Co-occurrence of *Sinuspores sinuatus* (Artüz) Ravn, 1986 with established palynological markers indicating younger strata: AK-1X well section (Pennsylvanian, Zonguldak Basin, NW Turkey) and the correlation to the stratigraphic system

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ABSTRACT

Part of the AK-1X well section from the Amasra area of the Zonguldak Basin in NW Turkey (Asia Minor) has been palynologically revised. Over the depth range -342.05 to -344.90 m atypical co-occurrences of the key stratigraphic spore species *Sinuspores sinuatus* together with *Vestispora fenestrata*, *V. laevigata*, *Torispora securis* and *Thymospora* spp. are recorded. By correlation to the ‘selected spore ranges and spore zonation of the Carboniferous system in Western Europe’, often used as a standard, these palynological assemblages would be correlated to the upper Bolsovian by the presence of *Thymospora* spp. with some reworked older material, represented by *S. sinuatus*. Alternative spore ranges are considered in this study, and miospore ranges of selected species from Western Europe and North America are discussed. The correlation of the palynological record from the re-investigated AK-1X well section to the chronostratigraphy corresponds with ages around the Duckmantian–Bolsovian boundary, and correlation to the uppermost Duckmantian is discussed as a possibility. However, recent studies lead to the conclusion that a lower Bolsovian age determination for the AK-1X well section is also most probable. Accordingly, *Sinuspores sinuatus* has a slightly expanded range top in NW Turkey and some taxa such as *Thymospora* spp. occur slightly earlier here than in Western Europe.

Keywords: palynology, Turkey, Bashkirian, Moscovian, Duckmantian, Bolsovian, Westphalian B, Westphalian C, Atokan, Sinuspores

1. INTRODUCTION

In the frame of IGCP575 (International Geological Correlation Programme 575) a short well section of the AK-1X well (well name changed due to economic interests), located in the Amasra area of the Zonguldak Basin of NW Turkey (Fig. 1A, B), has been revised. An atypical co-occurrence of palynological species such as *Sinuspores sinuatus*, *Vestispora fenestrata*, *V. laevigata*, *Torispora securis*, and few *Thymospora* spp. has been observed in the palynological assemblages from NW Turkey. All these species are well-known and most form part of the ‘selected spore ranges and spore zonation of the Carboniferous system in Western Europe’ (CLAYTON et al., 1977), which became, in modified form, part of the ‘Carboniferous Time Scale’ (e.g. GRADSTEIN et al., 2004). The application of this palynostratigraphic
zonation to the palynological record of the AK-1X well section, would indicate the upper Bolsovian (the upper Westphalian C) for the investigated deposits from NW Turkey. The enigmatic presence of Sinuspores sinuatus would, in that case, have to be interpreted as being recycled from older rock material. In Western Europe and North America this spore is only known from deposits of the Namurian, Westphalian A, and Westphalian B (stages according to the references of the original literature, e.g. in SMITH & BUTTERWORTH, 1967, as Punctatisporites sinuatus; in KOSANKE, 1988, as P. sinuatus; in PEPPERS et al., 1993 as S. sinuatus).

However, because the specimens of Sinuspores sinuatus, identified in the AK-1X well section, as well as the surrounding palynofacies, showed no indication of reworking or recycling, attempts have been made in this study to look for alternative spore ranges and further evidence, of whether contemporaneous primary deposition of all these spores would have been possible. The first and last occurrences of miospore ranges presented in RA VN (1986), HOWES (1988), and PEPPERS & BRADY (2007) were particularly useful, in combination with the stratigraphic framework of GRADSTEIN et al. (2004) and OGG et al. (2008), in concluding an age around the Duckmantian–Bolsovian transition (Westphalian B–Westphalian C transition) for the palynological assemblages from NW Turkey.

2. THE STUDY AREA: GEOLOGICAL BACKGROUND

The Zonguldak Basin is situated in the north-west of Turkey (Asia Minor) on the Black Sea coast of the western Pontides. The region belongs structurally to the Istanbul-Zonguldak Terrane (also known as the Istanbul Zone, e.g. OKAY, 2008, Fig. 1 A), which was, during Carboniferous times, located within the tropics and more or less on the equator (e.g. STAMPFLI, 2000). During the Pennsylvanian epochs, deposition of mainly clastics and coals took place. At present, the Zonguldak coalfield is a productive mining area (YALCIN et al., 2002, see also for further aspects on general geology, stratigraphy and geological setting of the basin). The main mining districts are the Armutçuk, Zonguldak and Amasra areas (Fig. 1 B). The coal-bearing sequence is subdivided into the Alacaagzi, Kozlu and Karadon formations, and is mainly composed of conglomerates, sandstones and...
Ellen Stolle: Co-occurrence of Sinuspores sinuatus (Artüz) Ravn, 1986 with established palynological markers indicating younger strata...

claystones, though each unit has more or less characteristic lithologies in its area. The investigated interval of this study is assigned to the Karadon Formation of the Amasra district. There, the Karadon Formation (named after the village Karadon, e.g. RALLI, 1933) lies conformably on the Kozlu Formation (CANCA et al., 1994; TÜY SÜZ et al., 2004) (Fig. 1 C), and it is disconformably overlain by the Permian-Triassic Cakraz Formation (AKBAS et al., 2002), or by younger sediments (e.g. Cretaceous in the subsurface, CANCA et al., 1994). According to well data, the formation can have a thickness of c. 500 m in the Amasra area (CANCA et al., 1994; TÜY SÜZ et al., 2004). The Zonguldak Basin underwent strong tectonic deformation (folding and faulting, e.g. YALCIN et al., 2002, fig. 1). TOKAY (1962) considered deposits from the Amasra area to be an allochthonous group, consisting of displaced and mixed slides of Westphalian C, B, A and Namurian age deposits. The age determination of the Karadon Formation was controversial in the past, and the unit was defined as Westphalian B, C and D (by DIL & KONYALI, 1978), as Westphalian A, B and C (by YERGÖK et al., 1987)³, whereas KEREY (1984) considered an age of Westphalian B and C. KARAYIGIT & ORHAN (1997) assigned ages of Westphalian B, C, and D. Westphalian B and C were considered in a recent study by TÜY SÜZ et al., (2004). Palynology and palaeobotany (macro plant fossils) were the main methods for the dating of clastic sections in the area. The Pennsylvanian from NW Turkey has traditionally been assigned to the European regional stages, for example to those that originated in the Westphalian mining area of ‘Ruhrgebiet’, Germany.

3. MATERIAL AND METHODS

This study is based on a revision of palynological data from the Amasra area, NW Turkey. Dark claystones, rich in organic matter, and coals from a drill core of the AK-1X well served as the raw material for palynological processing according to standard preparation methods.

The approximate location of the AK-1X well in the Amasra area is shown in Figure 1 B. The wider core section was assigned to the Karadon Formation (Fig. 1 C). The lithology of the core segment, relevant for this study, is depicted in Figure 2 as well as the productive sampling positions.

The palynostratigraphic concept of this study was using events specific to a single taxon (e.g. its first and last occurrence), preferably of palynological markers and in comparison with different regions. Previously, McLEAN et al. (2004), remarked (for a sequence along the Langsettian-Duckmantian boundary in Britain): “Recognition of the biozonal boundaries of CLAYTON et al. (1977) is also problematic, because the stratigraphic criteria that are used to define the base of the NJ Biozone (range top of S. rara, range top of Sinuspores sinuatus, range base of Microreticulatisporites nobilis) do not occur at the same horizon.”, and proposed: “The difficulties in these interpretations relate to using several criteria to define assemblages or assemblage biozones. A more suitable approach may be to define biosтратigraphic units using events specific to a single taxon.”

During the palynological investigations of this study, the features of the entire palynological assemblage were also taken into consideration (e.g. composition/ main components, co-occurring taxa, content and condition of organic matter), and are involved in the interpretation of the palynological data.

4. CO-OCCURRENCE OF PALYNOLOGICAL SPECIES IN THE WELL SECTION

Figure 2 shows the palynologically re-investigated AK-1X well section and the positions from where specimens of the distinct large brown, trilette spore species Sinuspores sinuatus have been identified, (specimens illustrated in Pl. 1, Figs. 1–6). Over the depth range -342.05 - -344.90 m S. sinuatus co-occurs with Vestispora fenestrata, Vestispora laevigata, Torispora securis, and Thymospora spp. (Pl. 1). From the stratigraphic perspective this co-occurrence seemed to be unusual. All these species are well-known and most form part of the ‘selected spore ranges and spore zonation of the Carboniferous system in Western Europe’ (CLAYTON et al., 1977). The zonation has in the meantime been established, with slight modifications by partial updates, as the microfloral zonation component of the Carboniferous Time Scale (GRA S T E I N et al., 2004). In CLAYTON et al. (1977), the lower limit of the NJ Zone is marked by, amongst others, the youngest range of S. sinuatus (as Punctatisporites sinuatus). The lower limit of the NJ Zone related to the early Westphalian B in 1977, is now equivalent with the lower Duckmantian and upper Bashkirian. According to CLAYTON et al. (1977), the base of the succeeding SL Zone (considered to be lowermost Westphalian C by the authors), coincides with the appearance of the first monolete spores Torispora securis and Vestispora fenestrata. The lower limit of the succeeding OT Zone (equating to the boundary between Westphalian C and D according to the authors), coincides with the appearance of monolete verrucose spores of the genus Thymospora. A plying the ‘zonation of the Carboniferous system in Western Europe’ to the palynological record from the AK-1X well section from NW Turkey, would result in an age determination in the range from latest Bolsovian (Westphalian C) toAsturian (Westphalian D), or younger, based on the presence of Thymospora spp. Occurrences of Sinuspores sinuatus would have to be interpreted as being reworked from older strata.

S. sinuatus was first described by ARTÜZ from the Sulu and Büyükk seams of the Zonguldak district of NW Turkey, later recorded by IBRAHİM-OKAY & ARTÜZ (1964) from the Domuzcu seam. The early finds were considered to be from Westphalian A sediments, as well as records for example in AK Y O L (1974) (Westphalian A, Namurian) and NA-KOMAN (1976, e.g. as Sinuspores sinuatus and Canisporenes corpulentus) from the same area. AK GÜN & AK Y O L (1992) reported it from the Amasra area (as Sinuspores coronatus) as well as A GRALI & KONYALI (1967, as Sinuspores sinuatus and S. coronatus). Outside of NW Turkey, the spore was recorded from Europe and North America, for example from the Russian Platform (EINOR, 1996), Scotland (BUTTERWORTH & WILLIAMS, 1958) and the North American midcontinent (RAVN & FITZGERALD, 1982) under S. sinuatus or under a synonym. According to the common literature the age range was considered to be (late) Visian (e.g. ETTENSOHN & PEPPERS, 1979; EINOR, 1996) to late Westphalian B (KOSANKE, 1988, West Virginia).

Whether a) Sinuspores sinuatus identified in the short AK-1X section is the same as the type species of ARTÜZ (1957), and whether b) the assignment of the AK-1X section to the Duckmantian (Westphalian B), based on the record of KOSANKE (1988), would be explicable and reliable is the subject of the following discussion.

5. BRIEF TAXONOMIC OUTLINE – S. SINUATUS FROM THE TYPE AREA

Sinuspores sinuatus (Artüz) Ravn 1986 was first described by ARTÜZ (1957) from the type locality in the Zonguldak district of the Zonguldak Basin, as having a size of 90–130 µm, a trilette mark of ⅔ of the radius, slightly opened and straight. On the surface of the spore are sine curve-like infrastructures present, which appear on the dark background as a light construction. At the margin of the spore body, a deep dark brown equatorial zone exists, which is 15–17 µm broad and structureless. In his emendation of the species, RAVN (1986) attributed a wider size range of 75–130 µm, and an exine thickness of 5 µm and more. SMITH & BUTTERWORTH (1967) described their specimens (under Punctatisporites sinuatus) as having an exine up to 5 µm in thickness (laevigate and with fine infrasculpture), usually highly folded, with folds broad and situated around the periphery of the spore, but sometimes also following the laeaeaeae, giving the appearance of broad lips. The thickness of the exine (thickenings at sine curve-like structures and/or exine accumulation by fold) is responsible for the dark brown areas on the spore body. The specimens found in the short AK-1X well section (e.g. Pl. 1, Figs. 4-6) are clearly assignable to the species S. sinuatus, based on their morphological features, such as distinct sine curve-like structures, the deep dark brown belt zone at the margin of the spore body, and sizes given in the original description.

6. CORRELATION OF MIOspore RANGES AND DATING

The palynological record of the AK-1X well section (see APPENDIX I for more details) has been compared to palynological events beyond Western Europe. RAVN (1986) showed miozopore ranges from Iowa, and also presented a comparison chart of the Iowa records compared with other regions (North America, Western Europe; Fig. 3 A). The given picture of first and last occurrences appears to be more individual in contrast to an overall zonation. However, it should be noted that dating was an individual process based on personal interpretation by each author. RAVN (1986) correlated the first occurrences of Vestispora fenestrata, Torispora securis, and particularly those of Vestispora laevigata and Thymospora spp. from the upper Kilbourn and lower

PLATE 1

Miospores of the AK-1X well from the Pennsylvanian of NW Turkey, relevant for this study. Each with dimensions in micrometres, slide number, and England Finder coordinates.

1. Sinuspores sinuatus, 101 µm, AK-1X/7.1.2, Q28.4.
2. Sinuspores sinuatus, 91 µm, AK-1X/7.1.1, O47, a relatively unfolded specimen.
3. Sinuspores sinuatus, 106 µm, AK-1X/7.1, U28.4.
4. Sinuspores sinuatus, same specimen as in 1), with focus on the trilete mark.
5. Sinuspores sinuatus, same specimen as in 1), with focus on an area with more or less well developed sine curve-like structures.
6. Sinuspores sinuatus, same specimen as in 1), with focus on an area, which appears relatively laevigate.
7. Vestispora costata, 106 µm, AK-1X/7.1.2, S48.3.
8. Vestispora fenestrata, 107 µm, AK-1X/7.1.1, L48.4.
9. Vestispora laevigata, 80 µm, AK-1X/7.3, O42.
10. Torispora secundis, 24 µm, AK-1X/7.1.2, P29.3.
11. Thymospora sp., 31 µm, AK-1X/7.3, C31.
12. Torispora secundis, 29 µm (one specimen), AK-1X/7.1.2, S48.3.
13. Raistrickia fulva, 58 µm (including ornament), AK-1X/19.1, C32.4.
forms of the genus \textit{Vestispora} for the AK-1X well section (by the occurrence of the species \textit{V. laevigata}. Results from this study were chosen for illustration. The horizontal band, marked in comparison, the oldest age suggestion for the Kalo formations to the upper Westphalian B (Fig. 3 B, also in HOWES, 1988). RAVN’s (1986) dating approximately corresponds with a foraminiferal dating by LAMBERT (1988a) from the Iowa coal succession, namely from shale below the thick limestone overlying the Aaddsdale coal (Fig. 3 B). LAMBERT (1988a) related the investigated strata to the Bsideina Zone (most of the specimens were 'primitive' forms of the genus \textit{Bsideina}). Notably, some remaining species represented one of the youngest occurrences of the genus \textit{Fusulinella} ('youngest' in an evolutionary sense). According to GRADSTEIN et al. (2004) the first \textit{Fusulinella} are correlated approximately with the mid Bolsovian (mid Westphalian C, late Atokan) (Fig. 3 C). According to OGG et al. (2008), the first \textit{Fusulinella} are correlated with the late Bolsovian (mid Westphalian C, late A tokan) (Fig. 3 D). The presence of the conodont species \textit{Neognathodus medadulti­mus} in overlying strata from the lower part of the Floris Formation (LAMBERT, 1988b; HOWES & LAMBERT, 1988, e.g. p. 32) support these correlations. The appearance of \textit{N. medadultimus} is according to GRADSTEIN et al. (2004), table 15.2, selected isotopic radiometric age dates) correlated with the upper K ashirian of the Mississippi Basin (mid Moscovian, approximate Bolsovian–Aturan transition according to OGG et al., 2008).

Discussion of the biostratigraphic data from the underlying Kalo Formation (Fig. 3 B) requires a more comprehensive explanation. However, LAMBERT (1988b) stated that the conodont genera \textit{Idiognathoides} and \textit{Dclignonathodus} do not range above the Blackoak Coal, and the species \textit{Neognathodus} bothrops was explicitly identified from a limestone lens which overlies the Blackoak Coal (HOWES & LAMBERT, 1988) (Fig. 3 B). It should be noted that the \textit{Neognathodus mededultimus}–\textit{N. Neognathodus bothrops} Zone, (standard conodont zones of GT52004 diagrams from Russian chart) GRADSTEIN et al., 2004), is correlated to the early \textit{M oscovian} (around 311 Ma, Fig. 3 C), and includes according to OGG et al. (2008) the early Bolsovian (early Westphalian C, mid A tokan). BARRICK et al. (2004) stated that \textit{Neognathodus uralicus} is a distinctive morphotype that is common in the southern M idcontinent, but has been referred incorrectly for instance to \textit{Neognathodus mededultimus}. \textit{N. uralicus} occurs in the \textit{Neognathodus atokanensis} Zone, (conodont zones midcontinent North America), which was correlated by BARRICK et al. (2004, fig. 1) to the mid Atokan (compare Figs. 3 C, D).

The underlying Kilbourn Formation of the lower Cherokee Group (Fig. 3 B) represents initial Middle Pennsylvanian deposition (e.g. ANDERSON, 2007, fig. 5, Pennsylvanian and \textit{M ississippian Stratigraphic Column of Iowa, Iowa Geolog­ical Survey}). A coringly, the base of the formation is assigned to the lowe­st M iddle Pennsylvanian, but may range to the uppermost Lower Pennsylvanian. The lowest base of the formation corresponds, according to OGG et al. (2008), with the uppermost Baskirian (Fig. 3 B), or with the early A tokan and a mid/late Duckmantian, latest Early Pennsylvanian, respectively (Fig. 3 D).

A recent paper of PEPPERS & BRADY (2007) correlates the first occurrences of \textit{Vestispora fenestrata} and \textit{Torrisonia securis} to approximately the mid A tokan (lowermost Westphalian C) (Fig. 3 E). Their records from the Illinois basin range stratigraphically down to the uppermost Westphalian B (uppermost Duckmantian). Their records from K ansas range down to the lowermost Westphalian C (lowermost Bolsovian). PEPPERS & BRADY’S (2007) correlation of the regional stages (approximately mid A tokan – Westphalian B–Westphalian C boundary) is in accordance with GRADSTEIN et al. (2004) (Fig. 3 C). It corresponds with GRADSTEIN’S et al. (2004) Duckmantian–Bols­ovian transition (Westphalian C–Westphalian B–Baskirian–M oscovian transition, respectively).

Following KOSANKE (1988) with his range top of \textit{S. sinuatus} in the uppermost Westphalian B (uppermost Duckmantian), and considering the miospore ranges of RAVN (1986), HOWES (1988), and PEPPERS & BRADY (2007), a ‘co-deposition’ or co-occurrence of \textit{S. sinuatus} with the other palynological markers mentioned above, is clearly possible, based on contemporaneous occurrences of the parent plants. Adapting PEPPERS & BRADY’S (2007) correlation of the regional stages (Fig. 3 E) to the Carboniferous Regional Subdivisions of OGG et al. (2008), (Fig. 3 D), PEPPERS & BRADY’s approximate mid Atokan (first occurrence \textit{T. securis}, first occurrence \textit{V. fenestrata}) correlates to the earliest Bolsovian (early M oscovian).

In comparison with the data shown above, the investigated A K-1X well section of this study clearly correlates ap-
Ellen Stolle: Co-occurrence of Sinusporina sinuatus (Artüz) Ravn, 1986 with established palynological markers indicating younger strata...

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proximately to the Duckmantian–Bolsovian transition (Westphalian B–Westphalian C transition). This is corroborated by a comprehensive palynological data record from the Amasra area of the Zonguldak Basin. The range charts from AGRALI & KONYALI (1969) include a) the vertical extensions of 108 form genera (tab. 1), and b) the vertical extension of the species from 52 genera (tab. 2, 1. Sporites, and tab. 3, II Pollenites); their source material were cores from 18 wells and samples from mining galleries. Some taxa were reliably identified from their plates and descriptions. The palynological events of selected taxa, relevant for this study, were extracted from their charts and are compiled in Table 1 from older to younger.

The short interval of the AK-1X well can be placed between positions (3) and (4). Species from (1) and (3) are already part of the palynological assemblages. Sinusposares sinuatus still occurs at this position, up to (4). Spinosporites species under (2) could not clearly be identified from the AK-1X well section. AGRALI & KONYALI (1969) observed that the presence of certain miospore types has a limited horizontal extension (regarding their entire study area). Considering the possibility of reworking or recycling of older rock material during the process of deposition, it should be noted that no other species besides S. sinuatus occur in the AK-1X well section that would indicate older ages (e.g. Langsettian or early Duckmantian, such as Schizospora spp., Bellisporites spp., in PEPPERS, 1996; OWENS et al., 2004). The environment of sedimentation in the position of the coal band (Fig. 2), where S. sinuatus is present, can be described as relatively autochthonous. An extremely well-preserved microflora within those palynological assemblages displays the facies of a typical coal swamp. Sample AK-1X/18 includes as the main components Torispora 50%, Laevigatosporites 22%, Densosporites 14%, Florinites 12%, and Punctatosporites; AK-1X/19 includes Laevigatosporites 93%, Florinites 3%, and Cirratiradites. Biscate pollen (signals from the hinterland) are non-existent.

The composition of the miospores (mainly from ferns and lycophytes) displays the influence of peat substrate and clastic substrate ever-wet vegetations of DIMITROVA et al., 2011, and the subordinate influence of a marginal vegetation. DIMITROVA et al. (2011) proved that the Florinites-producing cordaitanthaceans appear not to have been upland trees (as previously suggested), but occupied mainly coastal habitats, or riparian habitats on the margins of the wetland.

In other respect, no further species, which would indicate younger ages (e.g. a latest Bolsovian, Asturian), time-equivalent with occurrences of Thymospora spp., as for example shown in the range chart from Western Europe in CLAYTON et al. 1977 (e.g. Spinatosporites spinosus, Angulisporites sp., of Savitrisporites camptotus), occur in the AK-1X well section. These latter species are common in younger strata from NW Turkey (STOLLE & BUZKAN, 2011; STOLLE unpublished data). Even a key stratigraphic marker from CLAYTON’S et al. (1977) zonation supports the considerations of this study. Raistrickia fulva (Pl. 1, Fig. 13; the holotype was described from the Zonguldak area) is present in the palynological assemblages, also in those of coal sample AK-1X/19 (see above, and Fig. 2).

The upper range of R. fulva is according to CLAYTON et al. (1977) at the top of the NJ zone, and indicates as its youngest age, the earliest Bolsovian (Westphalian C). According to OWENS (in STEPHENSON & OWENS, 2006), the species only ranges from K underscoutian to Duckmantian. Whether the ages and relationship to the stages could be refined for the AK-1X well section is discussed below.

### 7. DISCUSSION

As shown above, the co-occurrence of Sinusposares sinuatus and Vestispora fenestrata, V. laevigata, Torispora securis, and few Thymospora spp. is most likely based on contemporaneous first occurrences. Therefore dating of the AK-1X well section over the depth range - 342.05 - 344.90 m, where these marker species occur, is in this study for the first time broadly related to the Duckmantian–Bolsovian transition (Westphalian B–Westphalian C transition).

Following RAVN (1986) and HOWES (1988), and also OWENS (in STEPHENSON & OWENS, 2006) regarding the upper range of Raistrickia fulva, the AK-1X well section could correspond to the uppermost Duckmantian (uppermost Westphalian B). The record of S. sinuatus in the Amasra area of NW Turkey and that of KOSANKE (1988, West Virginia, upper Westphalian B) would be approximate time-equivalents.

OWENS (1996) depicted a table of ‘principal Upper Carboniferous palynological events in the Northern Hemisphere’, in which the appearance of Torispora is placed at the base of the Bolsovian (Westphalian C). Following OWENS (1996), and also PEPPERS and BRADY (2007, their Kansas record with first Vestispora fenestrata and Torispora securis in their lowermost Westphalian C), and furthermore OGG et al. (2008) with the relationship that ‘PEPPERS and BRADY’s mid Atokan would be earliest Bolsovian (Westphalian C)’, consequently the A-1X well section would correspond to the lower Bolsovian (lower Westphalian C; lower Moscovian). The miospore range top regarding S. sinuatus would, according to this latter stratigraphic model, be slightly expanded in the Amasra area. Similar results have already been shown by AGRALI & KONYALI (1969) (Tab. 1), however, their reference to the regional stages (range top upper Westphalian C) has to be revised (details in prep., STOLLE et al.).
8. CONCLUSIONS

A n atypical co-occurrence of miospore species such as Sinusposes sinuatus, Vesti­spora fenestrata, V. laevigata, Toris­pora secundis and Thymospora spp. is observed in palyno­logical assemblages from a short well section from the Amsara area of the Zonguldak Basin of NW Turkey.

Palyneological re-investigation herein provides an age which corresponds with a time interval around the Duck­mantian–Bolsovian transition (Westphalian C–Westphalian B boundary and approximating to the Bashkirian–Mos­covian transition, respectively).

A correlation to the uppermost Duck­mantian (uppermost West­phalian B; Bashkirian–Moscovian transition) for this section is possible. However, recent studies lead to the conclusion that a correlation to the lower Bolsovian (lower West­phalian C; lower Mos­covian) for the AK-1X well section is most likely. This means that Sinusposes sinuatus has a slightly expanded range top in NW Turkey and some taxa such as Thymospora spp. occur slightly earlier here than in Western Europe.

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APPENDIX I

ADDITIONAL TAXA OF THE PALYNOLOGICAL RECORD OF THE AK-1X WELL SECTION, CO-OCCURRING WITH SINUSPORES SINUATUS


APPENDIX II

FULL NAMES (BRIEF HISTORY) OF SPECIES MENTIONED IN THIS PAPER

Alatisporites pustulatus (Ibrahim) Ibrahim, 1933
Angulisporites splendidus Bhardwaj, 1954
Cirratriradites saturnii (Ibrahim), Schopf, Wilson & Bentall, 1944
Crassispora kosankei (Potonié & Kremp) Bhardwaj, 1957
Densosporites triangularis Kosanke, 1950
Dictyotriletes bireticulatus (Ibrahim) Potonié & Kremp, 1954
Endosporites globiformis (Ibrahim) Schopf, Wilson & Bentall, 1944
Florinites junior Potonié & Kremp, 1956
Florinites mediapudens (Loose) Potonié & Kremp, 1956
Foveolatisporites coronatus (Artüz) Ravn, 1986
Microreticulatisporites nobilis (Wicher) Knox, 1950
Murospora kosankei Somers 1952 (synonymous to Westphaliansporites irregularis A. Ipem, 1958)
Raistrickia fulva Artüz, 1957 (first description from the Zonguldak area, NW Turkey)
Reticulatisporites reticulatus (Ibrahim) Ibrahim, 1933
Savirpisporites camptotus (A. Ipem) Doubinger, 1968 (synonymous to Savirpisporites majus Bhardwaj, 1957)
Schulzospora rara Kosanke, 1950
Sinusposes sinuatus (Artüz) Ravn, 1986
Sparisporites exigus Upshaw & Hedlund, 1967
Sparisporites spinosus A. Ipem, 1958
Torispora secundis (Balme) A. Ipem, Doubinger & Horst, 1965
Triquitrites sculpilis (Balme) Smith & Butterworth, 1967
Vestispora costata (Balme) Bhardwaj emend. Spode, in Smith & Butterworth, 1967
Vestispora laevigata Wilson & Venkatachala, 1963

Neognathodus atokaensis GRAY SON, 1984
Neognathodus bothrops MERRILL, 1972
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