Early Carboniferous (Mississippian) miospore assemblage from Persian Gulf, Southwest Iran

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Abstract
A Mississippian miospore assemblage has been recorded from well A in the Persian Gulf in Iranian offshore, for the first time. Fifteen species of spores have been recognized in the Early Carboniferous assemblage of this well which the most important of them are: *Spelaeotriletes arenaceus, Aratrisporites saharaensis, Spelaeotriletes balteatus, Spelaeotriletes triangulus* and *Radiizonates arcuatus*. Comparing this assemblage with their coevals from the North Africa, Middle East, Western Australia and South America reveals a very close similarity indicating the Gondwanic nature of the assemblage. Also, the Carboniferous strata in this area can be correlated with the Berwath Formation in Saudi Arabia. Based on the palynological data two hiatuses have been rcognized at the base and top of the Carboniferous strata.

Keywords: *Carboniferous; Mississippian; Gondwana; Miospore; Persian Gulf.*

Introduction

The exploratory borehole A, located in the Iranian offshore of Persian Gulf, drilled by the National Iranian Oil Company (NIOC) in 2014 (Fig. 1). Although, the Carboniferous strata are not well known in Zagros and are limited only to a few boreholes in the Southwest of the Zagros fold and thrust belt (Sabouri *et al.,* 2014). They are well known and described from the neighboring Saudi Arabia (Clayton, 1995; Clayton *et al.,* 2000). Therefore, it is important to search and report these rock units due to their paleogeographical position.

The Carboniferous deposits of the Central, Northern and Southwestern Iran have previously been investigated palynologically by Ghavidel–Syooki & Owens (2007), Sabouri *et al.* (2014), Aria–Nasab *et al.* (2016), Sabbaghiyan & Aria–Nasab (2016), Sabbaghiyan (2011; 2016). The first report on the miospore assemblages from the Carboniferous of Southwest Iran (Zagros fold and thrust belt) published by Sabouri *et al.* (2014). They examined cuttings of three boreholes in Fars area and assigned Visean–?early Serpukhovian age to the strata.

Materials and methods

Fourty cutting samples of dark colored, shaly sandstones and shales were collected from well A and prepared in the palynology laboratory of the National Iranian Oil Company (NIOC) for their palynomorph contents. Of these, 16 samples were productive and yielded miospores. Each sample was washed by runnig water to remove drilling mud and 30 grams of each sample were prepared by the method of Traverse (2007). Cold hydrochloric (10%) and hydrofluoric (40%) acids were used to dissolve carbonates and silicates. The residue was neutralized and centrifuged in ZnCl2 (specific gravity 1.9), then sieved with a 15 µm nylon mesh and mounted on microscopic slides using liquid Canada balsam. Two slides were made from each sample. The microscope slides were examined with an optical microscope and the index spore species were photographed and presented in Plates 1–2. All slides are housed at the Palynology laboratory of the National Iranian Oil Company.

Lithostratigraphy

Carboniferous deposits in well A are 82 m thick and composed of alternations of sandy claystone and sandy shale interbedded with thin bedded sandstone (Fig. 2). These strata here unconformably overlie the Zakeen Formation (Upper Devonian) and are overlain unconformably (an evidence of Hercynian Unconformity) by the Faraghan Formation recently attributed by Spina *et al*. (2018) to the Middle Permian. From lithological point of view, the Carboniferous rock unit in this well can be separated easily from the lower and upper rock units (Fig. 3).

Palynology and palynostratigraphy

In most of the investigated productive slides,

miospores are relatively abundant, diverse and well preserved. *Aratrisporites saharaensis, Calamospora liquida*, *Cingulizonates bialatus, Cyclogranisporites firmus, Densosporites spitsbergensis*, *Densosporites anulatus*, *Grandispora maculosa, Indotriradites daemonii*, *Radiizonates arcuatus*, *Vallatisporites vallatus, Tricidarisporites serratus, Spelaeotriletes arenaceus, Spelaeotriletes balteatus, Spelaeotriletes triangulus* and *Spelaeotriletes* sp. are the main palynomorphs recorded.

Figure 1. Location map of the studied well.

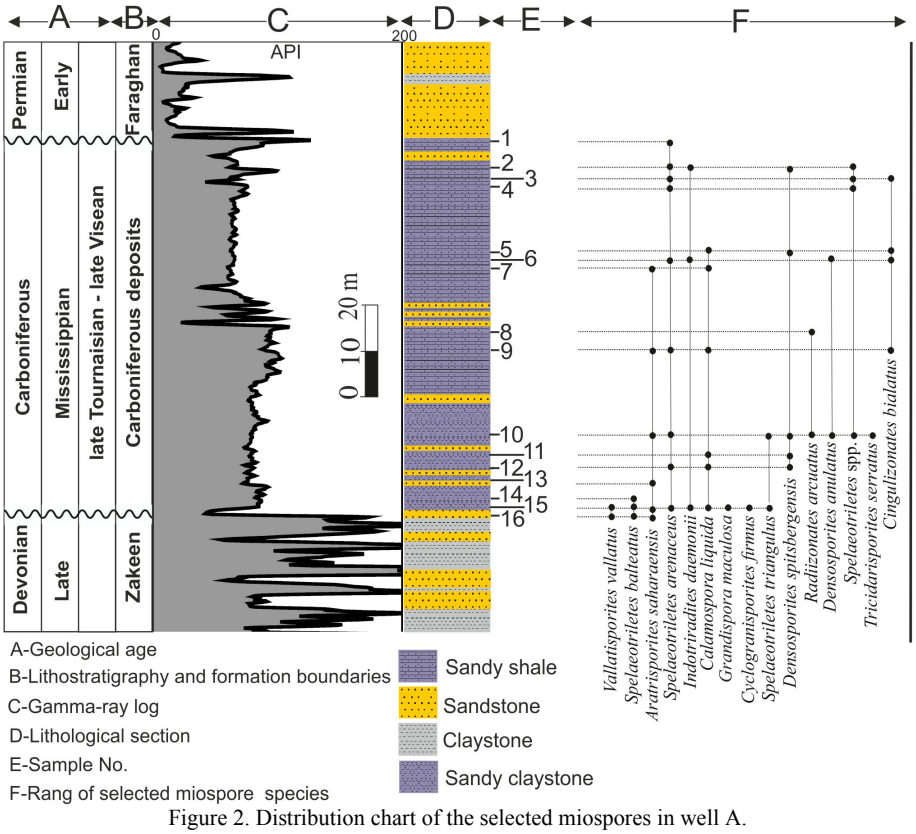

Figure 2. Distribution chart of the selected miospores in well A.

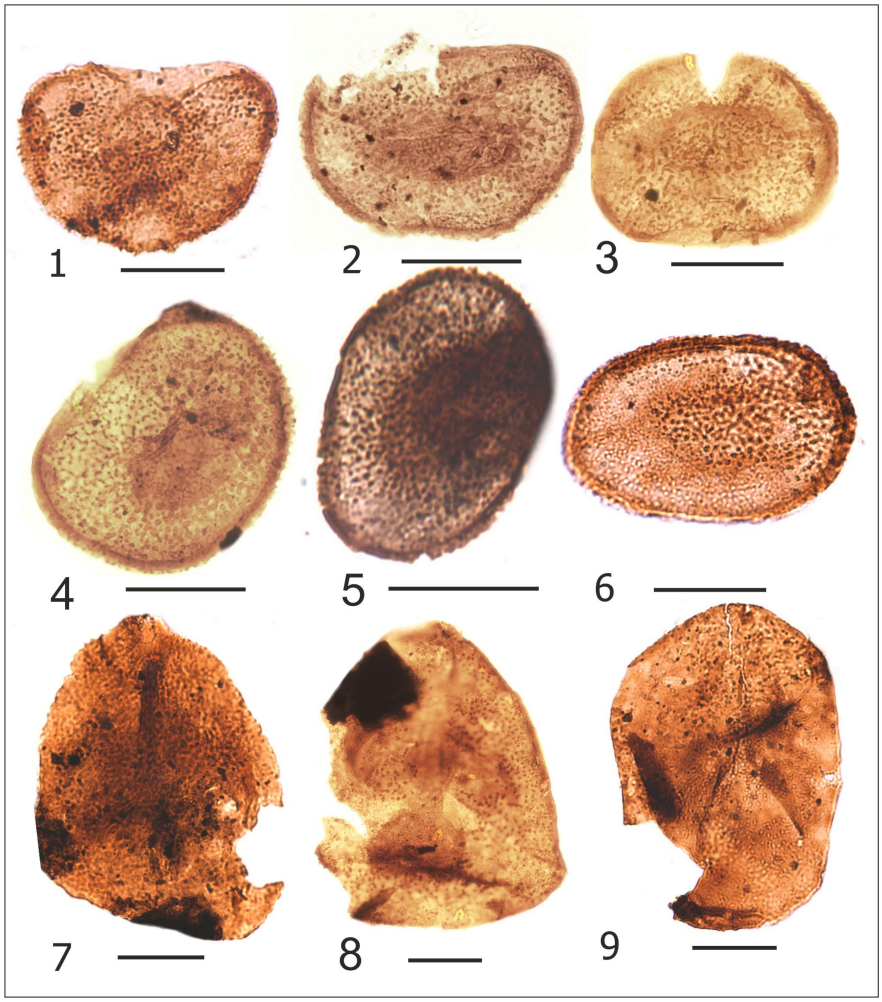

Plate 1. 1–3. *Aratrisporites saharaensis* Loboziak, Clayton & Owens, 1986. 1. Sample 13, 2. Sample 1, 3.sample 16. 4–5. *Spelaeotriletes balteatus* (Playford) Higgs, 1975. Sample 16. 6. *Aratrisporites saharaensis* Loboziak, Clayton & Owens, 1986. Sample 15. 7. *Spelaeotriletes sp.* sample 10. 8–9. *Spelaeotriletes arenaceus* Neves and Owens, 1966. 8. Sample 16, 9. Sample 10. Scale bar represent 25 µm

Most of these species have been reported from other parts of Gondwana such as Saudi Arabia (Clayton, 1995; Clayton *et al.,* 2000), Australia (Playford & Mory, 2017), Niger (Coquel *et al.,* 1995), Algeria (Coquel & Abdesselam–Rouighi, 2000), Libya (Massa *et al.,* 1980; Loboziak & Clayton, 1988), Morocco (Playford *et al.,* 2008) and Brazil (Melo & Loboziak, 2000).

Aratrisporites saharaensis is palaeogeographically a characteristic element of the Early Carboniferous North African *"Aratrisporites saharaensis* Microflora" (Clayton, 1985; Clayton, 1991) (Fig. 4). This species is known from late Visean deposits of Northern, Eastern and Western Gondwana (Clayton, 1995; Clayton *et al.,* 2000; Coquel & Abdesselam–Rouighi, 2000; Playford & Mory, 2017; Melo & Loboziak, 2000).

The species has also been reported from Early Carboniferous (late Tournaisian) deposits of Central Iran (Sabbaghiyan & Aria–Nasab, 2016; Aria–Nasab *et al.,* 2016; Sabbaghiyan, 2016) and Brazil (Playford *et al.,* 2012; Loboziak *et al.,* 1998).

The presence of this index spore in well A can show the relation between Iran and Gondwanan realm during this period of time.

In Northern Gondwana region *Spelaeotriletes arenaceus* has been recognized from late Visean strata (Playford *et al.,* 2008; Coquel & Abdesselam–Rouighi, 2000; Clayton *et al.,* 2000; Coquel *et al.,* 1995).

Densosporites anulatus has been recorded from the Tournaisian–Moscovian age, in Ambo Formation in Peru (Azcuy & di Pasquo, 2005).

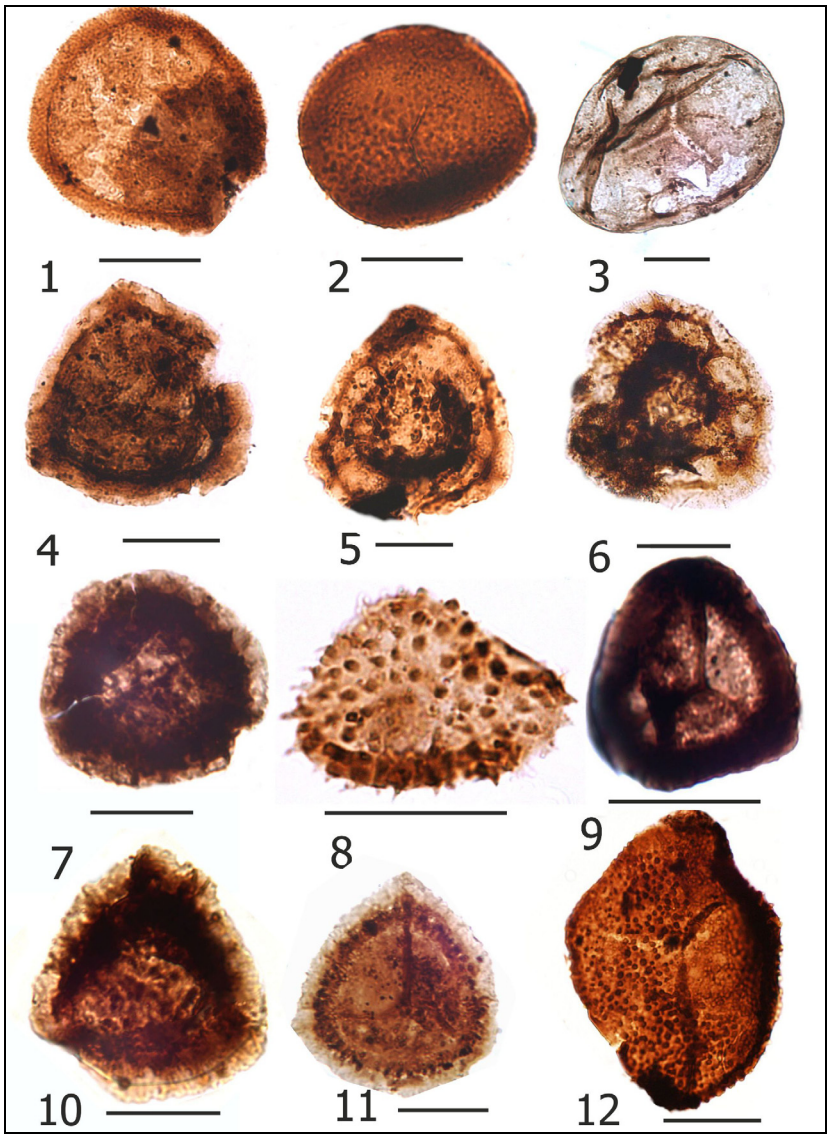

Plate 2. 1. *Grandispora maculosa* Playford & Helby, 1968. Sample 1. 2. *Cyclogranisporites firmus* Jones & Truswell, 1992. Sample 15. 3. *Calamospora liquida* Kosanke, 1950. Sample 5. 4. *Indotriradites daemonii* Loboziak et al., 1999. Sample 15. 5–6. *Radiizonates arcuatus* Loboziak et al., 2000. 5. Sample 10, 6. Sample 7. 7. *Cingulizonates bialatus* (Waltz) Smith and Butterworth, 1967. Sample 9. 8. *Tricidarisporites serratus* (Playford) Sullivan & Marshall 1966. Sample 10. 9. *Densosporites anulatus* (Loose) Smith and Butterworth, 1967. Sample 11. 10. *Densosporites spitsbergensis* Playford, 1963. Sample 10. 11. *Vallatisporites vallatus* Hacquebard, 1957. Sample 15. 12. *Spelaeotriletes triangulus* Neves and Owens, 1966. Sample 15. Scale bar represent 25 µm

Spelaeotriletes triangulus is important zonal species of the late Visean to early Serpukhovian. In northeast Libya and the base of the RT biozone is defined on the first appearances of this species and *Prolycospora rugulosa* (Clayton *et al.,* 2000; Loboziak & Clayton, 1988). *Aratrisporites saharaensis, Cingulizonates bialatus, Densosporites spitsbergensis*, *Indotriradites dolianitii*, *Radiizonates arcuatus*, *Spelaeotriletes arenaceus* and *Spelaeotriletes triangulus* have been reported from Visean deposit in Parnaba Basin, Northern Brazil (Melo & Loboziak, 2000).

Miospores as *Aratrisporites saharaensis*, *Cyclogranisporites firmus, Grandispora maculosa* and *Indotriradites daemonii* have been recorded from middle to late Visean *Grandispora maculosa* biozone of Western Australia (Playford & Mory, 2017).

Spelaeotriletes balteatus has been recorded from Tournaisian age within the *Spelaeotriletes balteatus–Rugospora polyptycha* (BP) and *Spelaeotriletes pretiosus–Raistrickia clavata* (PC)

biozones of Ireland (Brittain & Higgs, 2007) and Belgium (Higgs, 1996).

Several specimens of *Retispora lepidophyta* were recorded as reworked. Also this species has been recorded as reworked miospore in Carboniferous sediment in Saudi Arabia (Clayton, 1995; Clayton *et al.,* 2000; Owens *et al.,* 2000), Northeastern Brazil (Playford *et al.,* 2012) and Australia (Playford & Mory, 2017).

The palynoflora of the Carboniferous strata in well A show a close similarity to the Early Carboniferous palynofloras reported from other parts of Gondwanan regions indicating the Early Carboniferous (late Tournaisian–late Visean) age for this assemblage.

Discussion

The Carboniferous deposits of Saudi Arabia are represented by the Berwath Formation and only identified in subsurface sections (Powers, 1968). The type locality of the Berwath Formation is situated in well ST–8 in northern Saudia Arabia. In South of the Persian Gulf, the Berwath Formation has been recorded in wells 1, 2, 4–6 (Craigie *et al.,* 2016) and Abu Safah–29 well (Clayton, 1995; Clayton *et al.,* 2000) with late Tournaisian–early Serpukhovian age.

Clayton (1995) and Clayton *et al.* (2000) identified the Carboniferous miospores of three wells in Saudi Arabia. In Arabian side of Persian Gulf, Clayton *et al.* (2000) reported several miospore species such as *Aratrisporites saharaensis*, *Spelaeotriletes triangulus*, *Radizonates genuinus, prolycospora rugulosa* and *Spelaeotriletes arenaceus* with late Visean age from upper part of Berwath Formation in Abu Safah–29 well. Also, Hooker *et al.* (2011) reported two biozone (C4–C5) with late Tournaisian–late Visean age from Berwath Formation in Saudi Arabia.

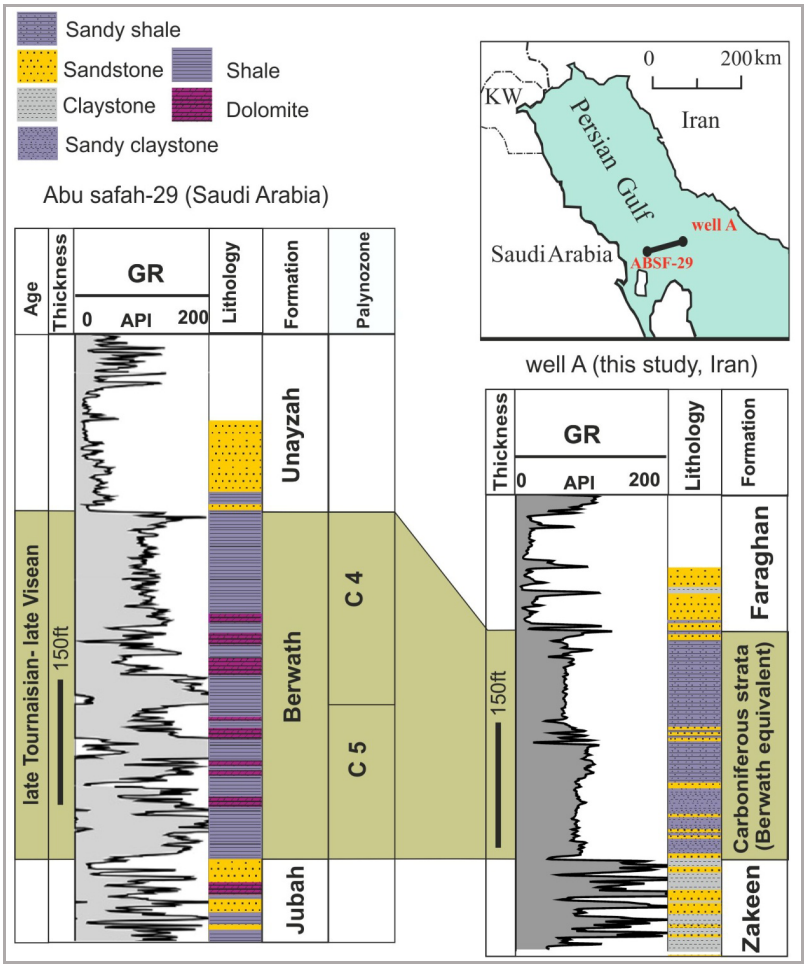

Figure 3. Lithostratigrapic comparison between the Carboniferous deposits of well A in southwest Iran with Berwath Formation of Abu Safah–29 (Gamma ray after Craigie *et al.,* 2016; Lithology redrawn from Clayton *et al.,* 2000) in SaudiArabia

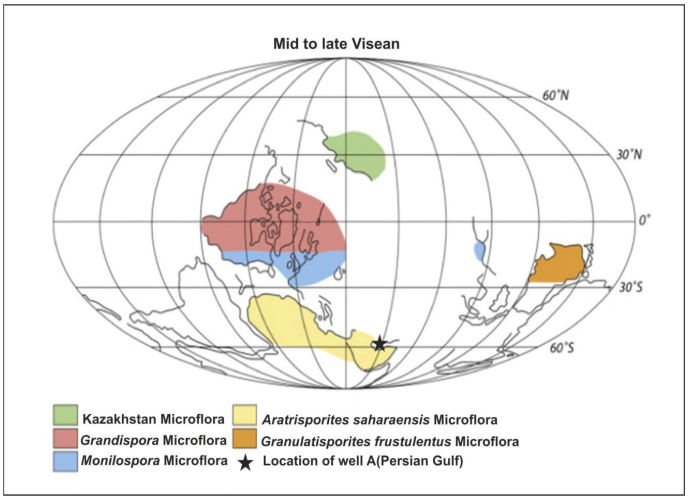

Figure 4. Distribution of Early Carboniferous (lateVisean) Microflora (after Lopes *et al.,* 2016).

Miospore assemblage of well A can be correlated to these two Biozones. For the first time in this study, Carboniferous deposits were identified in Iranian side of Persian Gulf. The recognized Early Carboniferous assemblage of this well dominantly contains *Spelaeotriletes arenaceus* and *Aratrisporites saharaensis*. Also the index species of Visean such as *Cingulizonates bialatus* and *Grandispora maculosa* are present in this assemblage.

However, all of these miospores more or less are quite similar to those of the Gondwanan realm. Also, the examined strata in well A are similar in fossil content and lithology to Berwath Formation of Saudi Arabia. The Carboniferous deposits in Iranian side of Persian Gulf (well A) are compared with their coeval deposits (Fig. 3) mainly from Arabian side of Persian Gulf (Abu Safah–29). The palynological evidence indicates the disconformity between Zakeen and Carboniferous deposits in this well can be assigned to the period of erosion because the latest Devonian index miospores (e.g. *Retispora lepidophyta*) appear as reworked specimen in carboniferous strata.

Conclusions

Moderate diversity and well–preserved palynofloras have been recorded from Early Carboniferous strata in well A of the Persian Gulf Southwest Iran that dominated by miospores. Based on the stratigraphic value of the recognized miospore taxa and comparison with other parts of the Gondwana a late Tournaisian–late Visean age attributed to the assemblage. Biostratigraphical data indicate two hiatuses in the base and top of the Carboniferous strata. The late Tournaisian–late Visean assemblage from well A in Southwest Iran is very similar to coeval Gondwanan assemblage (Algeria, Saudi Arabia, Libya, Morocco, north Brazil, Australia, Central and North Iran). Also, the examined Carboniferous strata in well A are lithologically similar to the Berwath Formation of Saudi Arabia and they are differentiated from the overlying (Faraghan) and underlying (Zakeen) deposits.

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References

Aria–Nasab, M., Spina, A., Cirilli, S., Daneshian, J., 2016. The palynostratigraphy of the Lower Carboniferous (middle Tournaisian–late Viséan) Shishtu Formation from the Howz-e-Dorah section, southeast Tabas, Central Iranian Basin. Palynology, 40: 247–263.

Azcuy, C.L., di Pasquo, M.M., 2005. Early Carboniferous palynoflora of the Ambo Formation, Pongo de Mainique, Perú. Review of Palaeobotany and Palynology, 134 (3–4):153–184.

Brittain, M., Higgs, K., 2007. The early Carboniferous *Spelaeotriletes balteatus – S. pretiosus* Miospore Complex:

Defining the base of the *Spelaeotriletes pretiosus–Raistrickia clavata* (PC) Miospore Biozone. Comunicações Geológicas, 94: 109–123

Clayton, G., 1985. Dinantian miospores and intercontinental correlation. *Compte Rendu 10th International Congress on Carboniferous Stratigraphy and Geology* (Madrid, 1983), 4: 9–23.

Clayton, G., Loboziak, S., Streel, M., Turnau, E., Utting, J., 1991. Palynological events in the Mississippian (Lower Carboniferous) of Europe, North Africa and North America. Courier Forsch.–Inst. Senckenb, 130: 79–84 (imprinted1990).

Clayton, G., 1995. Carboniferous miospore and pollen assemblages from the Kingdom of Saudi Arabia. Review of Palaeobotany and Palynology, 89: 115–123.

Clayton, G., Owens, B., Al–Hajri, S.A., Filatoff, J., 2000. Latest Devonian and early Carboniferous miospore assemblages from Saudi Arabia. In: Al–Hajri, S.A., Owens, B. (Eds.), Stratigraphic Palynology of the Paleozoic of Saudi Arabia, 1. GeoArabia Spec. Publ., pp. 146–153.

Coquel, R., Lang, J, Yahaya, M., 1995. Palynologie du Carbonifère du Nord Niger et de la plateforme saharienne–implications stratigraphiques et paléogeographiques. Rev Palaeobot Palynol, 89: 319–334.

Coquel, R., Abdesselam–Rouighi, F., 2000. Révision palynostratigraphique du Dévonien terminal–Carbonifère Inférieur dans le Grand Erg Occidental (Bassin de Béchar), Sahara algérien. Rev. Micropaléontol, 43: 353–364

Craigie, N.W., Breuer, P., Khidir, A., 2016. Chemostratigraphy and biostratigraphy of Devonian, Carboniferous and Permian sediments encountered in eastern Saudi Arabia: An integrated approach to reservoir correlation. Marine and Petroleum Geology, 72: 156–178.

Ghavidel–Syooki, M., Owens, B., 2007. Palynostratigraphy and palaeogeography of the Padeha, Khoshyeilagh, and Mobarak formations in the eastern Alborz Range (Kopet–Dagh region), northeastern Iran. Revue de micropaleontology, 50: 129–144.

Higgs, K., 1996. Taxonomic and systematic study of some Tournaisian (Hastrian) spores from Belgium. Review of Palaeobotany and Palynology, 93: 269–297.

Hooker, N., Breuer, P., Tourqui, H., 2011. Palynostratigraphy and palaeoenvironments of the Mississippian to Pennsylvanian succession in the subsurface, northern Saudi Arabia. In: Håkansson, E., Trotter, J.A. (Eds.), Programme & Abstracts: the XVII International Congress on the Carboniferous and Permian. Geological Survey of Western Australia. Record 2011/20, 70.

Loboziak, S., Clayton, G., 1988. The Carboniferous palynostratigraphy of Northeast Libya. In: El–Arnauti, A., Owens, B. and Thusu, B., Eds. Subsurface Palynostratigraphy of Northeast Libya, 129–149. Benghazi: Garyounis University Press.

Loboziak, S., Melo, J.H.G., Streel, M., 1998. Reassessment of Viséan miospore biostratigraphy in the Amazon Basin, northern Brazil. Review of Palaeobotany and Palynology, 104: 143–155.

Lopes, G., Mangerud, G., Clayton, G., Mørk, A., 2016.New insightson east Finmark Platform palynostratigraphy and paleogeography–A studyof three shallow cores from a Mississippian in the Barents sea, Norway.Palaeogeography, Palaeoclimatology, Palaeoecology, 450: 60–76.

Massa, D, Coquel, R., Loboziak, S., Taugourdeau–Lantz J. 1980. Essai de synthese stratigraphique et palynologique du Carbonifere en Libye occidentale. Ann. Soc. Geol. Nord 99: 429–442.

Melo, J.H.G., Loboziak, S., 2000. Visean miospore biostratigraphyand correlation of the Poti Formation (Parnaba Basin, northern Brazil). Review of Palaeobotany and Palynology, 112: 147–165.

Playford, G., Gonzalez, F., Moreno C. & Al Ansari A. 2008. Palynostratigraphy of the Sarhlef Series (Mississippian), Jebilet Massif, Morocco. Micropaleontology, 54: 89–124.

Playford, G., Melo, J.H.G., 2012. Miospore palynology and biostratigraphy of Mississippian strata of the Amazonas Basin, northern Brazil. Part one. Amer. Assoc. Strat. Palyn.Found, Contrib. Ser., 47: 1–89.

Playford, G., Mory, A.J., 2017.Composition and occurrence of the Grandispora maculosa zonal assemblage (Mississippian) in the subsurface of the Carnarvon basin and the Coolcalalaya sub basin of Western Australia, and its Gondwanan distribution. Rivista Italiana di Paleontologia e Stratigrafia, 123(2): 275–318.

Owens, B., Filatoff, J., Clayton, G., Al–Hajri, S.A., 2000. Evidence of mid–Carboniferous miospore assemblages from Central Saudi Arabia. In: Al–Hajri, S.A., Owens, B. (Eds.), Stratigraphic Palynology of the Paleozoic of Saudi Arabia, 1. GeoArabia Spec. Publ., pp. 154–167.

Powers, R.W., 1968. Lexique Stratigraphique International. Volume III, Asie, fas 10b 1, Arabia Saudite. CNRS, Paris, 177 p.

Sabbaghiyan, H., Aria–Nasab, M., 2016. Late Devonian–Early Carboniferous miospores and acritarches from the southern Tabas block (Zarand region) Central Iran. International congress on palaeozoic stratigraphy of Gondwana. Perugia, Italy, abstract book, 51.

Sabbaghiyan, H., 2016. Palynostratigraphy of the upper Devonian–Lower Carboniferous strata in the Gazestan stratigraphic section (southern Tabas block). NIOC Internal report No.897: 1–15.

Sabbaghiyan, H., 2011. Late Devonian–Early Carboniferous palynological study on the surface of the Shishtu and Sardar formations, Tabas Block, Central Iran. NIOC Internal Report No.823:1–32.

Sabouri, J., Mahmoudi, M., Sabbaghiyan, H., Aria–Nasab, M., 2014. The first evidences of Carboniferous (Middle–?Late Mississippian) sediments in Zagros Basin, Iran and its palaeogeographic implications. Abstract Volume and Proceedings of the Third International Symposium of the IGCP– 589, Development of the Asian Tethyan Realm: Genesis, Process and Outcomes: 29–34.

Spina, A., Stephenson, M.H., Cirilli, S., Aria–Nasab, M., Rettori, R., 2018. Palynostratigraphy of the Faraghan Formation in the Zagros basin, Southern Iran. Rivista Italiana di Paleontologia e Stratigrafia, 124(3): 573–595.

Traverse, A., 2007. Paleopalynology. Topics in Geobiology, second ed. Springer, Dordrecht, The Netherlands, 813 pp.