NEW DATE FOR THE LOWER PART OF THE KUHLAN FORMATION, NORTHWEST YEMEN

Mike H. Stephenson and Sa'ad Zeki A. Kader Al-Mashaikie

.

ABSTRACT

The siliciclastic beds outcropping around the village of Kuhlan, northwest Yemen were originally designated the Kohlan Series. Later the sandstone part of the sequence was renamed the Kuhlan Formation by the Yemeni Stratigraphic Commission. The lower part of the Kuhlan Formation (Unit A) yielded diverse and well preserved palynological assemblages. Their quantitative character and the presence of *Anapiculatisporites concinnus*, *Brevitrietes cornutus*, *B. parmatus, Deusilities tentus*, *Dibolisporites disfacies*, *Microbaculispora tentula, Spelaeotriletes triangulus* and *Verrucosisporites andersonii*, suggests a confident correlation to the 2165A to 2141A biozones of southern Oman, and to Arabian OSPZ2, indicating a late Carboniferous to earliest Permian age for the unit rather than the late Triassic to early Jurassic age given on the geological map of western Yemen. The date for the lower Kuhlan Formation indicates that the underlying Akbra Formation is probably not younger than the 2165A Biozone and therefore likely to be equivalent to the lower parts of the Al Khlata Formation of Oman.

INTRODUCTION

The siliciclastic beds outcropping around the village of Kuhlan, northwest Yemen, were originally designated the Kohlan Series by Lamar & Carpenter (1932). Later the sandstone part of the sequence was renamed the Kuhlan Formation by the Yemeni Stratigraphic Commission (Beydoun et al., 1998). Kuhlan village, where the type section and several typical outcrops of the Kuhlan Formation are situated, is located about 70 km northwest of Sana'a city (Fig. 1). There the formation has a thickness of about 200 m but also crops out in a narrow belt in the mountains of the high plateau of northwest Yemen. It wedges out southward having a thickness of 10 m at Jabal Bura'a and 14 m at Wadi Maksab (Kruck and Thiele, 1983; Beydoun et al., 1998). The formation extends subsurface east and northeastwards and is encountered in several oil wells in the Ma'rib-Jawf graben and Rub'Al-Khali basin (Diggens et al., 1988; Beydoun et al., 1998). The Kuhlan Formation overlies the dominantly argillacous Akbra Formation.

Lithologically, the Kuhlan Formation consists of yellowish brown, pinkish and red, massive, cross-bedded, medium to fine-grained sandstone, which is interbedded with thick, fissile and stratified siltstone/shale beds of grey to red colour (Fig. 2; Kruck & Thiele, 1983; Diggens et al., 1988; Beydoun et al., 1998). Al-Mashaikie (2005) described ten lithofacies types within the Kuhlan Formation. The lower part of the formation (Unit A of Al-Mashaikie, 2005), from which the palynological samples from this study came, consists of a series of alternating sandstones and fissile mudstones (Fig. 2). Plate 1 shows a range of lithofacies in Unit A of Al-Mashaikie (2005).

Unit A contains no macrofossils and overall the Kuhlan Formation lacks fossils apart from the uppermost 6–10 m which are composed of sandstone with intercalations of red and gray shale, marl and calcareous sandstone. These upper beds contain mollusc shells and a thin calcareous layer with plant impressions (Kruck & Thiele, 1983; Kruck et al. 1991). On this basis, Diggens et al. (1988) considered the age of the upper beds of the Kuhlan Formation to be late Triassic to early Jurassic. The Kuhlan Formation as a whole is portrayed as late Triassic to early Jurassic on the geological map of western Yemen (Kruck et al., 1991).

Samples of argillaceous layers of Unit A of the Kuhlan Formation were collected by the second author in 2008 with the aim of dating the unit using palynological assemblages.

PREVIOUS PALYNOLOGICAL STUDIES

There have been two previous attempts to date rocks in the Kuhlan area using palynology. Kruck et al. (1983) collected samples of grey claystone lithologies of the Akbra Formation (which underlies the Kuhlan Formation) from unspecified exposures along the Kuhlan – Hajjah road (Fig. 1; Neves *in* Kruck and Thiele 1983). The organic residues recovered by Neves contained abundant vitrinite or detrital wood fragments and a palynomorph population consisting of *Apiculatisporis* spp., *A.* aff. *abditus, Acanthotriletes* sp., *Cordaitina* sp., *Kraeuselisporites apiculatus*, *K. punctatus, Leiosphaeridia, Potonieisporites novicus, Protohaploxypinus goraiensis, P. jacobii , Punctatisporites* sp., *Reticulatisporites* sp., *Tympanicysta* sp. and

Vestigisporites sp. The assemblages were interpreted as being of Permian, possibly Early Permian age.

El-Nakhal et al. (2002) reported on six samples collected from the Akbra Formation at the Beit Al-Kooli section (2 km from southwest of Kuhlan village; Fig. 1). El-Nakhal et al. (2002) used a different lithostratigraphic nomenclature to that adopted here (and by the Yemeni Stratigraphic Commission) referring to a lower Sharas Siltstone Member (of the Kooli Formation = Akbra Formation) and an upper Khalaqah Shale Member (Fig. 3). The samples contained few palynomorphs and were dominated by dark brown and opaque wood fragments of probable land plant origin. Only two samples from the lower part of the Khalaqah Shale Member yielded palynomorphs including *Alisporites* cf. *indarraensis, Brevitriletes* cf. *cornutus, Cristatisporites* cf. *crassilabratus, ?Diatomozonotriletes* sp., *Deusilites tentus*, *Leiosphaeridia* sp., *Leiotriletes* cf. *directus, Plicatipollenites malabarensis, Pteruchipollenites* sp., *Rugospora* sp., *Verrucosisporites* sp., and indeterminate non-taeniate biasaccate pollen. These allowed only a tentative Late Carboniferous to Early Permian age for the lower part of the Khalaqah Shale Member.

MATERIALS AND METHODS

A number of samples were collected from the Kuhlan village type section (Fig. 2) and of these two (AF-5 and AF-8; dark grey siltstones) yielded well preserved and diverse

assemblages allowing application of palynological biozonal schemes of Oman and other parts of the Arabian peninsular. The preparation of strew mounts for palynological analysis comprised crushing, followed by hydrochloric and hydrofluoric acid treatments (Wood et al., 1996). The post-hydrofluoric acid organic residues were oxidized using Schulze's solution and dilute nitric acid. The slides are held in the Collection of the British Geological Survey, Keyworth, Nottingham, UK, NG12 5GG.

CHARACTER AND AGE OF THE PALYNOLOGICAL ASSEMBLAGES

The slides contain a rich organic residue consisting of brown well preserved palynomorphs, woody and sheet cellular material, and rare amorphous organic matter (Fig. 2). The full author citations of palynological taxa recorded are given in Appendix 1; selected taxa are shown in Plates 2 and 3.

The most common taxa are indeterminate monosaccate pollen (mainly radially-symmetrical forms, probably poorly preserved specimens of *Cannanoropollis Potonieisporites* and *Plicatipollenites*), *Cristatisporites* spp., *Cannanoropollis janakii*, *Deusilites tentus* and *Leiosphaeridia* sp. Other common taxa include *Brevitrietes cornutus*, *B. parmatus*, *Dibolisporites disfacies*, *Microbaculispora tentula* and

Verrucosisporites andersonii. There are no marked differences in the two samples, though the upper sample is slightly more diverse.

The quantitative character and the presence of *B. cornutus*, *B. parmatus, D. tentus*, *D. disfacies*, *M. tentula* and *V. andersonii* suggest close similarity with assemblages from the Al Khlata Formation of Oman. In particular, the presence of *Anapiculatisporites concinnus* and *Spelaeotriletes triangulus* suggests a confident correlation to the 2165A to 2141A biozones of south Oman (Penney et al., 2008) and to biozones B and C of the south Oman Mukhaizna Field (Stephenson et al., 2008) which correspond to the lower part of the general Arabian OSPZ2 Biozone of Stephenson et al. (2003). The 2165A to 2141A biozones correspond to the middle part of the Al Khlata Formation of Oman (PDO Production Units lower P1 and upper P5).

The 2165A to 2141A biozones, and biozones C and B of the Mukhaizna Field were originally considered Early Permian (Asselian to early Sakmarian) based on correlations with faunally-calibrated palynological biozones in Western Australia, in particular on dates established for the *Converrucosiporites confluens* Oppel Zone (see Stephenson, 2008, 2009). Recent work on radiometrically-dated sequences in Namibia (Stephenson, 2009) has shown that the range of *Converrucosiporites confluens* and the eponymous biozone probably extends lower than previously thought and therefore the 2165A to 2141A biozones (see Penney et al., 2008) may be slightly older than suggested by Penney et al. (2008). The Namibian data and data from the Brazilian Paraná Basin (César, 2007) suggest that the base of the *C. confluens* Oppel Zone is close to or below the Carboniferous-Permian boundary. The

age of its upper limit is uncertain, but in Oman is likely to be early Sakmarian (Angiolini et al., 2006). Thus the PDO 2165A to 2141A biozones and biozones C and B of the Mukhaizna Field probably extend into the latest Carboniferous (Fig. 4).

This new date for lower Kuhlan Formation indicates that the underlying Akbra Formation, which was previously dated by Neves *in* Kruck and Thiele (1983) and El-Nakhal et al. (2002) as Permian, possibly Early Permian age and Late Carboniferous to Early Permian respectively, is probably not younger than the 2165A Biozone and therefore likely to be equivalent to the lower parts of the Al Khlata Formation of Oman.

CONCLUSIONS

Two samples from the lower part of the Kuhlan Formation in northwest Yemen yieded diverse and well preserved palynological assemblages. Their quantitative character and the presence of *Anapiculatisporites concinnus*, *Brevitrietes cornutus*, *B. parmatus, Deusilities tentus*, *Dibolisporites disfacies*, *Microbaculispora tentula, Spelaeotriletes triangulus* and *Verrucosisporites andersonii* suggests a confident correlation to the 2165B to 2141A biozones of Oman (Penney et al. 2008).

A suite of samples was also collected from the higher parts of the Kuhlan Formation and it is hoped that this data will be reported in due course.

ACKNOWLEDGMENTS

Mike Stephenson publishes with the permission of the Executive Director of the British Geological Survey (NERC).

REFERENCES

Angiolini, L., M.H. Stephenson, and Y. Leven 2006. Correlation of the Lower Permian surface Saiwan Formation and subsurface Haushi Limestone, central Oman. GeoArabia, v. 11, p. 17-38.

Beydoun, Z.R., M. As-Sururi, H. El-Nakhal, I. Al-Ganad, R. Baraba, A. Nani, and M. Al-Awah 1998. International Lexicon of stratigraphy, vol., Asia, Fascicule 3(10b2), Republic of Yemen. IUGS publication No. 34: 245 p.

Césari, S.N. 2007. Palynological biozones and radiometric data at the Carboniferous-Permian boundary in western Gondwana. Gondwana Research, v. 11, p. 529-536.

Diggens, J., R. Dixon, R. Dowin, J. Harris, M. Jakubovski, S. Mathews, D. Southwood, and P. Ventris 1988. A geological model for the evolution of the Ma'rib-Jawd Basin, Yemen Arab Republic. Robertson Research International, Unpublished Report, No. 2616/Iib.

El-Nakhal, H. A., M. H Stephenson and B. Owens, 2002. New late Carboniferous – Early Permian palynological data from glacial sediments in the Kooli Formation, Republic of Yemen. Micropaleontology, v. 48, p. 222-228.

Kruck, W. and J. Thiele. 1983. Late Palaeozoic glacial deposits in the Yemen Arab Republic. Geologisches Jahrbuch, Reihe, v. B 46, p. 3–29.

Kruck, W., U. Scheffer and J. Thiele 1991. Geological map of the Republic of Yemen-western part (Former Yemen Arab Republic) Part-1 Explanatory notes. Report 156p. Federal Republic of Germany, Federal Institute for Geosciences and natural Resources (for the Ministry of Oil and Mineral Resources, Republic of Yemen). 1:500,000 Scale Map. Report: 156 p.

Lamare, P. and C.A. Carpenter 1932. Vegetaun fossils de Yemen. Bull. Sci. Geol. France, Ser. 5, 2, 83–92; Paris.

Mashaikie, S. Z. 2005. Lithofacies and petrography of siliciclastic red bed sequences: a new lithostratigraphic concept of the early Mesozoic Kuhlan Formation (NW Yemen). Freiberger Forschungshefte, C507: Palaontologie, Statigraphie, Fazies, v. 13, p. 27-47

Penney, R. A., I. Al Barram, and M. H. Stephenson 2008. A high resolution palynozonation for the Al Khlata Formation (Pennsylvanian to Lower Permian), South Oman. Palynology, 32, 213-231.

Stephenson, M.H., 2008. A review of the palynostratigraphy of Gondwanan Pennsylvanian to Lower Permian glacigene successions. In: Fielding, C.R., T.D. Frank and J.L. Isbell (Eds.), Resolving the Late Paleozoic Ice Age in Time and Space. Geological Society of America Memoir, 441, p. 317-330.

Stephenson, M. H. 2009. The age of the Carboniferous-Permian *Converrucosisporites confluens* Oppel Biozone: new data from the Ganigobis Shale Member, Dwyka Group, Namibia. Palynology, v. xx, p. xx.

Stephenson, M. H., P.L. Osterloff, and J. Filatoff 2003. Palynological biozonation of the Permian of Oman and Saudi Arabia; progress and challenges. GeoArabia, v. 8, p. 467-496.

Stephenson, M.H., A. Al Rawahi and B. Casey 2008. Correlation of the Al Khlata Formation in the Mukhaizna Field, Oman, based on a new downhole, cuttings-based palynostratigraphic scheme. GeoArabia, v. 13, p. 15-34.

Wood, G.D., A.M. Gabriel and J.C. Lawson 1996. Palynological techniques - processing and microscopy. In, J. Jansonius and D.C. McGregor (Eds.), Palynology: Principles and Applications. American Association of Stratigraphical Palynologists Foundation, Dallas, Texas, v. 1, p. 29-50.

APPENDIX – AUTHOR CITATIONS OF TAXA RECORDED

Alisporites cf. *indarraensis* Segroves, 1969

Anapiculatisporites concinnus Playford, 1962

Apiculatisporis aff. *abditus* (Loose) Potonié and Kremp, 1955

Brevitriletes cornutus (Balme and Hennelly) Backhouse, 1991

Brevitriletes parmatus (Balme and Hennelly) Backhouse, 1991

Cannanoropollis janakii Potonié and Sah, 1960

Converrucosisporites confluens (Archangelsky and Gamerro) Playford and Dino, 2002

Cristatisporites cf. *crassilabratus* Archangelsky and Gamerro, 1979

Deusilites tentus Hemer and Nygreen, 1967

Dibolisporites disfacies Jones and Truswell, 1992

Horriditriletes ramosus (Balme and Hennelly) Bharadwaj and Salujah, 1964

Horriditriletes uruguaiensis (Marques-Toigo) Archangelsky and Gamerro, 1979

Kraeuselisporites apiculatus Jansonius, 1962

Kraeuselisporites punctatus Jansonius, 1962

Leiotriletes cf. *directus* Balme and Hennelly, 1956

Lophotriletes sparsus Singh, 1964

Lundbladispora braziliensis (Pant and Srivastava) Marques-Toigo and Pons, 1976

Microbaculispora tentula Tiwari, 1965

Plicatipollenites malabarensis (Potonié and Sah) Foster, 1975

Potonieisporites novicus Bhardwaj, 1954 emend. Poort and Veld, 1997

Protohaploxypinus amplus (Balme and Hennelly) Hart, 1964

Protohaploxypinus goraiensis. (Potonié & Lele) Hart, 1964**,**

Protohaploxypinus jacobii (Jansonius) Hart,1964

Punctatisporites gretensis forma *minor* Hart, 1965

Spelaeotriletes triangulus Neves and Owens, 1966

Vallatisporites arcuatus (Marques-Toigo) Archangelsky and Gamerro, 1979

Verrucosisporites andersonii Backhouse, 1988

FIGURE CAPTIONS

Fig. 1. Location of studied section. A, Republic of Yemen; B, inset showing area of Kuhlan Formation type section.

Fig. 2. Lithology and palynology of the lower part of the Kuhlan Formation (Unit A).

Fig. 3. Comparison of lithostratigraphic nomenclature used in this paper and by El-Nakhal et al. (2002). Samples for this study come from Unit A of Al-Mashaikie (2005).

Fig. 4. Correlation of Oman and Arabian Peninsula biozones and correlative range of lower Kuhlan Formation, based on Stephenson et al. (2008). Age recalibration to the standard Permian stages follows Stephenson (2009).

PLATE 1

(a) General view of the Kuhlan and Akbra formations at the type section of the Kuhlan Formation; (b) Contact between Akbra (lower) and Kuhlan (upper) formations; (c) Out-sized clasts (dropstones) embedded within argillaceous matrix,

pen 9 cm long; (d) Diamictite facies between shale bed and sandstone bed, hammer 30 cm long.

PLATE 2

Palynomorphs of the lower part of the Kuhlan Formation. The specimen locations are given using the England Finder coordinate, then the slide number; dimensions for each specimen are also given. The final code is the BGS collection number (prefixed MPK). a, *Cristatisporites* sp. Q50, 58566, 54µm, MPK XXXXX; b, *Spelaeotriletes triangulus*, F51/4, 58566, 105 µm, MPK XXXXX; c, *S. triangulus*, H62, 58566, 80µm, MPK XXXXX; d, *S. triangulus*, Q65, 58566, 105µm, MPK XXXXX; e, *Complexisporites* sp., E58/1, 58566, 112µm, MPK XXXXX; f, *Dibolisporites disfacies*, E50/3, 58566, 42µm, proximal face, MPK XXXXX; g, *D. disfacies*, E50/3, 58566, 42µm, distal face, MPK XXXXX. h, *Anapiculatisporites concinnus*, H64, 58566, 34µm, distal face MPK XXXXX; i, *Anapiculatisporites concinnus*, H64, 58566, 34µm, proximal face, MPK XXXXX; j, *Microbaculispora tentula*, P67, 58566, 39µm, MPK XXXXX; k, *Brevitriletes parmatus*, Q60, 58566, 29µm, MPK XXXXX; l, *Brevitriletes cornutus*, S50/2, 58566, 42µm, MPK XXXXX; m, *Horriditriletes ramosus*, K66, 58566, 39µm, MPK XXXXX; n, *Cristatisporites* sp. M62/2, 58567, 73µm, MPK XXXXX.

PLATE 3

a, *Microbaculispora tentula*, N44/4, 58567, 33µm, MPK XXXXX; b, *Vallatisporites arcuatus*, F70, 58567, 60 µm, MPK XXXXX; c, *Vallatisporites arcuatus*, M55/2, 58567, 82µm, MPK XXXXX; d, *Potonieisporites* sp., R59, 58567, 104µm, MPK XXXXX; e, *Brevitriletes parmatus*, P61/4, 58567, 33µm, MPK XXXXX; f,

Lundbladispora braziliensis, N44, 58567, 48µm, MPK XXXXX; g, *Lundbladispora braziliensis*, J65, 58567, 60µm, MPK XXXXX; h, *Deusilites tentus*, F49/4, 58567, 83µm, MPK XXXXX.

ABOUT THE AUTHORS

Mike H. Stephenson, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, email: mhste@bgs.ac.uk

Sa'ad Zeki A. Kader Al-Mashaikie, Consultant, Geological Survey and Mineral Resources Board, Sana'a, Yemen. E-mail: geozakee@yahoo.com