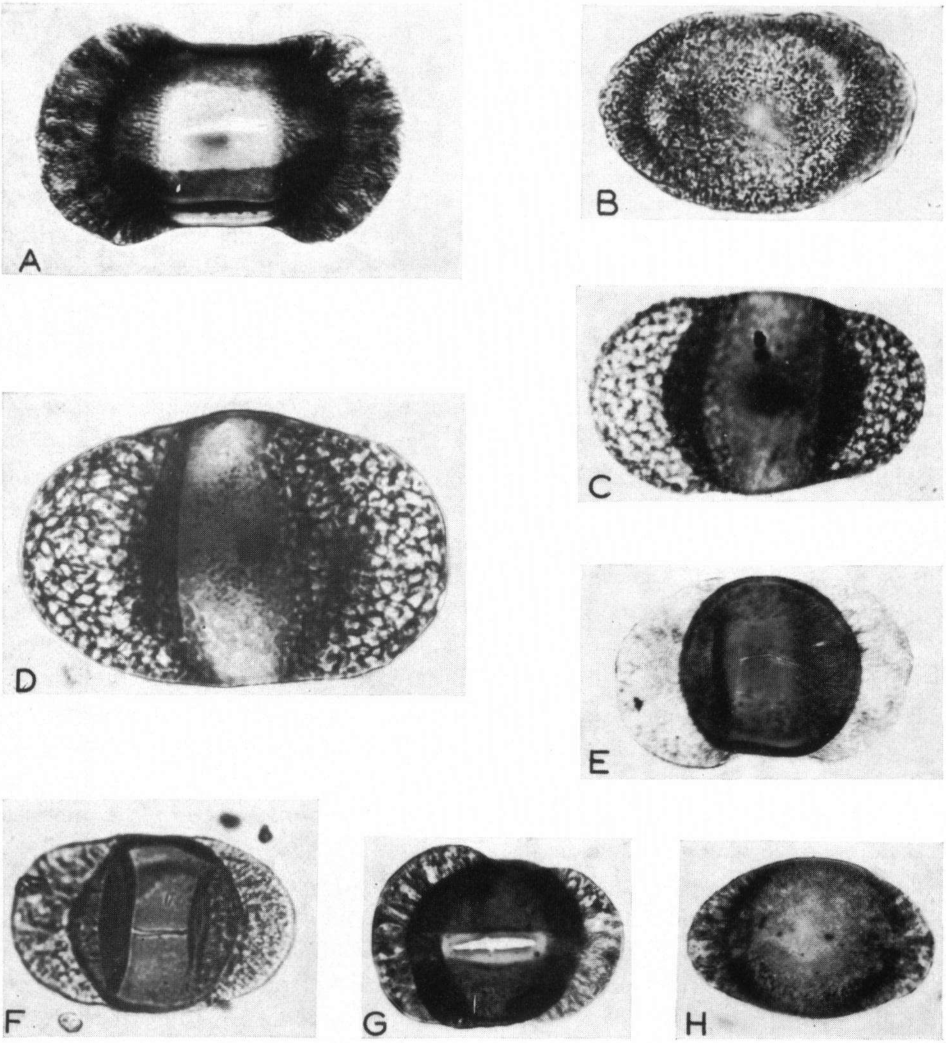
The Zechstein assemblages are characterized by the dominance of *Lueckisporites virkkiae* POTONIÉ et KLAUS, 1954, together with important percentages of *Klausipollenites schaubergeri* (POTONIÉ et KLAUS, 1954) JANSONIUS, 1962, and *Limitisporites rectus* LESCHIK, 1956b (synonym: *Jugasporites delasaucei* LESCHIK, 1956b). Additional elements, commonly present, are, e.g., *Labiisporites granulatus* LESCHIK, 1956b, *Falcisporites zapfei* (POTONIÉ et KLAUS, 1954) LESCHIK, 1956b, and *Nuskoisporites dulhuntyi* POTONIÉ et KLAUS, 1954.

Also the interesting—probably extra-Alpine—salt deposits of Provadia, Bulgaria, yielded an identical microflora (SCHIRMER and KURZE, 1960), showing a good example of long-distance correlation of evaporites. No comparable assemblages have been found in the available Russian palynological literature.

The microflora of the Austrian Alpine evaporites and associated shales have been studied intensively by Dr. W. Klaus, Vienna. Justified by the presence of comparable percentages of *Lueckisporites virkkiae*, *Klausipollenites schaubergeri*, *Limitisporites rectus*, *Labiisporites granulatus*, *Falcisporites zapfei*, *Nuskoisporites dulhuntyi*, and many other species of saccate pollen (KLAUS, 1953, 1963, 1965; POTONIÉ and KLAUS, 1954; PLÖCHINGER et al., 1963) the tectonically extremely complicated salt deposits in the northern Austrian Alps have appeared to represent the Alpine equivalent of the Zechstein sediments. In northern Italy, the microflora of the Grödner strata and the overlying *Bellerophon* strata—partly evaporitic—of the Dolomites (KLAUS, 1963), and the Vincentinian Alps (DE BOER, 1963) show the same composition. This also applies to assemblages from the Hungarian Mecsec Mountains and Balaton uplands (DEÁK, 1959; STUHL, 1962), and probably to the extensive evaporites in the subsoil of Yugoslavia (SIKOŠEK and MEDWENITSCH, 1965).

Plate I shows a selection of European Upper Permian miospores.

PLATE I



Some European Upper Permian miospores.
A. *Lueckisporites virkkiae*, Upper Permian, Austrian Alps; × 600.
B. *Klausipollenites schaubergeri*, Upper Permian, Austrian Alps; × 650.
C. *Falcisporites zapfei*, Zechstein, The Netherlands; × 600.
D. *Falcisporites zapfei*, Upper Permian, Austrian Alps; × 650.
E. *Limitisporites rectus*, Upper Permian, Italian Alps; × 600.
F. *Limitisporites rectus*, Zechstein, Germany; × 600.
G. *Lueckisporites virkkiae*, Zechstein, The Netherlands; × 600.
H. *Klausipollenites schaubergeri*, Zechstein, The Netherlands; × 600.

Triassic

Within the European Triassic, two strikingly different facies occur: (*1*) the Germanic—epicontinental—facies, and (*2*) the Alpine—geosynclinal—facies. Since the Germanic Triassic is mainly lithostratigraphically classified, correlations with the biostratigraphical subdivisions of the Alpine Triassic often remain inaccurate. The Germanic facies is not restricted to deposits outside the Alpine realm, as the geosynclinal facies is found in only part of the Alpine fold belt; in many parts the epicontinental facies predominates. Even in those areas in which an Alpine facies is exposed, sediments may often resemble the Germanic facies. What is particularly suggestive is the existence of more or less important evaporite stages, e.g., in the Austrian and Italian Alps, and in the Balkan mountains.

Again the evaporites are the main source of palynological information. Restricting this discussion to some results of Lower and Middle Triassic palynology, I refer to the following authors in regard to the Upper Triassic palynology in various parts of Europe: (*1*) British Keuper (CLARKE, 1965a); (*2*) German Keuper (MÄDLER, 1964a, b; REINHARDT, 1964a; SCHULZ, 1965); (*3*) Polish Keuper (PAUTSCH, 1958); (*4*) Swiss Keuper (LESCHIK, 1956a; BADOUX and WEIDMANN, 1964); (*5*) Austrian Upper Triassic (KLAUS, 1960; BHARADWAJ and SINGH, 1964); (*6*) Rumanian Upper Triassic (BEJU, 1965).

Lower Triassic

By far the greatest part of the Germanic Lower Triassic (Bunter, Buntsandstein) consists of red beds, palynologically sterile. No palynological data are known from the Lower Bunter. Middle Bunter pollen grains and spores are reported by SCHULZ (1964) and by REINHARDT and SCHMITZ (1965). However, as there is no unanimity about the criteria for the important boundary between the Middle and the Upper Bunter (TRUSHEIM, 1963; VISSCHER, 1966), we ought to reckon with the possibility of an Upper Bunter age.

On the other hand, many palynological data from the Röt Group of the Upper Bunter have been published recently (FREUDENTHAL, 1964; KLAUS, 1964; MÄDLER, 1964a; REINHARDT, 1964a, b; REINHARDT and SCHMITZ, 1965; SCHULZ, 1965; VISSCHER, 1966). Though some of the minor elements appear closely related to Upper Permian miospores (e.g., *Falcisporites snopkovae* VISSCHER, 1966) the microflora compared with that of the Zechstein has changed into an almost totally new composition, with a dominance of typically Triassic bisaccate pollen forms like *Triadispora* spec. div. KLAUS, 1964, *Voltziaceaesporites heteromorpha*, KLAUS, 1964, *Alisporites grauvogeli* KLAUS, 1964, and *Angustisulcites klausii* FREUDENTHAL, 1964. Quantitative information is still limited. Fig.4 shows the percentages of the species mentioned, as found in a sample from the Röt of Hengelo, The Netherlands (cf. VISSCHER, 1966, table 3b).

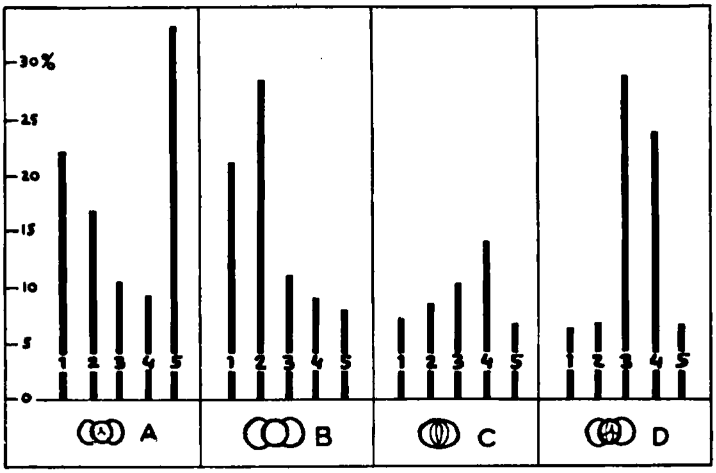


Fig.4. Comparative diagram showing quantitative distribution of (*A*) *Triadispora* spec. div., (*B*) *Voltziaceaesporites heteromorpha*, (*C*) *Alisporites grauvogeli*, and (*D*) *Angustisulcites klausii* in samples from the Lower and the Middle Triassic of The Netherlands, Spain and Sardinia. (*1*) Upper Bunter (Röt), Hengelo, The Netherlands; (*2*) Upper Bunter, Montroig, northeastern Spain; (*3*) Upper Bunter–Lower Muschelkalk transition, Hengelo, The Netherlands; (*4*) Lower Muschelkalk, La Nurra, Sardinia; (*5*) Middle Muschelkalk, Pradell, northeastern Spain.

Palynological data obtained from the Alpine Lower Triassic (Scythian or Werfenian) were published by KLAUS (1964, 1965) and by SINGH (1965). The latter author described a possibly Lower Scythian assemblage from the "Nördliche Einlagerung", a huge tectonically bounded pelitic intercalation in the salt deposits of Hallstatt, Austria. Its microflora still shows the dominance of Upper Permian elements like *Lueckisporites*, *Gigantosporites*, etc. A continuation of many Upper Permian elements during the Lower and Middle Scythian is supported by the interesting diagram composed by KLAUS (1965). This diagram also illustrates the palynological data obtained from Austrian Upper Scythian evaporites (Campiller strata); compare also KLAUS (1964). Again it is evident that the composition of the uppermost Lower Triassic assemblages is almost entirely new (with *Triadispora*, *Voltziaceaesporites*, *Alisporites* and *Illinites;* the latter genus being pro parte identical with *Angustisulcites*).

One of the most striking examples of a nearly complete Germanic Triassic in Alpine Europe occurs in the Catalánides, the coastal mountain chain in Catalonia, northeastern Spain. This Triassic has been described and classified by VIRGILI (1958). The Lower Triassic consists mainly of red beds, locally gypsiferous in the upper part, and paleobotanically characterized by the presence of *Voltzia heterophylla*. A preliminary palynological study of small greyish silty intercalations in the conglomeratic standstone in the vicinity of Montroig, province of Tarragona, yielded a determinable microflora. The average percentages of the four main components are very close to those of the Dutch Röt (Fig.4). Species like *Api-*

culatasporites plicatus VISSCHER, 1966, *Verrucosisporites jenensis* REINHARDT et SCHMITZ, in: REINHARDT, 1964b, *Kraeuselisporites hoofddijkensis* VISSCHER, 1966, *Augustisulcites gorpii* VISSCHER, 1966, *Taeniaepollenites jonkeri* VISSCHER, 1966, *Taeniaepollenites multiplex* VISSCHER, 1966, and *Tubantiapollenites balmei* (KLAUS, 1964) VISSCHER, 1966 make a resemblance even more striking.

Other Alpine areas in Europe in which the Lower Triassic evaporite stage may be present are, e.g., the external zones of the Alps, the Croatian Dinarides, and the Betic Cordillera. However, a preliminary investigation of samples from the—according to KOCKEL (1963)—Bunter evaporite deposits in the vicinity of Ardales, province of Málaga, in the western Betic Cordillera, revealed a probably Upper Triassic (Rhaetic) age.

Middle Triassic

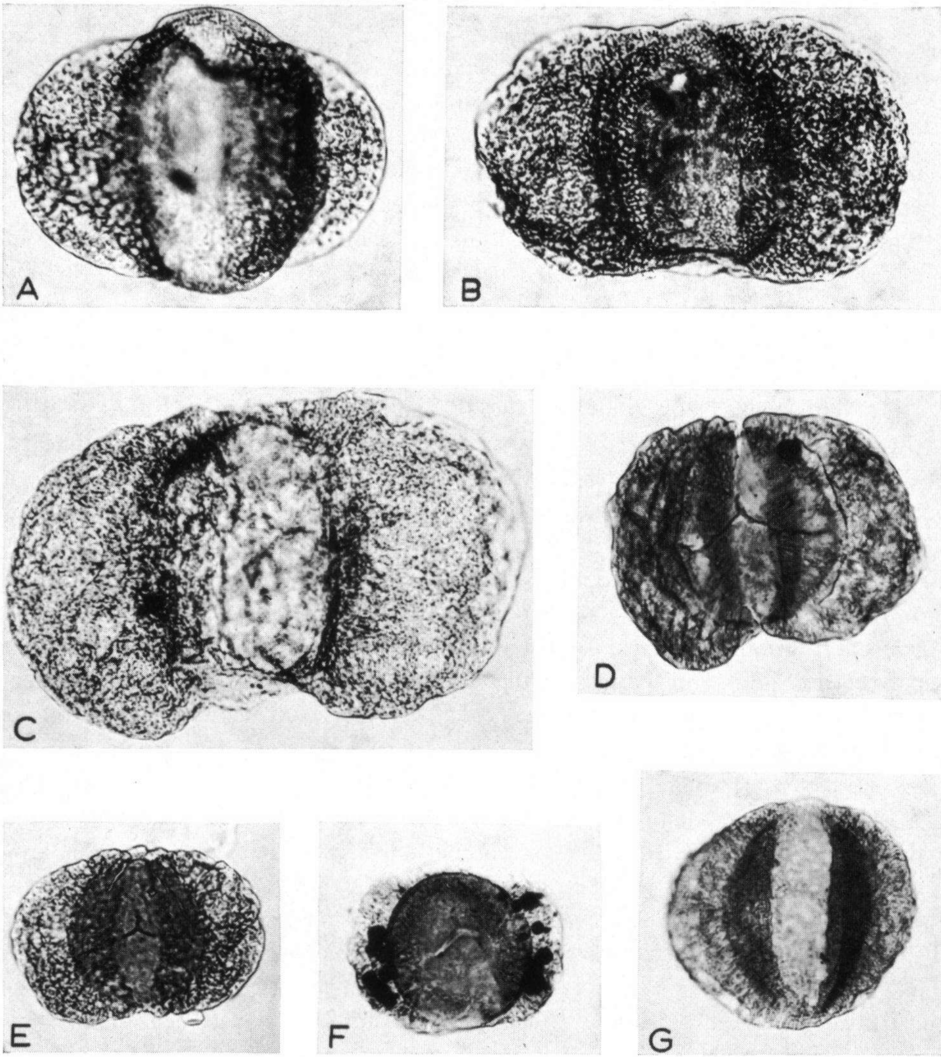
With the exception of the middle part, the Germanic Middle Triassic (Muschelkalk) is characterized by its mainly calcareous shallow-sea sediments. The transition Upper Bunter–Lower Muschelkalk in the subsoil of the eastern Netherlands yielded an already changed quantitative distribution of miospores (VISSCHER, 1966). The different character is especially due to the increased percentages of *Angustisulcites klausii* at the cost of *Voltziaceaesporites heteromorpha* and *Triadispora crassa* (Fig.4). A comparable composition can be found in the microflora obtained from the Lower Muschelkalk dolomitic limestone—possibly partly evaporitic—from a quarry in the vicinity of Winterswijk, province of Gelderland, investigated by COMMISSARIS (1965). A rather badly conserved microflora from the German Lower Muschelkalk has been reported by MÄDLER (1964a).

From the Alpine equivalent, the Lower Anisian, no data are available. A study of the Catalonian succession proved the Lower Muschelkalk to be palynologically sterile. However, the comparable succession of northwesterd Sardinia (La Nurra area, studied stratigraphically by OOSTERBAAN, 1936) yielded percentages of *Triadispora* spec. div., *Voltziaceaesporites heteromorpha, Alisporites grauvogeli,* and *Angustisulcites klausii,* comparable with those in the Dutch assemblages (Fig.4).

The Germanic Middle Muschelkalk evaporites have been studied by KLAUS (1964), but no quantitative data have been published. *Triadispora epigona* and *T. plicata* seem to be the most dominant species in the Middle Muschelkalk of Kockendorf, Germany, and Sarralbe, France. Also *Voltziaceaesporites heteromorpha,* showing a decreasing trend during the Muschelkalk, and *Illinites melanocorpus* KLAUS, 1964, probable synonym of *Angustisulcites klausii,* are reported.

A similar microflora was found near Recoaro, Italy, in the Anisian evaporite stage in the succession of the Vincentinian Alps (KLAUS, 1964), the very region from which aberrant paleomagnetic data is available. In geological literature (e.g., DE BOER, 1963), these gypsiferous sediments are usually regarded as Lower

PLATE II



Some European Lower and Middle Triassic miospores.

A. *Falcisporites snopkovae*, Upper Bunter, The Netherlands; × 600.
B. *Voltziaceaesporites heteromorpha*, Upper Bunter, Catalonia; × 600.
C. *Voltziaceaesporites heteromorpha*, Lower Muschelkalk, Sardinia; × 600.
D. *Angustisulcites klausii*, Lower Muschelkalk, The Netherlands; × 600.
E. *Triadispora crassa*, Upper Bunter, Catalonia; × 600.
F. *Triadispora crassa*, Lower Muschelkalk, The Netherlands; × 600.
G. *Alisporites grauvogeli*, Upper Bunter, The Netherlands; × 600.

Anisian; however, an Alpine equivalent of the Germanic Middle Muschelkalk (transition Anisian–Ladinian) seems more likely. The changed microfloral composition of the Middle Triassic evaporite stage in central Europe is demonstrated by KLAUS (1965).

Also in Catalonia Middle Muschelkalk evaporites are very well developed (VIRGILI, 1958). Samples taken from a gypsum quarry in the vicinity of Pradell, province of Tarragona, yielded high percentages of *Triadispora* spec. div., and, with regard to the Dutch and Sardinian Lower Muschelkalk, decreased amounts of *Alisporites grauvogeli* and *Angustisulcites klausii* (Fig.4).

The Middle Muschelkalk evaporite stage has also been recorded from Alpine Europe (compare, e.g., RICOUR, 1963) and from the Balkan mountains in Bulgaria. However, no palynological data are available. This also applies to the European Upper Muschelkalk, in which no evaporite stages are present.

A selection of European Lower and Middle Triassic miospores is shown on Plate II.

CONCLUSIONS

Both paleomagnetism and palynology may independently furnish useful diagnostic facts for recognizing long-distance movements of the earth's crust. With respect to the Tethys twist, however, the results of paleomagnetism disagree with a palynological approach.

In a large part of Europe the Upper Permian evaporites contain similar spore-pollen assemblages. Apart from local minor differences microfloras are identical in both Meso-Europe and Alpine Europe. This phenomenon can also be observed in the Lower and Middle Triassic. These Upper Permian and Triassic assemblages differ markedly from those assemblages so far reported from the Near East, the U.S.S.R., China and India. In Europe, the ubiquity of similar microfloras supports the idea of an important, distinct paleophytogeographical unit in which contemporaneous compositional changes may reflect the floral evolution as well as ecological plant succession. No important compositional changes occur within an evaporite stage which is in favour of the modern idea of relatively short durations of evaporite phases.

Upper Permian and Lower and Middle Triassic climatological and physiographical conditions must have evolved similarly everywhere in the area bounding the ancient evaporating basins. This suggests stability of this area as a whole, which opposes the extreme mobility of its Alpine part as assumed in the Tethys-twist hypothesis. Apart from the Alpine crustal shortening—in the order of hundreds of kilometers—the possibility of post-Carboniferous horizontal translations and/or rotations in this area still remains; however, a westward drift in the order of thousands of kilometers seems unlikely. For a more detailed approach we ought to collect more palynological information, especially with regard to the eventual prolongation of the European Lower Mesophytic phytogeographical unit in Asia and Africa in order to fix its actual limits.

Though seemingly contradicting the palynological observations, the paleomagnetic data remain, and have to be explained. One factor causing errors in paleomagnetic considerations might be an inadequate dating of the rock samples studied. The abrupt transition between Paleophytic and Mesophytic floras, palynologically confirmed, suggests the incompleteness of the Permian stratigraphical succession in Europe. The whole Permian is generally supposed to represent 40–50 million years; yet it is unknown what part of this time has to be attributed to the Rotliegendes and to the Zechstein, respectively. One ought to reckon with the possibility of an enormous hiatus—possibly interrupted by the problematic Saxonian—between the Lower Rotliegendes and Zechstein, owing to a general uplift during the post-orogenic Saalic phase. Paleomagnetic measurements in pre-Saalic, Saalic, and post-Saalic rocks will probably show different magnetic poles; therefore, accurate chronostratigraphical correlations between the areas studied are required in order to limit the possibility of interpreting paleomagnetic data erroneously. Combined paleomagnetic and palynological investigations may avoid these errors.

REFERENCES

BADOUX, H. et WEIDMANN, H., 1964. Sur l'âge de la série salifère de Bex (Ultrahelvétique). *Bull. Lab. Géol. Minéral. Géophys. Musée Géol. Univ. Lausanne*, 148: 12 pp.

BEJU, D., 1965. Associations palynologiques d'âge Triassique supérieur de la plate-forme Moesienne. *Carpatho-Balkan Geol. Assoc., Congress, 7th, Sofia, 1965, Rept.*, 2(2): 23–33.

BHARADWAJ, D. C. and SINGH, H. P., 1964. An Upper Triassic miospore assemblage from the coals of Lunz, Austria. *Palaeobotanist*, 12(1): 28–44.

BORCHERT, H. and MUIR, R. O., 1964. *Salt Deposits—The Origin, Metamorphism and Deformation of Evaporites.* Van Nostrand, London, 338 pp.

CLARKE, R. F. A., 1965a. Keuper miospores from Worcestershire, England. *Palaeontology*, 8(2): 294–321.

CLARKE, R. F. A., 1965b. British Permian saccate and monosulcate miospores. *Palaeontology*, 8(2): 322–354.

COMMISSARIS, A. L. T. M., 1965. *Pollenanalytisch Onderzoek van de Winterswijkse Muschelkalk (Onder Muschelkalk).* Unpublished Report, Division of Palaeobotany, Botanical Museum and Herbarium, State Univ., Utrecht, 28 pp.

DEÁK, M. H., 1959. A Mecsek-hegységi gipsz kísérleti palinológiai vizsgálata. *Földt. Közl.*, 89(2): 170–173.

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

DE BOER, J., 1965. Paleomagnetic indications of megatectonic movements in the Tethys. *J. Geophys. Res.*, 70(4): 931–944.

DIETZEL, G. F. L., 1960. Geology and Permian paleomagnetism of the Merano region, province of Bolzano, N Italy. *Geol. Ultraiectina*, 4: 58 pp.

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

DOUBINGER, J., 1965. Sur l'âge des gisements houillers des Vosges. *Bull. Serv. Carte Géol. Alsace Lorraine*, 18(2): 49–64.

FREUDENTHAL, T., 1964. Palaeobotany of the Mesophytic, 1. Palynology of Lower Triassic rock salt, Hengelo, The Netherlands. *Acta Botan. Neerl.*, 13: 209–236.

GORTANI, M., 1956. Recenti progressi nella conoscenza strutturale dell'Italia. In: F. LOTZE (Herausgeber), *Geotektonisches Symposium zu Ehren von Hans Stille*. Enke, Stuttgart, pp.143–176.

GREBE, H., 1957. Zur Mikroflora des niederrheinischen Zechsteins. *Geol. Jahrb.*, 73: 51–74.

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

GUICHERIT, R., 1964. Gravity tectonics, gravity field and paleomagnetism in northeast Italy. *Geol. Ultraiectina*, 14: 125 pp.

JANSONIUS, J., 1962. Palynology of Permian and Triassic sediments, Peace River area, western Canada. *Palaeontographica, B*, 110 (1–4): 35–98.

KLAUS, W., 1953. Mikrosporen-Stratigraphie der ostalpinen Salzgebirge. *Verhandl. Geol. Bundesanstalt (Austria)*, 3: 161–175.

KLAUS, W., 1955. Über die Sporendiagnose des deutschen Zechsteinsalzes und des alpinen Salzgebirges. *Z. Deut. Geol. Ges.*, 105: 776–788.

KLAUS, W., 1960. Sporen der karnischen Stufe der ostalpinen Trias. *Jahrb. Geol. Bundesanstalt (Austria), Sonderber.*, 5: 107–183.

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

KLAUS, W., 1964. Zur sporenstratigraphischen Einstufung von gipsführenden Schichten in Bohrungen. *Erdöl Z.*, 4: 119–132.

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

KŁOSOWSKA, T. i DOWGIAŁŁO, J., 1964. Sporomorfy w solach cechsztyńskich z otworu Lębork IG I. *Kwart. Geol.*, 8: 791–796.

KOCKEL, F., 1963. Die Geologie des Gebietes zwischen dem Río Guadalhorce und dem Plateau von Ronda (Südspanien). *Geol. Jahrb.*, 81: 413–480.

LESCHIK, G., 1956a. Die Keuperflora von Neuewelt bei Basel, 2. Die Iso- und Mikrosporen. *Schweiz. Paläontol. Abhandl.*, 72: 1–70.

LESCHIK, G., 1956b. Sporen aus dem Salzton des Zechsteins von Neuhof (bei Fulda). *Palaeontographica, B*, 100 (4–6): 122–142.

LOFFLER, J. und SCHULZE, G., 1962. Die Kali- und Steinsalzlagerstätten des Zechsteins in der deutschen demokratischen Republik, 3. Sachsen-Anhalt. *Freiberger Forschungsh., C*, 97(3): 347 pp.

MÄDLER, K., 1964a. Die geologische Verbreitung von Sporen und Pollen in der deutschen Trias. *Geol. Jahrb., Beih.*, 65: 147 pp.

MÄDLER, K., 1964b. Bemerkenswerte Sporenformen aus dem Keuper und unteren Lias. *Fortschr. Geol. Rheinland Westfalen*, 12: 169–200.

OOSTERBAAN, A. M., 1936. *Étude Géologique et Paléontologique de La Nurra (Sardaigne)*. Thesis, State Univ., Utrecht, 136 pp.

ORŁOWSKA-ZWOLIŃSKA, T., 1962. Pierwsze znalezisko sporomorf cechsztyńskich w Polsce. *Kwart. Geol.*, 6: 283–297.

PAUTSCH, M. E., 1958. Keuper sporomorphs from Swierczyna, Poland. *Micropaleontology*, 4(3): 321–325.

PERŽEL, M., 1966. Nové poznatky o stratigrafii chočského príkrovu malých karpat. *Geol. Práce, Zpravy*, 38: 89–98.

PLÖCHINGER, B., KLAUS, W., KOLLMANN, K. und OBERHAUSER, R., 1963. Exkursionen in den Grünbachgraben am Untersberg-Ostfuss (Salzburg). In: R. GRILL, K. KOLLMANN, H. KÜPPER und R. OBERHAUSER (Herausgebers), Exkursionsführer für das achte mikropaläontologische Kolloquium in Österreich. *Verhandl. Geol. Bundesanstalt (Austria), Sonderh.*, F: 57–67.

POTONIÉ, R. und KLAUS, W., 1954. Einige Sporengattungen des alpinen Salzgebirges. *Geol. Jahrb.*, 68: 517–546.

REINHARDT, P., 1964a. Über die Sporae dispersae der Thüringer Trias. *Monatsber. Deut. Akad. Wiss. Berlin*, 6(1): 609–614.

REINHARDT, P., 1964b. Einige Sporenarten aus dem oberen Buntsandstein Thüringens. *Monatsber. Deut. Akad. Wiss. Berlin*, 6(8): 609–614.

Reinhardt, P. und Schmitz, W., 1965. Zur Kenntnis der Sporae dispersae des mitteldeutschen oberen Buntsandsteins. *Freiberger Forschungsh., C,* 182: 19–36.

Ricour, J., 1963. Particularités paléogéographiques des Alpes occidentales françaises aux temps Triassiques. Dans: M. Durand Delga (Rédacteur), *Livre à la Mémoire du Professeur Paul Fallot, 2.* Soc. Géol. France, Paris, pp.395–405.

Schaarschmidt, F., 1963. Sporen und Hystrichosphaerideen aus dem Zechstein von Büdingen in der Wetterau. *Palaeontographica, B,* 113 (1–4): 1–91.

Schirmer, H. und Kurze, M., 1960. Die stratigraphische Stellung des Salzsedimentes der Bohrung Nr. 5 von Provadia auf Grund des Sporomorpheninhaltes. *Bull. Inst. Geol. Strašimir Dimitrov (Sofia),* 8: 29–45.

Schulz, E., 1964. Sporen und Pollen aus dem mittleren Buntsandstein des germanischen Beckens. *Monatsber. Deut. Akad. Wiss. Berlin,* 6(8): 597–606.

Schulz, E., 1965. Sporae dispersae aus der Trias von Thüringen. *Mitt. Zentr. Geol. Inst.,* 1: 257–287.

Schulz, E., 1966. Erläuterungen zur Tabelle der stratigraphischen Verbreitung der Sporen und Pollen vom oberen Perm bis untersten Lias. In: H. Döring, W. Krutzsch, D. H. Mai und E. Schulz, Erläuterungen zu den sporenstratigraphischen Tabellen vom Zechstein bis zum Oligozän. *Abhandl. Zentr. Geol. Inst.,* 8 (Vorabdruck): 3–26.

Schwarz, E. J., 1962. Geology and paleomagnetism of the valley of the Río Aragón Subordan north and east of Oza (Spanish Pyrenees, province of Huesca). *Estud. Geol., Inst. Invest. Geol. Lucas Mallada (Madrid),* 18: 193–240.

Sikošek, B. und Medwenitsch, W., 1965. Neue Daten zur Fazies und Tektonik der Dinariden. *Verhandl. Geol. Bundesanstalt (Austria), Sonderh.,* G: 86–102; *Z. Deut. Geol. Ges.,* 116(2): 342–358.

Singh, H. P., 1965. Saccate pollen grains from the Lower Triassic of Hallstatt, Austria. *Palaeobotanist,* 13(1): 74–81.

Stover, L. E., 1964. Comparison of three spore-pollen assemblages from Maryland and England. In: A. T. Cross (Editor), *Palynology in Oil Exploration—Soc. Econ. Paleontologists Mineralogists, Spec. Publ.,* 11: 143–152.

Stuhl, Á., 1962. A Balatonfelvidék perm idözaki üledékeiben végzett spóravizsgálatok eredményei. *Földt. Közl.,* 91(4): 405–412.

Sullivan, H. J., 1965. Palynological evidence concerning the regional differentiation of Upper Mississippian floras. *Pollen Spores,* 7(3): 539–563.

Trusheim, F., 1963. Zur Gliederung des Buntsandsteins. *Erdöl Z.,* 7: 277–292.

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

Van Bemmelen, R. W., 1964a. Phénomènes géodynamiques à l'échelle du globe (géonomie), à l'échelle de l'écorce (géotectonique), à l'échelle de l'orogenése alpine (tectonique). *Mém. Soc. Belge Géol. Paléontol. Hydrol.,* 8: 126 pp.

Van Bemmelen, R. W., 1964b. The evolution of the Atlantic mega-undation. *Tectonophysics,* 1(5): 385–430.

Van Bemmelen, R. W., 1965. The evolution of the Indian Ocean mega-undation. *Tectonophysics,* 2(1): 29–57.

Van Bemmelen, R. W., 1966. On mega-undations: a new model for the earth's evolution. *Tectonophysics,* 3(2): 83–127.

Van der Lingen, G. J., 1960. Geology of the Spanish Pyrenees, north of Canfranc (Huesca). *Estud. Geol., Inst. Invest. Geol. Lucas Mallada (Madrid),* 16: 205–242.

Van Hilten, D., 1960. Geology and Permian paleomagnetism of the Val-di-Non area (W Dolomites, N Italy). *Geol. Ultraiectina,* 5: 95 pp.

Van Hilten, D., 1962. Presentation of paleomagnetic data, polar wandering, and continental drift. *Am. J. Sci.,* 206: 401–426.

Van Hilten, D., 1964. Evaluation of some geotectonic hypotheses by paleomagnetism. *Tectonophysics,* 1(1): 3–71.

Virgili, C., 1958. El Triássico de los Catalánides. *Bol. Inst. Geol. Minero España,* 69: 856 pp.

Visscher, H., 1966. Palaeobotany of the Mesophytic, 3. Plant microfossils from the Upper Bunter of Hengelo, The Netherlands. *Acta Botan. Neerl.,* 15: 316–375.