Reworked Carboniferous palynomorphs from the Lower Jurassic of Bornholm and their palaeogeographic significance.

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Reworked Carboniferous palynomorphs are found in the Lower Jurassic Rønne Formation on Bornholm. Carboniferous sediments are unknown in the Jurassic provenance areas, which were the Fennoscandian Shield and local highs in the Bornholm area. Their presence is thus of importance to interpretations of Carboniferous palaeogeography.

The northern-limit of proven Carboniferous sediments mainly follows the southern margin of the Ringkøbing-Fyn Arkona High. However, structural evidence suggests that this limit is attributed to post-depositional uplift, faulting and erosion. The reworked palynomorphs indicate that Carboniferous sediments were originally deposited north of their present area of distribution. Down-faulting related to Permo-Carboniferous extension led to the preservation of Carboniferous deposits until uplift made the deposits available for erosion during the Late Triassic and Jurassic.

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Introduction

Large numbers of samples for palynological analysis have been collected from outcrops of Lower and Middle Jurassic sediments on Bornholm in order to refine earlier stratigraphic schemes of Gry (1969), Gravesen, Rolle & Surlyk (1982) and Hoelstad (1985). The samples from the Lower Jurassic contain a fair number of Carboniferous palynomorphs together with a Hettangian to Sinemurian assemblage (Koppelhus 1988). The aim of this paper is to describe the reworked palynomorphs and to discuss their provenance and palaeogeographic implications.

Geological setting

The island of Bornholm is located within the Fennoscandian Border Zone and constitutes a complex fault block mosaic (fig. 1). The northeastern two thirds of Bornholm consist of Precambrian crystalline basement rocks, whereas an incomplete Palaeozoic and Mesozoic succession is preserved in downfaulted blocks along the western and southwestern coasts (fig. 2). Palaeozoic and Mesozoic tectonic movements and sealevel fluctuations have resulted in numerous hiatuses (fig. 3), the longest being that encompassing the Upper Silurian to Middle Triassic. Lower Jurassic deposits rest on both lower Palaeozoic and Upper Triassic rocks (Gry 1969).

The structural elements of Bornholm and the surrounding areas have been defined by onshore and offshore mapping (Gry 1969, Gravesen et al. 1982, Vejbæk 1985, Liboriussen, J., Ashton, P. & Tygesen, T. 1987, Jensen & Hamann 1989). The Rønne Graben, which is one of the major tectonic elements, straddles the west coast of the island (fig. 2). It is bounded by northeast-southwest trending normal faults which merge to the north and consists of a number of individual fault blocks. To the south the graben continues into the Gryfice Graben of offshore East Germany and Poland. The Rønne Graben was probably initiated in late Carboniferous to early Permian times as a pull apart basin by fault movements in a transtensional dominated dextral wrench system (Vejbæk 1985, Liboriussen et al. 1987). Part of the Mesozoic graben fill is exposed on Bornholm as a result of the Late Cretaceous to early Tertiary Laramide inversion which led to vertical movements of the order of 1 km for the Rønne-Hasle Fault Block (fig. 2). Contemporaneous

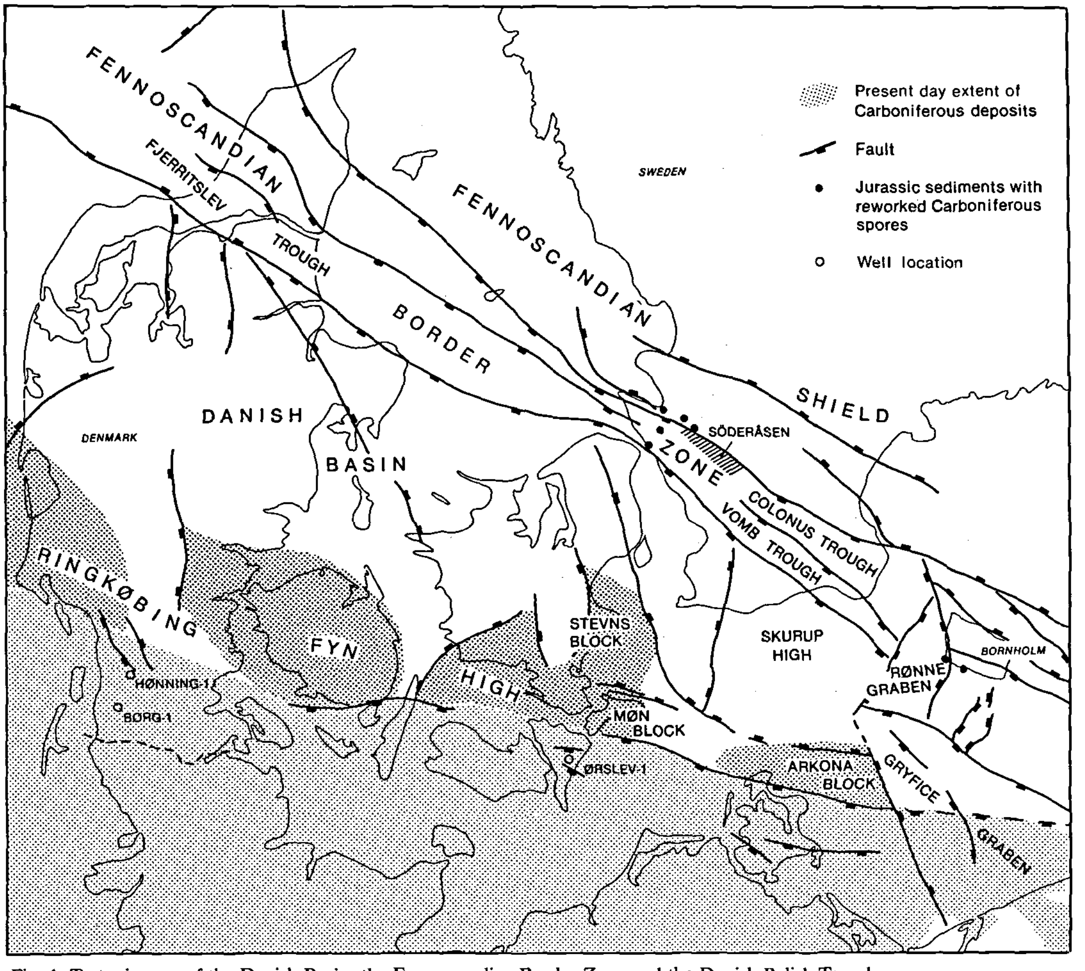

Fig. 1. Tectonic map of the Danish Basin, the Fennoscandian Border Zone and the Danish-Polish Trough.

sediments deposited on the Arnager-Sose Fault Block can be studied in outcrops on the south coast.

Reworked Carboniferous palynomorphs

Material

The analysed material was collected from the type sections of the members of the Lower Jurassic Rønne and Hasle Formations, and from the Middle Jurassic Bagå Formation. These exposures comprise only a minor part of the complete succession.

The Munkerup Member, the lowermost part of the Rønne Formation, is exposed in a 2 m high section of clay from which 3 samples were collected. The overlying Sose Bugt Member of the Rønne Formation (fig. 4) crops out in Sose Bugt where 18 samples were collected. The localities of the two members on the south coast of Bornholm occur within the Arnager-Sose Fault Block (fig. 2). The uppermost Galgeløkke Member of the Rønne Formation is exposed in the Galgeløkke coastal cliff just south of Rønne. 10 samples were collected from here (fig. 4).

Four were also taken from the type locality of the Hasle Formation to the south of the town of Hasle.

The Bagå Formation is well exposed in the clay pit of the Hasle Klinkerfabrik on the west coast of Bornholm from which 17 samples were collected. The last three localities occur within the Rønne-Hasle Fault Block (fig. 2).

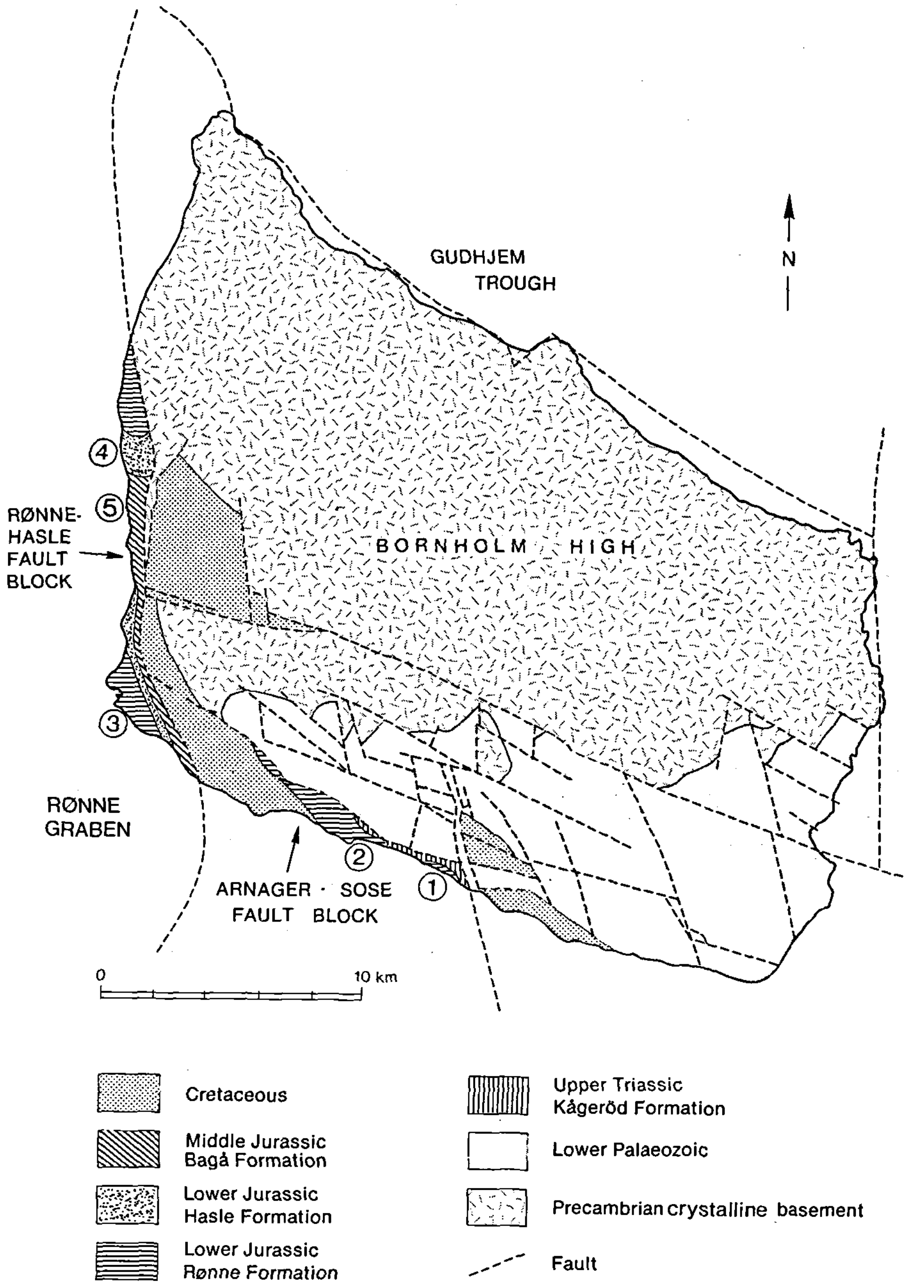

Fig. 2. Geological map and structural elements of the Bornholm area. Encircled numbers indicate type sections: Munkerup Member (1), Sose Bugt Member (2), Galgeløkke Member (3), Hasle Formation (4), Bagå Formation (5). Based on Gravesen et al. (1982).

Methods

All of the samples were palynologically prepared following the routine described by Gudmundson (1985). 10–75 grams of each were ground to a grain size of about 1 mm. They were then packed in bags of filter cloth with a mesh size of 10 µm, and washed with citric acid in a standard washing machine to remove calcareous matter. Afterwards the samples were treated in a HF-maceration tank with cold commercial grade hydrofluoric acid for 8–15 days to remove mineral matter.

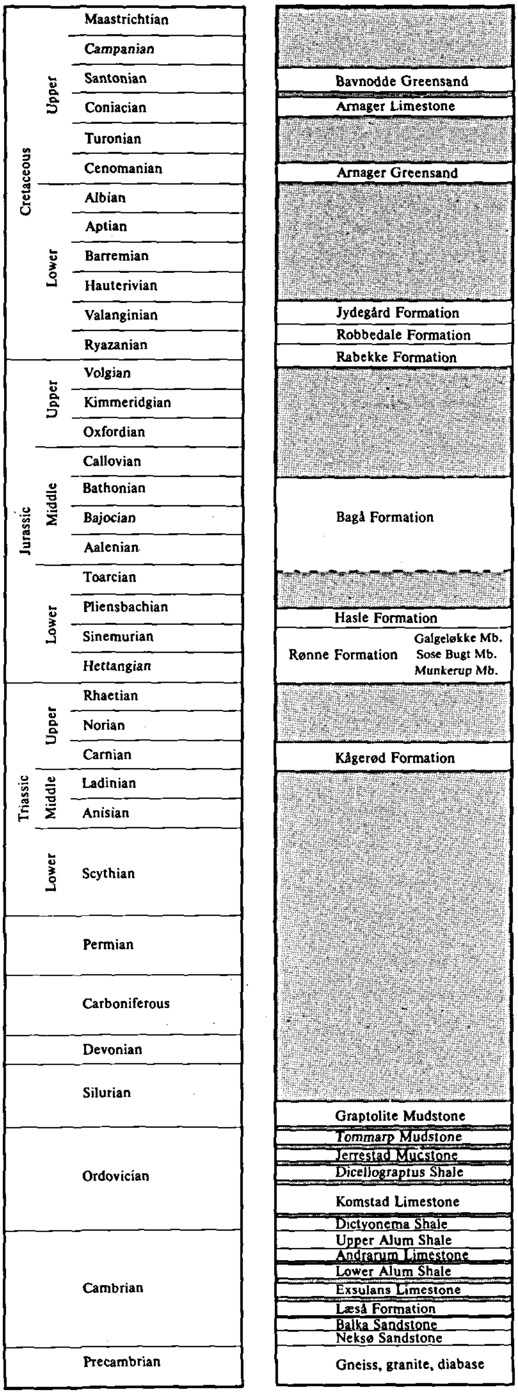

Fig. 3. Stratigraphic scheme for Bornholm, based on Michelsen (1986).

The residues of the samples were then washed with water in the tank until they were neutral (about 2 days), washed again in the washing machine with citric acid at 90°C and then twice with water at 50°C. Heavy liquid separation was used if necessary. Finally, the material was swirled to separate the lighter material from the heavier. The organic residue of each sample was mounted in glycerin jelly. Several slides of each preparation were examined under a microscope, for transmitted light.

Results

The three sections of the Rønne Formation yielded rich and well preserved spores and pollen. *Pinuspollenites minimus* and *Chasmatosporites hians* are abundant in the assemblages from the Munkerup and lower part of the Sose Bugt Members. The presence of these two species and the lack of *Cerebropollenites macroverrucosus* indicate the presence of the *Pinuspollenites – Trachysporites* Zone of Lund (1977), which he dated as Hettangian.

In the assemblages from the upper part of the Sose Bugt and the Galgeløkke Members specimens of *Pinuspollenites minimus* continue to be common and *Cerebropollenites macroverrucosus* occurs sporadically. The assemblage is assigned to Lund's (op. cit.) unnamed zone with *Cerebropollenites macroverrucosus,* which he referred to the Sinemurian.

The palynomorphs in the preparations from the Hasle Formation did not yield any useful stratigraphic information.

The samples from the Bagå Formation proved to be rich in such Middle Jurassic spores and pollen grains as *Ischyosporites variegatus, Manumia variverrucata, Sestrosporites pseudoalveolatus,* and different species of the genera *Leptolepidites* and *Callialasporites.* The association confirms the latest late Toarcian to Bathonian age previously suggested for the formation (Hoelstad 1985).

Reworked Carboniferous spores were found in the Sose Bugt and the Galgeløkke Members. Counts of 200 palynomorphs per slide were found to include one to ten, with an average of four, of Carboniferous age. None was recovered from the Munkerup Member, Hasle Formation or Bagå Formation, although Hoelstad (1985) reported a

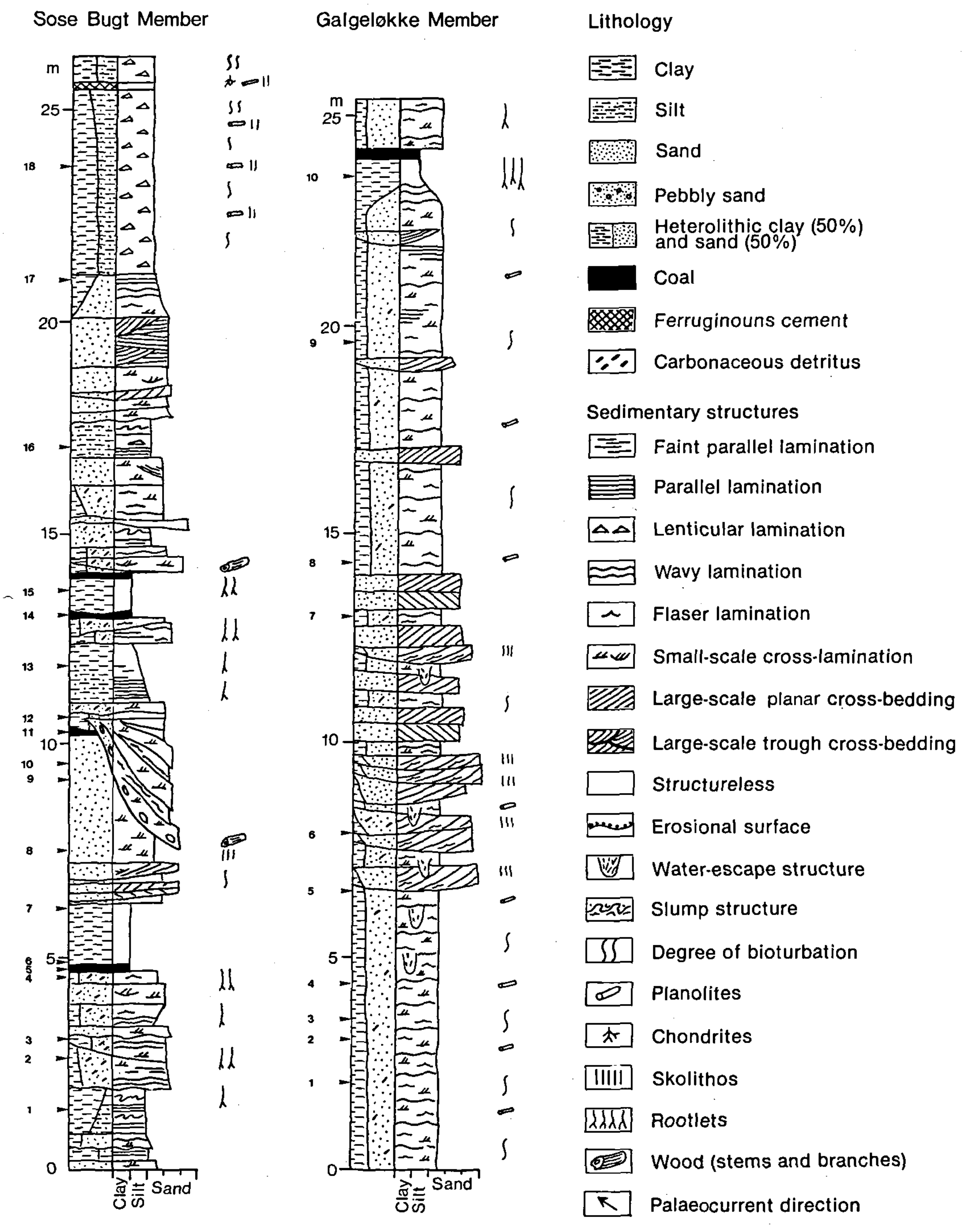

Fig. 4. Type section of the Sose Bugt Member (left) and the Galgeløkke Member (right). Position of the investigated samples is indicated by arrows (from Gravesen et al. 1982).

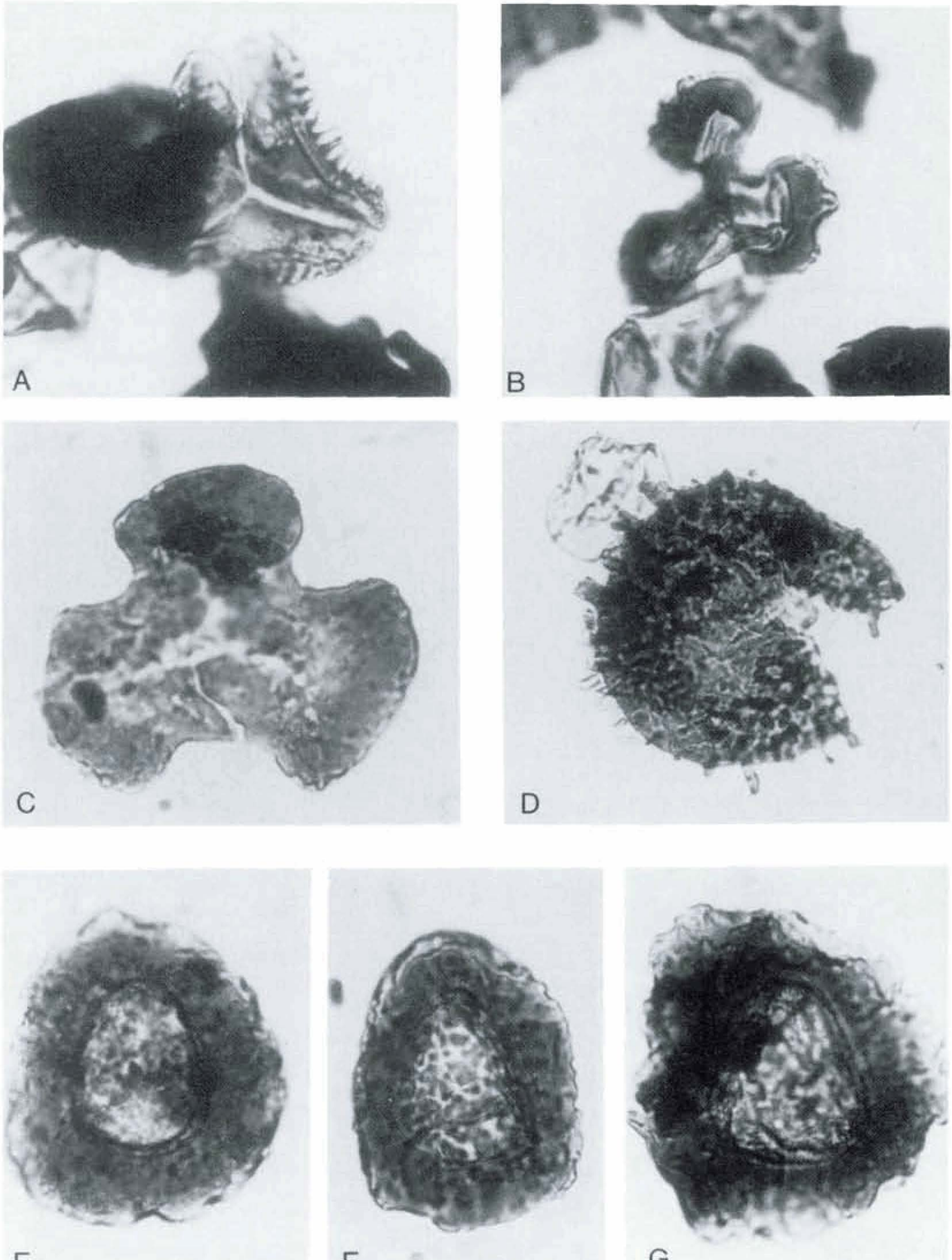

Fig. 5. Reworked Carboniferous spores from Lower Jurassic deposits on Bornholm. Magnification approximately x1000. A: *Diatomozonotriletes saetosus* (Hacquebard & Barss) Hughes and Playford 1961. B: *Tripartites trilinguis* (Horst) Smith & Butterworth 1967. C: *Tripartites vetustus* Schemel 1950. D: *Raistrickia nigra* Love 1959. E, F & G: *Densosporites variabilis* (Waltz) Potonié & Kremp 1956.

single specimen of cf. *Platyptera triloba* Naumova from the latter.

The most common Carboniferous spores are *Densosporites variabilis* (figs 5E, 5F and 5G), *Densosporites anulatus* (fig. 6A), *Lycospora pusilla* (figs 6C and 6E) and *Lycospora pellucida* (fig. 6D) These species are geographically widespread (USSR, northwest Europe, UK and USA) and their stratigraphical range (fig. 7) is from Visean to Westphalian D, apart from that for *Densosporites variabilis* which is from Tournaisian to Stephanian (Luber & Waltz 1938, Smith & Butterworth 1967, Bertelsen 1972, Clayton et al. 1977, Ravn 1979, 1986). Other reworked species are rare but have short ranges. These include *Diatomozonotriletes saetosus* (fig. 5A) and *Tripartites trilinguis* (fig. 5B), which occur in the uppermost Visean and Namurian, and *Tripartites vetustus* (fig. 5C) and *Raistrickia nigra* (fig. 5D), which occur only in the uppermost Visean and Namurian A (fig. 7) (Luber & Waltz 1938, Hacquebard & Barss 1957, Dybova & Jachowicz 1957, Hughes & Playford 1961, Smith & Butterworth 1967, Bertelsen 1972, 1977, Neves et al. 1972, and Clayton et al. 1977). This suggests that at least some of the source sediments must have been originally deposited during the latest Visean and Namurian A.

The reworked specimens differ significantly from the Lower Jurassic spores in size, shape, and colour. Their colour corresponds to an approximate TAI (Thermal Alteration Index) value of 5 on the scale of Batten (1980) in contrast to a value of 2 for the Jurassic assemblage. The preservation is good (see figs 5 and 6), which suggests a relatively short distance of transport.

The stratigraphic order of occurrence of the redeposited spores does not show any reverse appearance, i.e. the youngest Carboniferous spores are not present in the oldest Jurassic sediments. This may suggest that the source sediments represent only the interval from uppermost Visean to Namurian A.

All of the reworked species are known from Carboniferous miospore assemblages described from northwest European paralic sediments by Smith et al. (1967) and Clayton et al. (1977). Farther east, in the Moscow Basin, the contemporaneous deposits consist of marine limestones, with a different palynomorph assemblage. It is, therefore, concluded that the source sediments belonged to the northwest European paralic realm.

Species of *Tripartites, Densosporites* and *Lycospora* have previously been reported as reworked in the Rhaetian and Lower Jurassic deposits in the Rødby-1 well (Lund 1977) and in the Lower Jurassic of the Gassum-1 well (Dybkjær 1988). Furthermore, reworked Carboniferous spores are found commonly in Rhaetian and Jurassic deposits in Scania (Nilsson 1958, Guy 1971, Tralau et al. 1972, Guy-Ohlson, D., Lindquist, B. & Norling, E. 1987). The Carboniferous spores from Scania were determined to be of Namurian age on the basis of the presence of *Tripartites* (Guy-Ohlson et al. 1987).

Provenance area for the reworked Carboniferous palynomorphs

Present day distribution of Carboniferous sedimentary rocks

Carboniferous deposits are well-known from a wide west-east trending belt extending from Ireland to England and Scotland, the southern North Sea, Holland, West Germany, East Germany, and Poland (e.g. Bartenstein 1979). In the Danish onshore and west Baltic areas, the northern limit of Carboniferous deposits coincides with the southern flank of the Ringkøbing-Fyn High and the faults extending eastward to the Arkona Block (fig. 1). Carboniferous as well as other upper Palaeozoic deposits are unknown from Bornholm, Sweden and Finland. However, the present northern limit is mainly erosional due to later uplift, and does not preclude the occurrence of Carboniferous sedimentary rocks in the Danish Basin. Upper Carboniferous limestone has been reported from the Oslo Graben (Olaussen 1981, Bergström, Bless & Paproth 1985) and Carboniferous deposits have been suggested to occur in the Horn Graben (Vejbæk 1990).

In the Danish area, south of the Ringkøbing-Fyn High, Carboniferous rocks have been demonstrated in the Ørslev-1 well located south of the Møn Block (fig. 1). More than 500 m of Lower-Middle Visean beds of alternating claystones, marls, and limestones were encountered. These are separated from overlying Permian (or Upper Carboniferous ?) red beds by an angular unconformity (Michelsen 1971, 1972, Bertelsen 1972). In the Hønning-1 well (fig. 1), a pre-Permian, steeply dipping shale of possible Carboniferous age is present below an angular unconformity (Sorgenfrei & Buch 1964), and in the recently drilled Borg-1 well located in the same area, shales of Carboniferous age were encountered (Underwood 1988).

On the island of Rügen, offshore East Germany, and offshore Poland south of Bornholm, Lower and Upper Carboniferous rocks rapidly wedge out towards the north because of faulting and truncation before the Permian sediments were deposited (Dadlez 1974, 1987). In the southeastern Baltic area, Devonian and Lower Carboniferous rocks are truncated by erosion (Flodén 1980), and the western margin of the Carboniferous in northwest Russia is also a result of erosion (Bergström et al. 1985). A reconstruction of the Carboniferous palaeogeography is hampered by the extensive later erosion, and palaeogeographical maps prepared by various authors differ considerably (e.g. Bertelsen 1972, Michelsen 1972, Ziegler 1982, 1988, Glennie 1984, Bergström et al. 1985, Dadlez 1987).

During the Visean, deposition of marine carbonates dominated in northwest Europe, northern East Germany, and Poland. A gradual change to deposition of continental and marginal marine clastics in the Variscan foredeep occurred during the Namurian and Westphalian, with input from the Variscan Foldbelt to the south, and the Scottish Highlands and the Fennoscandian area in the north (Ziegler 1982, 1988, Glennie 1984, Bergström et al. 1985, Dadlez 1987). In the northern part of East Germany and Poland, clastic paralic and limnic sedimentation occurred in increasingly isolated basins because of decreasing rates of subsidence. At the end of the period the area became emergent. This resulted in an incomplete Upper Carboniferous sequence in northwest Poland and the northern part of East Germany, with a Namurian hiatus presumably of non-depositional origin and a restricted areal extent of Westphalian owing to both non-deposition and erosion (Pozaryski & Dembowski 1984, Dadlez 1987, Ziegler 1988).

Early Jurassic palaeogeography and depositional environment

The Rønne Formation constitutes a heterogeneous sequence of interbedded sand, silt, and clay, approximately 500 m-thick in the Rønne-Hasle Fault Block and approximately 200 m-thick in the Arnager-Sose Fault Block (fig. 2). Thin autochtonous coal beds and dark clays with rootlets are fairly common, and dispersed organic matter and fragments of leaves and woody material occur throughout. The trace fossils *Skolithos* and *Planolites* are abundant locally. Except for rare occurrences of the brackish bivalves *Cardinia follini* and *Cyrena menki,* macrofossils are absent and only a few agglutinating foraminifera have been found.

The formation is interpreted as fluvio-deltaic and tidal marine (Gry 1969, Sellwood 1972, Rolle, Koch, Frandsen & Surlyk 1979, Gravesen et al. 1982). The depositional environment is similar to that for the relatively coarse-grained deltaic and marginal marine deposits occurring at the basin margin along the Fennoscandian Border Zone, as represented by the Gassum Formation in North Jylland and North Sjælland, the Helsingborg Member of the Höganäs Formation in Scania, and the Mechowo and Radowo Beds in NW Poland. Marine shelf claystones occur more centrally in the Danish Basin (Dadlez & Kopik 1972, Michelsen 1975, 1978, Bertelsen 1978, Sivhed 1984, Pedersen 1985, Dadlez 1987, Nielsen, Larsen & Frandsen 1989).

Clastic material shed into the Danish Basin was mainly derived from the Fennoscandian Shield northeast of the Border Zone (Larsen 1966). Areas south of the Ringkøbing-Fyn High and south and east of Bornholm are precluded as provenance areas for the Rønne Formation because contemporaneous sediments accumulated on top of the Triassic in these areas (Bertelsen & Michelsen 1970, Michelsen 1973, Dadlez 1974, 1987, Lund 1977, Norling & Skoglund 1977, Kumpas 1978, 1979). Besides the Fennoscandian Shield, it is also possible that local highs contributed to the formation of the Rønne Formation, e.g. the Skurup High, where Upper Cretaceous sediments locally rest on basement (Vejbæk 1985, figs 6 and 7), and the Bornholm High where lower Palaeozoic sediments and Precambrian crystalline basement are exposed today.

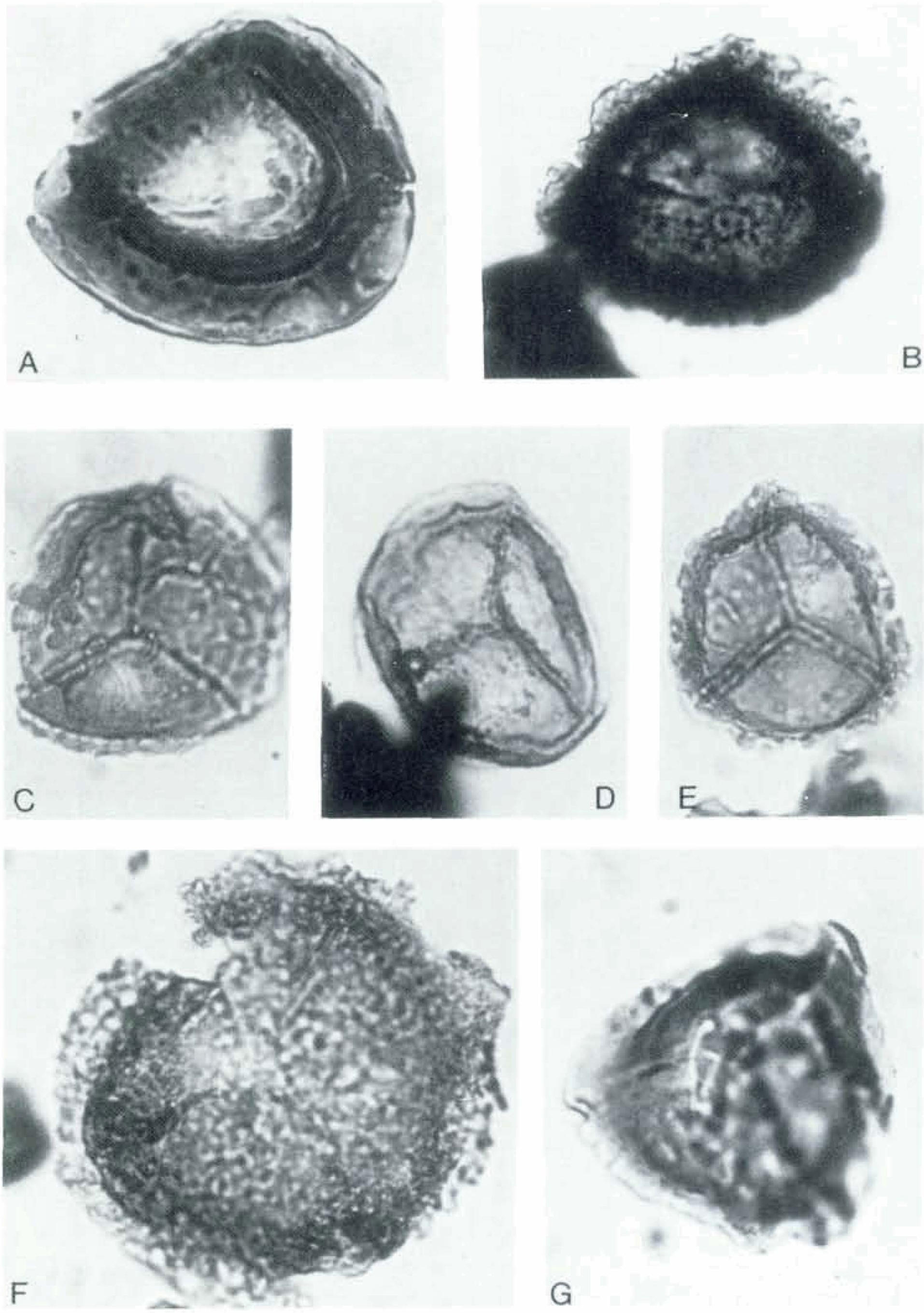

Fig. 6. Reworked Carboniferous spores from Lower Jurassic deposits on Bornholm. Magnification approximately x1000. A: *Densosporites anulatus* (Loose) Smith & Butterworth 1967. B: *Densosporites* sp. C & E: *Lycospora pusilla* (Ibrahim) Schopf, Wilson et Bentall 1944. D: *Lycospora pellucida* (Wicher) Schopf, Wilson et Bentall 1944. F & G: *Lycospora* sp.

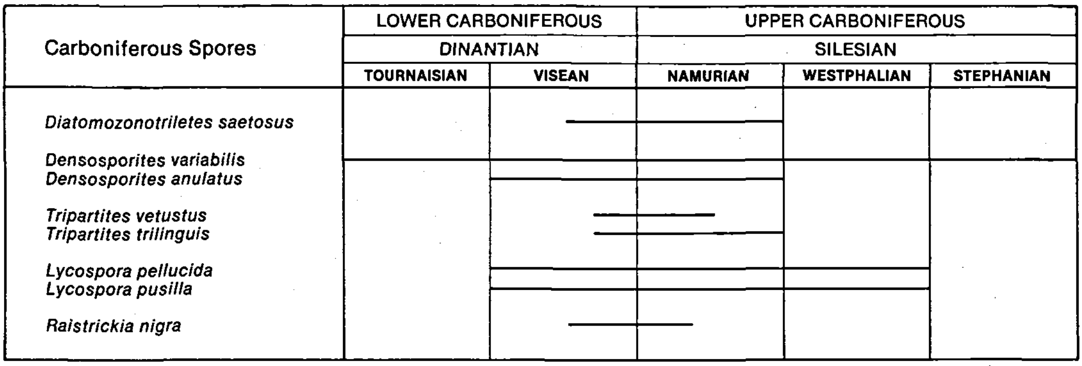

Fig. 7. Range chart of the Carboniferous spores occurring as reworked in the Lower Jurassic of Bornholm. The stratigraphical ranges are from Schulz (1967), Smith et al. (1967), Neves et al. (1971), and Clayton et al. (1977).

The occurrence of angular, basement-derived pebbles in the marine sandstone of the early Pliensbachian Hasle Formation suggests that the Bornholm High was exposed during this period. Sedimentary structures and palaeocurrent data suggest that the formation was deposited in water depths of 10–40 m along a coastline controlled by the Rønne-Hasle Fault separating the Bornholm High from the Rønne Graben (Surlyk & Noe-Nygaard 1986). Mudflow deposits in the Bagå Formation with large kaolinized basement blocks indicate that during Bajocian to Bathonian times the Bornholm High also was exposed to erosion (Gry 1960, 1969, Gravesen et al. 1982).

Discussion

The reworked Carboniferous spores found in the Rønne Formation were derived from deposits of a late Visean to Namurian A age which were probably of paralic to non-marine origin. Their good preservation and relative abundance precludes a prolonged distance of transport and repeated deposition and erosion. Furthermore, the continental to marginal marine origin of the Rønne Formation makes it unlikely that the Carboniferous spores were supplied via long distance transport by marine currents. It is thus suggested that Carboniferous sediments were eroded fairly close to the area of deposition of the Rønne Formation. The Early Jurassic land-sea distribution discussed above and the presence of Permian or Triassic rocks overlying Carboniferous rocks to the west and south of Bornholm make it unlikely that Carboniferous spores could have been supplied from these areas.

It is, therefore, concluded that late Visean-Namurian A deposits occurred north of Bornholm in Scania and possibly also on Bornholm, supporting a similar conclusion reached by Guy-Ohlson et al. (1987) and Guy-Ohlson & Norling (1988). This conclusion raises the question of where Carboniferous sediments were deposited in the Scania-Bornholm area and how they were preserved until Jurassic time. The numerous Permo-Carboniferous feeder dykes in Scania without related remnants of extrusives suggest that considerable erosion took place between the Early Permian and the onset of local Mesozoic sedimentation (Bergström et al. 1985). The most likely places of Carboniferous sedimentation and preservation of such deposits north of their present limit are down-faulted areas such as the Colonus Trough and the Rønne Graben. These were probably formed as a result of extension related to Permo-Carboniferous wrench-faulting which may also have caused intrusion of the dyke swarm in Scania, the initiation of the Oslo Graben and the Fjerritslev Trough (Klingspor 1976, Ziegler 1982, 1988, Vejbæk 1985, Liboriussen et al. 1987, Ro et al. 1990). The Colonus Trough and southwestern-most Scania are the only places in Scania where lower Palaeozoic rocks are preserved. Elsewhere, the Permo-Carboniferous tectonism caused uplift of basement blocks and erosion, corresponding to the extensive Permian erosion known from the northwest European region (Norling & Bergström 1987). Bergström (1980) measured conodont colour alteration (CAI) values on Ordovician conodonts from the

Colonus Trough and found high values corresponding to a post-mature stage. He interpreted this to be related to the presence of intrusives because he believed that the degree of heating associated with the depth of burial would have been insufficient to cause such a change in maturation level. However, the Palaeozoic burial history of Scania is difficult to assess (e.g. Bergström 1984). Cambrian-Silurian sediments with thicknesses of up to 4 km occur in areas structurally linked to the Colonus Trough, such as the Fjerritslev Trough, and locally in the Kattegat area and south and east of Bornholm (Vejbæk 1985, Liboriussen et al. 1987, Ro et al. 1990). This is suggestive of a regional subsidence during early Palaeozoic times. Isotope data from Ordovician limestones on Bornholm (Buchardt & Nielsen 1984) and fission track analyses from southern Sweden (Zeck et al. 1988) support this.

Guy-Ohlson et al. (1987) measured TAI values in Scania of 6 and 3 for the Carboniferous and Jurassic spores respectively. In the material from Bornholm, the analogous values are 5 and 2, corresponding to approximate vitrinite reflectance of 0.9 and 0.3 (Batten 1980). The latter value was confirmed by direct measurement, giving a range from 0.3–0.4. The TAI values clearly indicate a pronounced thermal alteration of the Carboniferous spores to a mature stage. It is thus possible that major subsidence of the Colonus Trough continued during the Permo-Carboniferous tectonic phase, which would explain the high CAI values and allow maturation of the Carboniferous sediments and their preservation until Late Triassic – Early Jurassic time. A thorough evaluation of the maturation profile is prevented because relationships between CAI, TAI and vitrinite reflectance measurements are somewhat ambiguous, and insufficient data are available on the thicknesses of the Silurian, the upper Palaeozoic, and the Triassic. However, the general trend of post-mature Ordovician, mature Carboniferous, and pre-mature Jurassic is significant.

The localities in Scania with reworked Carboniferous spores are situated in the northwestern part of the Colonus Trough, and the Bornholm area is at the southeastern end (fig. 1). Jurassic deposits are absent in the central part mainly because of erosion caused by post-Jurassic inversion movements. However, initial upheaval of the Colonus Trough and the central part of the Scania fault zone by inversion tectonics may have already occurred during the Late Triassic and Early Jurassic (Kumpas 1984, Norling 1984, Norling & Bergström 1987). Such movements could have provided uplifted blocks with Carboniferous sediments which became source areas during the Jurassic. Based on the proportional frequency and degree of preservation of reworked Carboniferous spores in different well sections in Scania, Guy-Ohlson & Norling (1988) suggested that the »Söderåsen« block (fig. 1) was such a source area, indicating a very local origin.

Reworked Carboniferous spores are present in the major part of the Jurassic of Scania (Guy-Ohlson et al. 1987), but have only been found in the Lower Jurassic of Bornholm, except for a single specimen in the Middle Jurassic (Hoelstad 1985). This may suggest that erosion of the Bornholm High during the Early to Middle Jurassic progressed downwards through a Carboniferous and lower Palaeozoic sedimentary cover down to the crystalline basement. Alternatively, it may indicate that the dominating source area of the Bagå Formation at the type locality was the immediately adjacent basement horst, also as indicated by the large boulders of kaolinized basement embedded in the formation.

Conclusion

Reworked Carboniferous spores occur commonly in Jurassic deposits of Europe (Windle 1979) and is in most cases related to local reworking of Carboniferous rocks. The common presence of Carboniferous spores in the Lower Jurassic on Bornholm, and in the Lower, Middle, and Upper Jurassic of Scania, suggests that sediments of late Visean to Namurian age were originally present in Scania and possibly also on Bornholm. It is proposed that the Carboniferous deposits were preserved in the down-faulted Colonus Trough until the Jurassic as a result of Permo-Carboniferous transtensional fault movements. During the initial uplift of the area in Late Triassic to Early Jurassic time with associated local block faulting, the Carboniferous deposits were exposed and eroded. Owing to further inversion during the Kimmerian tectonic phases, source areas with Carboniferous deposits were continually renewed during the Jurassic as indicated by the occurrence of Carboniferous spores in the major part of the Swedish Jurassic.

The former presence of Carboniferous deposits in the Scania-Bornholm area makes it possible that equivalent deposits are preserved in down-faulted areas around Bornholm such as the Rønne Graben, where subsidence occurred during most of the Mesozoic Era. If present, such rocks may possess an exploration potential, as Carboniferous strata are important sources of hydrocarbons in many fields in northwest Europe (e.g. Bartenstein 1979).

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Dansk sammendrag

Palynologisk analyse af aflejringer fra nedre jura på Bornholm har vist, at karbone sporer forekommer sporadisk i en palynomorf flora af hettangien til sinemurien alder. Tilsvarende omlejrede karbone sporer er også fundet i øvre trias og jura aflejringer i Skåne. Deres hyppighed og forholdsvis velbevarede form udelukker lang og gentagen transport. Tilstedeværelsen af de karbone sporer er interessant, *fordi* karbone aflejringer ikke findes i dag i det jurassiske kildeområde, som hovedsagelig var det Fennoskandiske Skjold. Karbone aflejringer findes i dag i området syd for Ringkøbing-Fyn Højderyggen og Arkona blokken, men det kan udelukkes, at sporerne stammer fra dette område. Det foreslås derfor, at karbone sedimenter af sen viséen til namurien A alder blev aflejret i Skåne- og Bornholmsområdet og hovedsageligt blev bevaret i områder som Colonus Truget og Rønne Graven, der var præget af extension tektonik i sen karbon – tidlig perm. På grund af hævning i sen trias og jura blev de karbone aflejringer eroderet og palynomorferne indlejret i yngre sedimenter. Hvis karbone aflejringer endnu er tilstede i Rønne Graven, kan de øge prospektiviteten af området, idet karbone aflejringer er vigtige moderbjergarter for hydrokarboner i mange felter i nordvest Europa.

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