Palynostratigraphic correlation of the Sardhai Formation (Permian) of Pakistan

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Abstract

Palynological assemblages from the Sardhai Formation shale (Permian), lying between the red-bed Warchha Formation and the Amb Formation limestones in the Salt and Khisor ranges of Pakistan contain abundant bisaccate pollen grains and few spores. In particular, well-preserved specimens of *Florinites* ?*balmei*, a bilaterally symmetrical monosaccate pollen grain, are common. The presence of this pollen and the stratigraphic context suggest that the Sardhai Formation correlates with the Khuff transition beds of Oman and the basal Khuff clastics of central Saudi Arabia. *Florinites* ?*balmei* was first described by Stephenson and Filatoff in 2000 from the basal Khuff clastics of Saudi Arabia, and it has since been reported from Oman, Kuwait, southeastern Turkey, Iraq, United Arab Emirates and Qatar. This suggests that the plant that produced *Florinites* ?*balmei* had a rather limited palaeogeographic distribution in the Mid-Permian which

may be useful in reconstructing the problematic tectonic and palaeogeographic history of this complex region.

Keywords: Permian; Palynology; Sardhai Formation; Salt Range; Khisor Range; Nilwahan Group; Zaluch Group.

Introduction

The Permian succession of Pakistan crops out in the Salt Range and Trans-Indus Khisor and Marwat ranges and partly in the Surghar Range (Fig. 1), which represent the southern side of a rift flank basin, along the northern Gondwanan coastal margin (Wardlaw and Pogue, 1995). The Salt Range and the Trans-Indus ranges of Pakistan are regarded as important reference areas for Permian strata; however despite considerable research in the area, few studies have dealt with biostratigraphy (e.g. Pakistani-Japanese Research Group, 1985; Wardlaw and Pogue, 1995; Mertmann, 1999). Most studies have concentrated on taxonomy of various groups, and Permian-Triassic boundary problems (e.g. see Waagen, 1882-1885; Noetling, 1901; Diener, 1912; Grabau, 1931; Balme, 1970; Kummel and Teichert, 1970; Rowell, 1970; Grant, 1970; Glenister and Furnish, 1970; Kummel, 1970; Sohn, 1970; Sweet, 1970; Sarjeant, 1970).

The Permian succession is divided into two groups (Fig. 2), representing two different depositional settings: the largely terrestrial Gondwana succession, represented by the Nilwahan Group, and the shallow marine Tethyan succession, represented by the overlying Zaluch Group (Wardlaw and Pogue, 1995). The base of the Nilawahan Group is characterized by the Tobra Formation, showing glacially-influenced sedimentation

(Ghauri et al., 1977). It is overlain by the Dandot Formation, in the Salt Range. But this formation is absent in the Khisor Range and western Salt Range. The Dandot Formation consists of pale grey to olive green sandstone having occasionally scattered pebbles of up to 10 cm in diameter or pebbly beds with subordinate dark grey and greenish splintery shales (Shah, 1977) and containing the bivalve *Eurydesma* and the conularid, *Conularia* (Reed, 1936; Pascoe, 1959). Many species of Bryozoa and Ostracoda along with a few brachiopod taxa have also been described from the formation..

Arid conditions are indicated by the succeeding Warchha Formation, which consists of medium- to coarse-grained, purple, arkosic sandstone, conglomeratic in places with interbeds of reddish shale. The conglomerate clasts are mostly granitic in nature, though quartzitic clasts are also present.

More humid conditions are indicated by the overlying Sardhai Formation (Sultan, 2004). The name Sardhai Formation, as approved by the Stratigraphic Committee of Pakistan, comes from Gee (written comm. 1964). Prior to which, Gee (in Pascoe, 1959) called it "Lavender clay stage". Earlier, Wynne (1878) called it "Lavender clay" whereas Noetling (1901) called the formation "upper part of Warchha Group" (Shah, 1977). The type locality of the formation has been suggested by Gee, as the Sardhai Gorge in the eastern Salt Range (Shah, 1977). The formation is composed of bluish to greenish-grey claystone with subordinate sandstone and siltstone interbeds. It is also reported to contain minor carbonaceous clays. These clays are lavender in colour and contain copper minerals, as well as jarosite, chert and gypsum (Shah, 1977). Shah (1977) observed lateral facies changes from the lavender- coloured clays in the Salt Range to black shale and brownish argillaceous limestone in the Khisor Range. Generally the formation is reported to be unfossiliferous with occasional plant remains in the exposures in the Salt Range (Shah, 1977); however well-developed limestone interbeds from the Khisor Range, have been reported by Shah (1977) to have yielded determinable brachiopods and bryozoans. Hussain (1967) reported the fossils, *Anastomopora* sp., *Fenestella* sp., *Athyris* sp., *Spirifer* sp. from the sandy limestone beds exposed at the Saiyiduwali in the Khisor Range and assigned an Early Permian age to the formation (Alam, 2008). Moreover a unit recognized as Sardhai from the Jang drill core (Fig. 1; Alam et al., 1987), following Wardlaw and Pogue (1995) contained common fish debris. One of the samples also yielded common paleoniscoid fish teeth and a single *Hindeodus* conodont, the presence of which by Wardlaw and Pogue (1995) has been attributed to the deposition of the formation in a very shallow marine settings. Variable thicknesses of the formation have been observed in eastern and western Salt Range and Trans-Indus Khisor Range. At the type locality i.e Sardhai Gorge, it is reported to be 42m thick, in the western Salt Range, it is 65m thick, whereas in the Khisor Range, it makes up 50m (Shah, 1977). Its lower contact with the Warchha Formation has been assigned as transitional, whereas the upper contact, following Shah (1977) is conformable with the overlying Amb Formation. Wardlaw and Pogue (1995) have mentioned the presence of the significant hiatus between the Nilawahan and Zaluch Group. Based on the presence of the conodont in the upper part of the Nilawhan Group (Sardhai Formation) Wardlaw and Pogue (1995) suggested the climatic amelioration from the significantly cold, non- existent conodont glacial waters to cool, conodont-bearing waters. The Nilwahan Group, indicates marginal marine fluvial deposition, that was glacially controlled, especially in the Tobra and Dandot formations, thus reflecting the combined effects of the overall Permian climatic amelioration, i.e. the southward expansion of the warmer climatic zones and the northward continental movement into the milder climatic zones (Wardlaw and Pogue, 1995).

The overlying Zaluch Group is a well-exposed succession of the shallow marine to inter-tidal carbonate facies of the Amb, Wargal and Chhidru formations (Fig. 2), that were deposited when a large carbonate platform developed on the Gondwana continental crust close to the Indian Shield (Mertmann, 2003). The contrast between the largely cool climate continental "Gondwanan" deposits of the Nilawahan Group and the richly fossiliferous, marine "Tethyan" deposits of the Zaluch Group appears great, showing gradual change from the marginally glacial sedimentation to marginally warm water deposition (Wardlaw and Pogue, 1995).

Thus the Permian succession of Pakistan provides information on the changing palaeoclimate and palaeogeography of the region, comprising a record of warming as the Carboniferous-Permian glaciations waned and northern Gondwana drifted northwards (Stephenson et al., 2007; 2008).

Biostratigraphical dating has suggested a range of ages for Salt Range units. The brachiopods of the Amb Formation were considered by Waterhouse (1976; 1981) to be Late Baigendzinian (upper Artinskian). The fusulinid fauna from the formation was also assigned as Baigendzinian by the Pakistani-Japanese Research Group (1985). Pollen and spores investigated by Balme (1970), suggested an Artinskian age. The most recent age determination is that of Wardlaw and Pogue (1995), who used conodonts, which indicate a Wordian (middle Guadalupian, Kazanian) age.

The Pakistani-Japanese Research Group (1985) reported a number of megafossils from the Wargal Formation, including commonly occurring brachiopods. Gastropods and corals have also been reported, along with common occurrences of small foraminifera throughout the formation. The fusulinids and foraminifers indicate a late Murghabian, Tethyan equivalent of Capitanian, through early Dzhulfian, Tethyan equivalent of Wuchiapingian. The brachiopods indicate an early Dzhulfian (Wuchiapingian) age (Pakistani-Japanese Research Group, 1985). The conodonts have been assigned to Capitanian through Wuchiapingian age by Wardlaw and Pogue (1995). The overlaying Chhidru Formation is reported to include small foraminifera, along with brachiopods, molluscan fossils, Bryozoa and rare ammonoids (*Cycolobus*). The conodonts are commonly dominated by the near-shore *Hindeodus* (Wardlaw and Pogue, 1995). The foraminifers from the formation support correlation with the Wachiaping Formation of South China and thus it has been assigned to the late Dzhulfian (Wuchiapingian) by the Pakistani-Japanese Research Group (1985).

Palynological study of the Permian succession is confined to the Salt Range; there are no reports of palynology from the Trans-Indus ranges. Virkki (1946) and Venkatachala and Kar (1966, 1968) studied samples from a horizon 20-25 feet above the Tobra Formation (see Balme, 1970). Balme (in Teichert, 1967) also described assemblages from the Tobra Formation at Zaluch Nala, eastern Salt Range and assigned them to the Permian (Teichert, 1967). Kemp (1975) examined two samples from the Tobra Formation at Zaluch Nala and reported the presence of *Brevitriletes* sp. cf. *B. unicus, Lophotriletes* sp. cf. *L. scotinus, Horriditriletes- Lophotriletes* sp. *Potonieisporites neglectus*, *Dentatisporites* sp. along with acritarchs, referable to the genus *Cymatiosphaera*, while

Khan et al., (2001) reported Tobra Formation assemblages from Nilawahan Gorge, central Salt Range.

There is no palynological work on the Sardhai formation, but Balme (1970) made a detailed taxonomic survey of the carbonate dominated succession of the overlying Amb, Wargal and Chhidru formations. He recovered pollen and spores from the plant-bearing horizons of the Amb Formation at three localities in the Salt Range: Zaluch Nala, Dhodha Wahan, and near Warchha Water Tank. Trilete spores represented were: *Acanthotriletes tereteangulatus*, *Camptotriletes warchianus*, *Leiotriletes* cf. *adnatus*, *Lophotriletes novicus* and *Verrucosisporites* sp. cf. *V. planiverrucatus*, while *Reticuloidosporites warchianus* was the only monolete spore taxon. The monosaccate pollen included *Plicatipollenites indicus* and *Potonieisporites novicus.* Balme (1970) reported a high diversity of bisaccate pollen including the taeniate taxa *Corisaccites alutas, Guttulapollenites hannonicus, Hamiapollenites insolitus, Lueckisporites singhii, Protohaploxypinus limpidus, P. goraiensis, P. diagonalis, P.varius, Striatopodocarpites cancellatus, S. rarus* and *S. pantii,*. Non-taeniate bisaccate taxa included *Alisporites tenuicorpus, Falcisporites nuthallensis, Pinuspollenites thoracatus, Sulcatisporites ovatus, S. nilssoni* and *Vitreisporites pallidus*. Balme (1970) noticed similarities between the palynological assemblages from the Zaluch Group of Pakistan with those of the Madagascar, Australia and the then USSR.

For the present study, two samples (Figs. 3 and 4) were collected from a 22 meter-thick exposure of the Sardhai Formation in the Khisor Range at N32^{o} 11$^{//}$ 52.1$^{/}$ E 70^{o} 59$^{//}$ 18.0$^{/}$. One more sample, 25 meters above base of the Sardhai Formation was collected from an approximately 30 meter-thick exposure of the same formation at Zaluch Nala, Salt Range at N32^{o} 46$^{//}$ 58.4$^{/}$ E 71^{o} 38$^{//}$ 49.4$^{/}$.

Assuming that the Salt and Khisor ranges comprise a potential Permian reference section for the South Tethys, because of their good outcrop exposures, palyniferous lithologies and the presence of abundant marine fauna for age calibration, yet the aim of this paper is to only document and describe the assemblages of the Sardhai Formation and to correlate them with the other reported assemblages from the southern Tethyan region including the standard palynostratigraphic scheme of Arabia. Our long term intention would be to develop such palynological succession and studies on the Tobra, Dandot and Warchha formations.

Materials and methods

The preparation of strew mounts for palynological analysis involved established procedures of crushing followed by hydrofluoric and hydrochloric acid treatments (Wood et al., 1996). Post-hydrofluoric acid organic residues were oxidized with Schulze's Solution and dilute nitric acid. The photography was done with a DP11 Olympus digital camera mounted on a Zeiss Universal microscope. The samples collected and palynological slides prepared are housed at the laboratories of the British Geological Survey, UK.

Description of assemblages

The yield of the samples was mainly poor, however it was possible in most cases to count at least two hundred specimens per slide. Thirty five taxa were identified from these samples, including the palynostratigraphically important *Camptotriletes warchianus, Florinites* ?*balmei* and *Lueckisporites virkkiae*. A list of all palynomorph species with author citation is given in Appendix 2 and selected taxa are displayed in Plates I and II.

The quantitative character of assemblages from the Sardhai Formation at Zaluch Nala and Khisor Range is shown in Tables 1 and 2.

Correlation with Arabia

The most extensively studied Tethyan Permian sections are those of Oman and Saudi Arabia (Stephenson and Filatoff, 2000a,b; Stephenson, 2008). Stephenson et al., (2003) and Stephenson (2006) established eight palynological biozones (OSPZ 1 to OSPZ6); and OSPZ5 and OSPZ6 are considered Mid- and Late Permian in age. OSPZ5, associated with the lower to middle parts of the Upper Gharif member in Oman, is dominated by distally-taeniate bisaccate pollen including *Distriatites insolitus* and *Hamiapollenites dettmannae,* but also contains *Densiopollenites indicus*, *Platysaccus* cf. *queenslandi*, *Playfordiaspora cancellosa* and *Thymospora opaqua*.

The base of the succeeding biozone, OSPZ6, represents a considerable palynological change because a number of taxa appear for the first time at this level, and because diversity increases. The base of OSPZ6 is defined by the first occurrence of *Florinites* ?*balmei* which is usually very common. Other taxa of OSPZ6 include *Camptotriletes warchianus*, *Pyramidosporites cyathodes* and *Protohaploxypinus uttingii* though many taxa such as *Alisporites nuthallensis*, *Laevigatosporites callosus*, *Lueckisporites virkkia*e, *Thymospora opaqua* and *Reduviasporonites chalastus* persist from OSPZ5 (Stephenson et al., 2003; Stephenson, 2006, 2008).

The base of OSPZ6 occurs in the highest parts of the Upper Gharif member in Oman a few meters below the base of the succeeding carbonate Khuff Formation in beds sometimes referred to as the Khuff Transition beds (see Stephenson, 2006, 2008) and the biozone extends into the Khuff Formation. In central Saudi Arabia, assemblages assigned to OSPZ6 (i.e. containing *Florinites* ?*balmei*) also occur in clastic sedimentary rocks below the base of the Khuff Formation.

The lower age limit of OSPZ6 is difficult to constrain since no independent palaeontological data are available from the clastic sedimentary rocks of the Upper Gharif member. In Oman the base of OSPZ6 occurs consistently a few metres below the base of the carbonate Khuff Formation (see Stephenson, 2006, 2008) and the lower beds of the Khuff Formation are dated as early Wordian in age (Angiolini et al., 2003). Since no significant hiatus is present between the Upper Gharif member and the lower Khuff Formation the lower limit of the age of OSPZ6 is likely to be Wordian. The upper age limit of OSPZ6 in Oman and Saudi Arabia is yet to be defined but the assemblages that characterise it are not known to extend into the Triassic.

The presence in the Sardhai Formation of *Florinites* ?*balmei* in addition to *Alisporites nuthallensis*, *Corisaccites alutas*, *Camptotriletes warchianus*, *Laevigatosporites callosus* and *Thymospora opaqua* suggests a correlation with the OSPZ6 Biozone of Arabia. The Amb Formation above the Sardhai Formation is similar palaeontologically and lithologically to the Arabian Khuff Formation and is widely considered to be its temporal and sedimentological equivalent (see Angiolini and Bucher, 1999) having been formed by essentially the same marine transgression associated with neo-Tethyan sea floor spreading (Angiolini et al., 2003; Mertmann, 2003). The evidence thus suggests that the Sardhai Formation correlates with the immediate pre-carbonate clastic sedimentary rocks of Arabia, including the basal Khuff clastics and the Khuff transition beds. In the light of this correlation, a Wordian age is tentatively suggested for the Sardhai Formation.

Tethyan correlation

Recently Stolle (pers. comm) investigated the Permian Kas and Gomaniibrik formations in southeast Turkey. The Kas Formation has been dated as Wordian by foraminifera (Stolle, pers. comm.) The assemblages in the Kas Formation are dominated by spores, particularly monolete taxa, including *Punctatisporites* spp., *Spinosporites* sp., *Torispora* spp., and *Thymospora opaqua*, but also contain common *Camptotriletes warchianus*, *Distriatites insolitus*, *Florinites* ?*balmei* (up to 23% of assemblages) and *Hamiapollenites dettmannae*. Stolle (pers. comm.) correlated the Kas Formation assemblages with OSPZ6, and noted similarities with northern Iraqi subsurface assemblages described by Nader et al., (1993) and Singh (1964). Stolle's figure 5 illustrates a correlation of OSPZ6 assemblages across the Tethyan region, including Turkey, Iraq, Saudi Arabia and Oman and this chart is here modified to include the Salt and Khisor ranges Sardhai Formation OSPZ6 assemblages (Fig. 5).

Palaeogeographic distribution of *Florinites* ?*balmei*

This correlation shows that the distinctive pollen *Florinites* ?*balmei* is present in approximately coeval rocks in an area of the southern Neotethys which is now represented by southeast Turkey and northern Iraq. In addition *Florinites* ?*balmei* has recently been described from the basal Khuff clastics in Kuwait (Tanoli et al., 2008) and is known to occur in the same unit in the United Arab Emirates and Qatar (BGS unpublished reports; Fig. 6). Its occurrence in the Salt and Khisor ranges and apparent absence from Middle Permian rocks elsewhere in Gondwana, Euramerica and Cathaysia suggests that the plant that produced *Florinites* ?*balmei* had a rather restricted palaeogeographic distribution along the palaeotropical coast of the Tethys Ocean (Fig. 6). It also tends to support the palaeogeographic reconstructions of Ricou in Dercourt et al., (1993), Ziegler et al., (1998) and Gaetani et al., (2000) showing the Salt Range area in contiguity with the southern part of the Arabian Plate.

The complex palaeogeography and palaeotectonics of the Tethyan margin from the Early to Mid Permian has been discussed by amongst others Sengör (1979), Ricou (in Dercourt et al., 1993), Ziegler et al., (1998), Gaetani et al., (2000) and Angiolini (2001). Angiolini's (2001) reconstruction of the Wordian shows the Mega Lhasa Block or Cimmerian blocks (comprising Iran, Afghanistan, Karakorum and Sibumasu, Thailand) in contiguity and in relative proximity to the Gondwanan margin, however the form and position of the Mega Lhasa Block is generally considered uncertain

(Gaetani, 1997; Muttoni et al., personal communication), thus further work to establish whether *Florinites* ?*balmei* occurs in the Mega Lhasa Block; especially Thailand might shed more light on such reconstructions.

The well known Oman Gharif palaeoflora (e.g. Broutin et al., 1995; Berthelin et al., 2003) was described from the uppermost Gharif Formation in the Huqf area in interior Oman, and is believed to consist of a mixture of Gondwanan, Cathaysian and Euramerican fossil plant taxa. Plant taxa of the Permian Cathaysian Paleokingdom present in Oman were considered by Berthelin et al., (2003) to indicate a close relationship between the Neotethys realm and south China. Further work should aim to establish whether *Florinites* ?*balmei* occurs in the Cathaysian Paleokingdom.

Conclusion

The presence of *Florinites* ?*balmei* together with other stratigtraphically important taxa, e.g. *Camptotriletes warchianus*, suggest that the Sardhai Formation correlates with the Khuff transition beds of Oman and the basal Khuff clastics of central Saudi Arabia and can be likewise assigned to the Arabian OSPZ6 biozone, indicating a tentative Wordian age. Overall the Salt Range Permian succession is also similar in lithological character to that of the Arabian Peninsula: both have successions of glacial diamictites at the base, overlain by the red beds, followed by distinctive dark shale-sandstone interbeds and conclude with thick limestones.

This work has also shown that monosaccate pollen grain *Florinites* ?*balmei* had a limited palaeogeographic distribution in the Mid-Permian across most of the southern Tethys and Arabia, whereas it is apparently not reported elsewhere in Gondwana and Euramerica. If this distribution can be more precisely delineated in regions in the wider Middle East and parts of present day southeast Asia, it would help reconstruct this region's complex palaeogeography and tectonics.

Appendix 1

Systematic Palynology

Florinites Schopf, Wilson and Bentall 1944

Type Species: *Florinites pellucidus* (Wilson and Coe) Wilson, 1958.

***Florinites* ?*balmei* Stephenson and Filatoff 2000**

Plate I, figures 1-15.

Florinites ?*balmei* Stephenson and Filatoff 2000: plate 2, figs j-m, p. 208-212

Florinites millotti Butterworth and Williams 1954 – Nader et al., 1993: plate 13, figures 7-8 [no description].

Florinites millotti Butterworth and Williams 1954 - Akyol, 1975: plate 9, figures 12-16 [no description].

Florinipollenites millotti (Butterworth and Williams) Coquel 1966 - Agrali and Akyol, 1967: plate 8, figures 21-24 [*Florinipollenites* Laveine 1965 is an obligate junior synonym of *Florinites* Schopf, Wilson and Bentall 1944].

Description: Pollen, monosaccate, bilaterally symmetrical; amb oval. Corpus almost imperceptible, though its presence is suggested by a narrow, oval fold structure in the saccus. Long axis of corpus parallel to the long axis of the grain; diameter of the corpus approximately half that of the grain overall. The detachment of the saccus from the corpus is imperceptible. Saccus coarsely infrareticulate; brochi 1-2µm in diameter, muri width <1µm. equatorial margin of the saccus is slightly thickened in some specimens.

Appendix 2. List of taxa recorded

Alisporites sp.

Alisporites indarraensis Segroves, 1969

Alisporites cf. *nuthallensis* Clarke, 1965

Barakarites rotatus (Balme and Hennelly) Bharadwaj and Tiwari, 1964

Brevitriletes parmatus (Balme and Hennelly) Backhouse, 1991

Brevitriletes sp.

Camptotriletes warchianus Balme, 1970

322 *Corisaccites alutas* Venkatachala and Kar, 1966

323 *Cedripites* sp.

324 *Cannanoropollis janakii* Potonié and Sah, 1960

325 *Complexisporites polymorphus* Jizba, 1962

326 *Distriatites* sp.

327 *Florinites* ?*balmei* Stephenson & Filatoff, 2000

328 *Guttulapollenites hannonicus* Goubin, 1965

329 *Hamiapollenites* sp.

330 *Hamiapollenites dettmannae* Segroves, 1969

331 *Hamiapollenites karrooensis* (Hart 1963) Hart, 1964

332 *Horriditriletes tereteangulatus* (Balme and Hennelly) Backhouse, 1991

333 *Kingiacolpites subcircularis* Tiwari and Moiz, 1971

334 *Laevigatosporites callosus* Balme, 1970

335 *Lueckisporites virkkiae* Potonié and Klaus emended Clarke, 1965

336 *Lundbladispora* sp.

337 *Punctatisporites* spp.

338 *Protohaploxypinus uttingii* Stephenson and Filatoff, 2000

Protohaploxypinus sp.

Plicatipollenites sp.

Potonieisporites sp.

Retusotriletes sp.

Striatopodocarpites cancellatus (Balme and Hennelly) Bharadwaj, 1962

Striatopodocarpites fusus (Balme & Hennelly) Potonié, 1958

Strotersporites indicus Tiwari, 1965

Spelaeotriletes sp.

Thymospora opaqua Singh, 1964

Taeniasporites sp.

Verrucosisporites andersonii Backhouse, 1988

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Figure Captions

Figure 1. Location map of the study area. Showing Salt and Khisor ranges of Pakistan (Modified after Gee 1980, 1989).

Figure 2. Simplified Permian stratigraphy of the Salt Range and central part of Khisor Range. (Modified after Gee, 1989; Sohail et al., 2004).

Figure 3. Vertical beds of the Sardhai Formation underlain by red beds of the Warchha Formation (to the right in the photo). Samples studied were from levels 1.8m and 16.2m above base of the Sardhai Formation. Rock outcrop to the left is 5m high.

Figure 4. Measured section of the Sardhai Formation in the Khisor Range Pakistan.

Plate I. The monosaccate pollen grain *Florinites* ?*balmei* identified from Sardhai Formation Khisor Range, Pakistan. The slide number followed by the England finder coordinates are given as follows,

(1). MPA-57533. W 12/3. (2). MPA-57533. Y11. (3). MPA-57533. W25. (4). MPA-57533. S19. (5). MPA-57533. V8/1. (6). MPA-57533. V29/1. (7). MPA-57533. V33/2. (8). MPA-57533. W 20/3. (9). MPA-57533. T10/3. (10). MPA-57533. S17/4. (11). MPA-57533. U3/3. (12). MPA-57533. W27/4. (13). MPA-57533. L 29/3. (14). MPA-57533. O12. (15). MPA-57533. P5.

Plate II. Palynomorphs from the Sardhai Formation, Pakistan. Each with slide number followed by England finder coordinates is given as follows,

(1). *Lueckisporites virkkiae,* MPA-57528, T23/3 (proximal focus). (2). *Lueckisporites virkkiae*, MPA-57528, T23/3 (distal focus). (3). *Corisaccites alutas*, MPA-57528, Q33/3.

(4). *Striatopodocarpites fusus*, MPA-57528, N24. (5). *Camptotriletes warchianus*, MPA-57528, S21. (6). *Protohaploxypinus uttingii*, MPA-57528, S35. (7). *Alisporites nuthallensis*, MPA-57528, W32/1. (8). *Guttulapollenites hannonicus*, MPA-57528, X29/1. (9). *Taeniaesporites* sp, MPA-57528, D31/4. (10). *Thymospora opaqua*, MPA-57528, S22. (11). *Laevigatosporites callosus*, MPA-57528, U4/1. (12). *Lundbladispora* sp., MPA-57528, R4/1. (13). *Alisporites nuthallensis*, MPA-57528, Q19/2. (14). *Protohaploxypinus* sp., MPA-57528, Q19/2. (15). *Guttulapollenites hannonicus,* MPA-57528, E17.

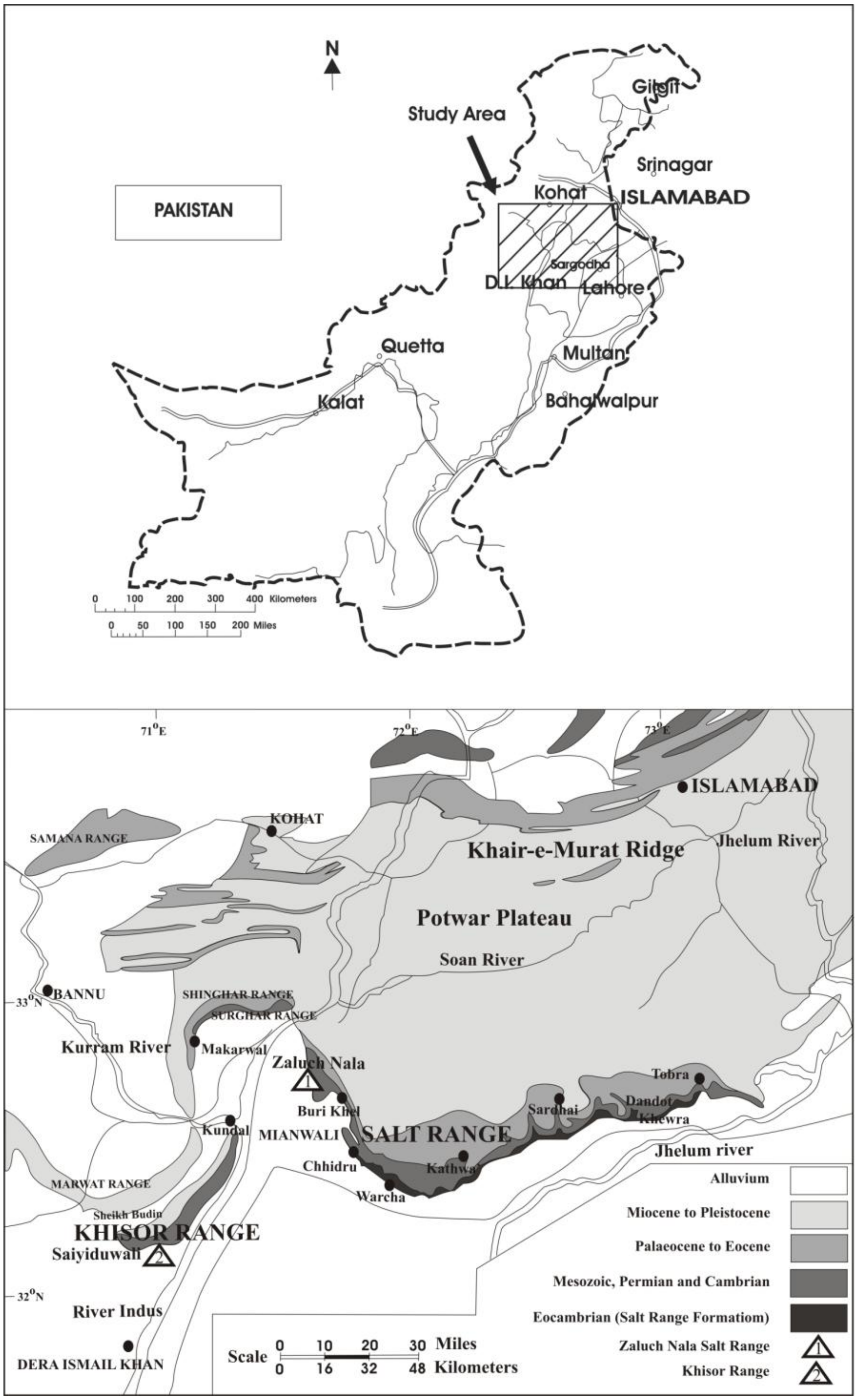
Table 1. Percentage abundance of taxa, Zaluch Nala. Data from sample 25m (MPA-57528) above base of the Sardhai Formation.

Table 2. Percentage abundance of taxa, Khisor Range. Data from sample 1.8m (MPA-57533) and 16.2m (MPA-57532) above base of the Sardhai Formation.

Figure 5. Correlation of the OSPZ6 biozone between Southeast Turkey, northern Iraq, central Saudi Arabia, Oman and Pakistan (Modified after Stolle, pers. comm.).

Figure 6. The mid-Permian (Roadian-Wordian) continental configuration. Solid circles indicate the location of *Florinites* ?*balmei* across, 1- Oman, 2- Salt Range, 3- UAE, 4- Kuwait, 5- Saudi Arab, 6- Qatar and 7- southeast Turkey (Modified after Angiolini et al., 2001).

Figure1



N
Study Area
PAKISTAN
Gilgit
Srinagar
Kohat
ISLAMABAD
Sargodha
D.I. Khan
Lahore
Quetta
Multan
Kalat
Bahawalpur
0 100 200 300 400 Kilometers
0 50 100 150 200 Miles
71°E
72°E
73°E
ISLAMABAD
KOHAT
SAMANA RANGE
Khair-e-Murat Ridge
Jhelum River
Potwar Plateau
Soan River
BANNU
33°N
SHINGHAR RANGE
SURGHAR RANGE
Kurram River
Makarwal
Zaluch Nala
Tobra
Sardhai
Dandot
Khewra
Buri Khel
MIANWALI
SALT RANGE
Kundal
Jhelum river
Chhidru
Kathwai
Warcha
MARWAT RANGE
Sheikh Budin
KHISOR RANGE
Saiyiduwali
32°N
River Indus
DERA ISMAIL KHAN
Scale 0 10 20 30 Miles
0 16 32 48 Kilometers
Alluvium
Miocene to Pleistocene
Palaeocene to Eocene
Mesozoic, Permian and Cambrian
Eocambrian (Salt Range Formatiom)
Zaluch Nala Salt Range
Khisor Range

Figure2

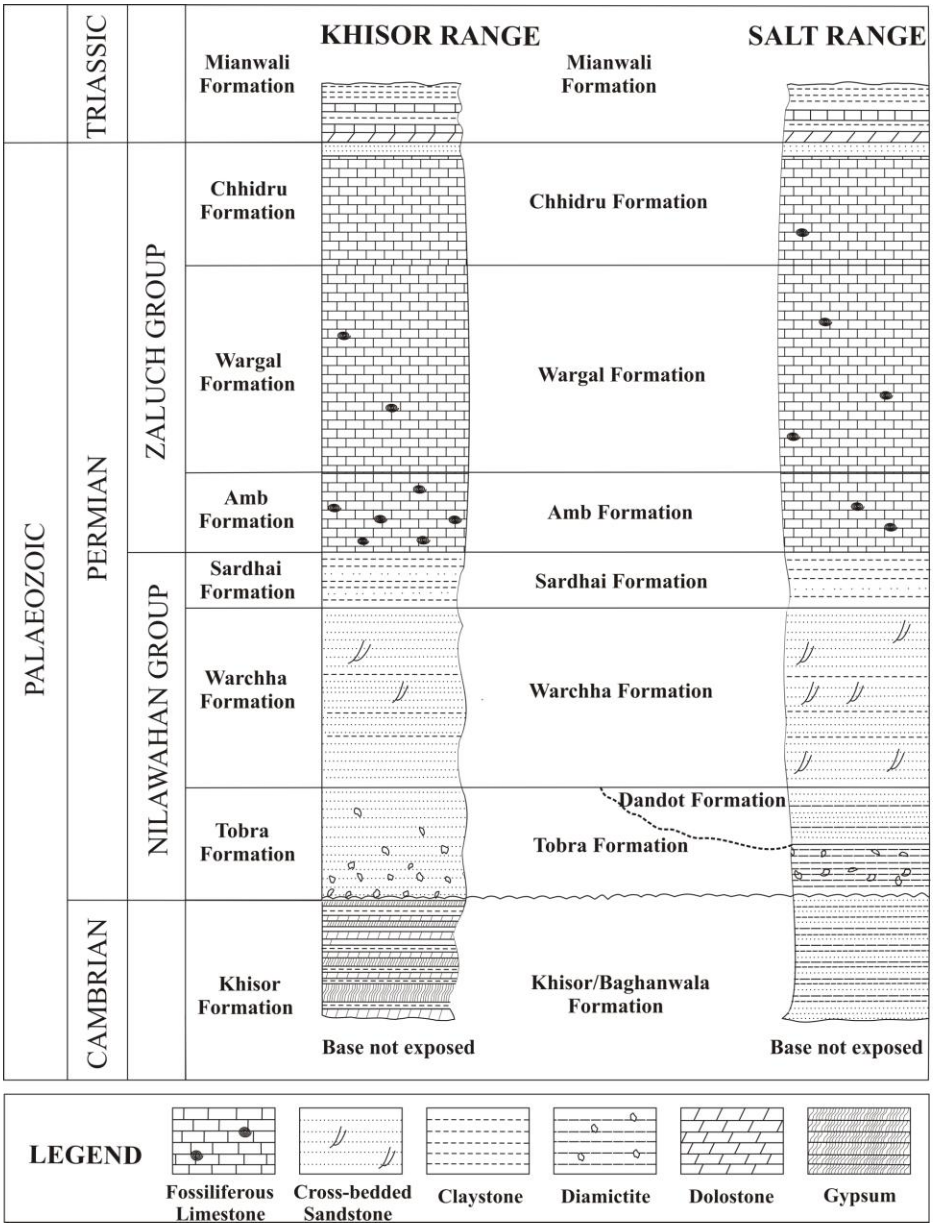
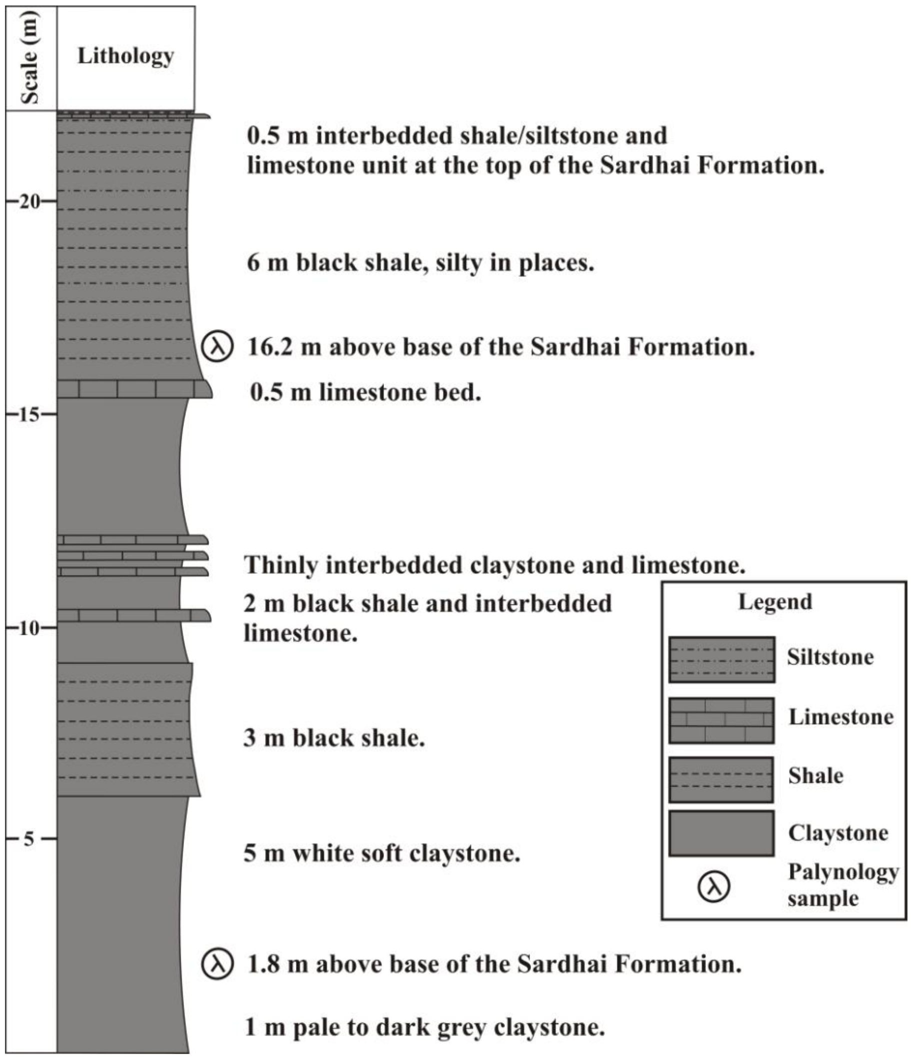

KHISOR RANGE
SALT RANGE
PALAEOZOIC
TRIASSIC
PERMIAN
CAMBRIAN
ZALUCH GROUP
NILAWAHAN GROUP
Mianwali Formation
Mianwali Formation
Chhidru Formation
Chhidru Formation
Wargal Formation
Wargal Formation
Amb Formation
Amb Formation
Sardhai Formation
Sardhai Formation
Warchha Formation
Warchha Formation
Dandot Formation
Tobra Formation
Tobra Formation
Khisor Formation
Khisor/Baghanwala Formation
Base not exposed
Base not exposed
LEGEND
Fossiliferous Limestone
Cross-bedded Sandstone
Claystone
Diamictite
Dolostone
Gypsum

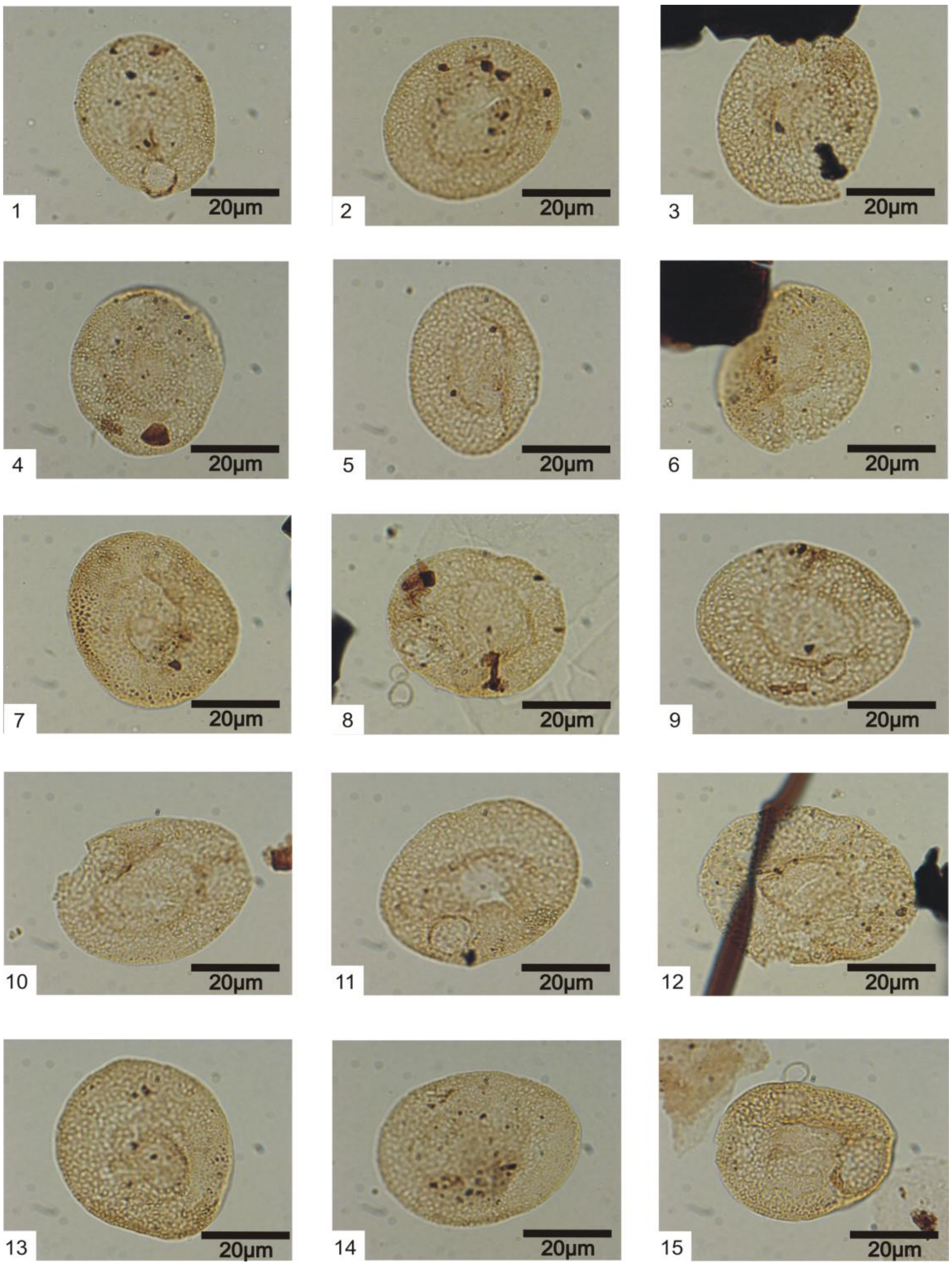
Figure3


Top of Warcha Formation
16.2m above base of the Sardhai Formation
1.8m above base of the Sardhai Formation

Figure4


Scale (m)
Lithology
20
15
10
5
0.5 m interbedded shale/siltstone and limestone unit at the top of the Sardhai Formation.
6 m black shale, silty in places.
16.2 m above base of the Sardhai Formation.
0.5 m limestone bed.
Thinly interbedded claystone and limestone.
2 m black shale and interbedded limestone.
3 m black shale.
5 m white soft claystone.
1.8 m above base of the Sardhai Formation.
1 m pale to dark grey claystone.
Legend
Siltstone
Limestone
Shale
Claystone
Palynology sample

PlateI


1
20µm
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3
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14
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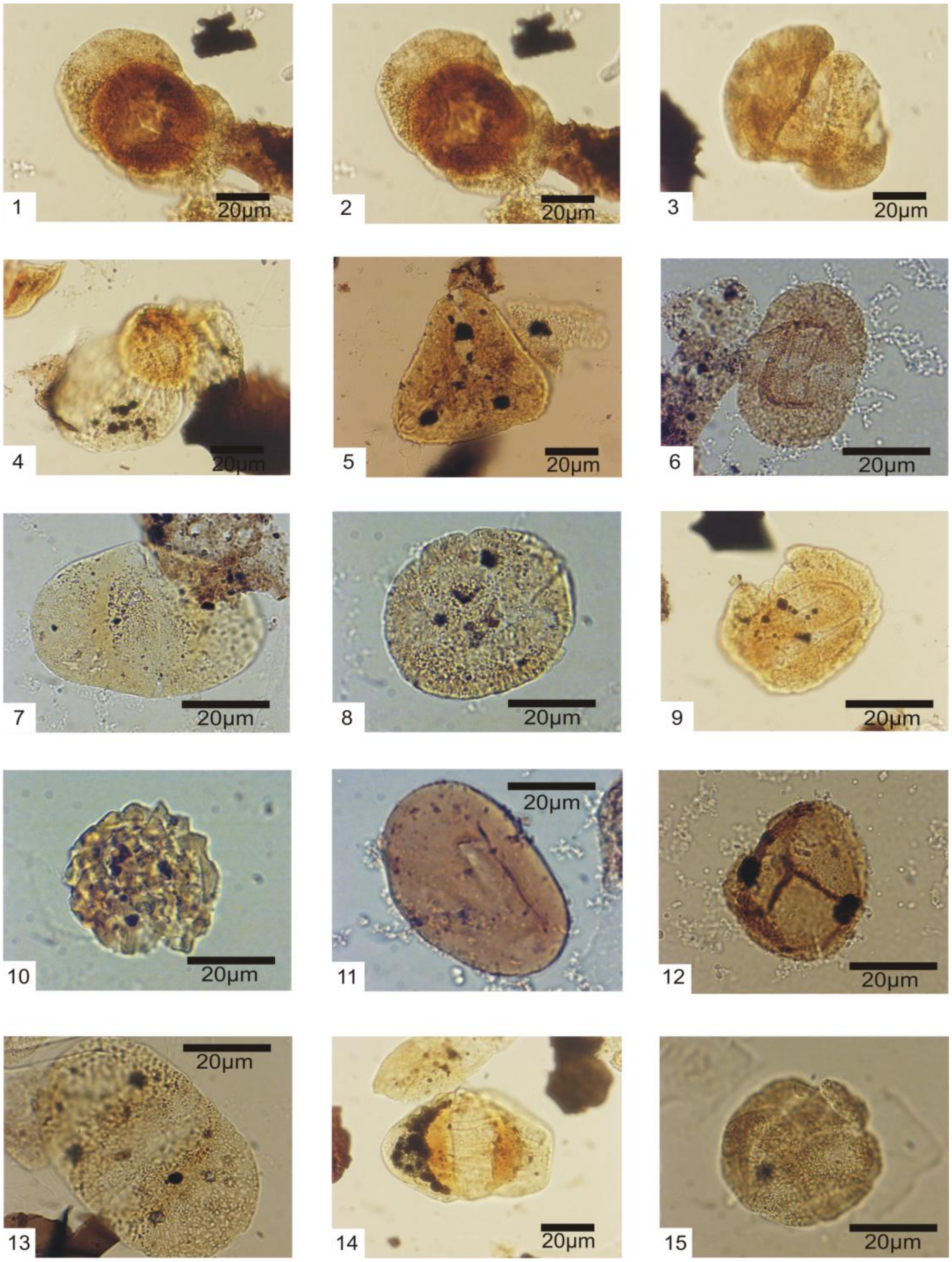
15
20µm

PlateII


1
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10
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11
20μm
12
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13
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14
20μm
15
20μm

Table1

Taxon	% age Abundance (MPA 57528)
Alisporites indarraensis	15
Alisporites nuthallensis	1
Brevitriletes parmatus	2
Barakarites rotatus	2
Cannanoropollis janakii	1
Corisaccites alutas	14
Cedripites sp.	1.5
Complexisporites polymorphus	0.5
Camptotriletes warchianus	1
Distriatites sp.	3
Florinites ?balmei	0.5
Guttulapollenites hannonicus	2.5
Hamiapollenites sp.	0.5
Horriditriletes tereteangulatus	0.5
Kingiacolpites subcircularis	4.5
Lundbladispora sp.	1
Laevigatosporites callosus	3
Lueckisporites virkkiae	1
Plicatipollenites sp.	0.5
Protohaploxypinus sp.	1
Protohaploxypinus uttingii	0.5
Punctatisporites spp.	3
Potonieisporites sp.	2
Retusotriletes sp.	0.5
Striatopodocarpites cancellatus	0.5
Striatopodocarpites fusus	1
Strotersporites indicus	1
Spelaeotriletes sp.	0.5
Thymospora opaqua	2
Taeniaesporites sp.	1
Verrucosisporites andersonii	3
Indeterminate monosaccate pollen	2
Indeterminate bisaccate pollens	27

Table2

Taxon	% age Abundance (MPA-57533)	% age Abundance (MPA-57532)
Alisporites indarraensis	3.5	22.5
Alisporites nuthallensis	1	
Alisporites sp.	3	
Brevitriletes sp.		0.5
Corisaccites alutas	1	1
Distriatites sp.		0.5
Florinites ?balmei	60	1.5
Hamiapollenites dettmannae	0.5	
Hamiapollenites karrooensis		0.5
Kingiacolpites subcircularis		0.5
Laevigatosporites callosus	22	1
Punctatisporites spp.	3.5	
Protohaploxypinus uttingii		55.5
Strotersporites indicus		0.5
Thymospora opaqua	2	2
Verrucosisporites andersonii	1	
Indeterminate monosaccate pollen	1.5	
Indeterminate bisaccate pollens	1	14

Figure5

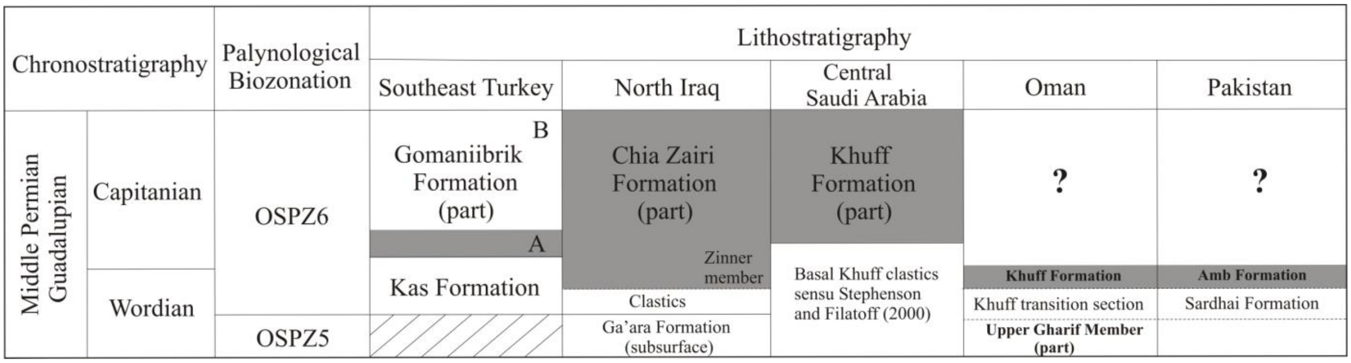
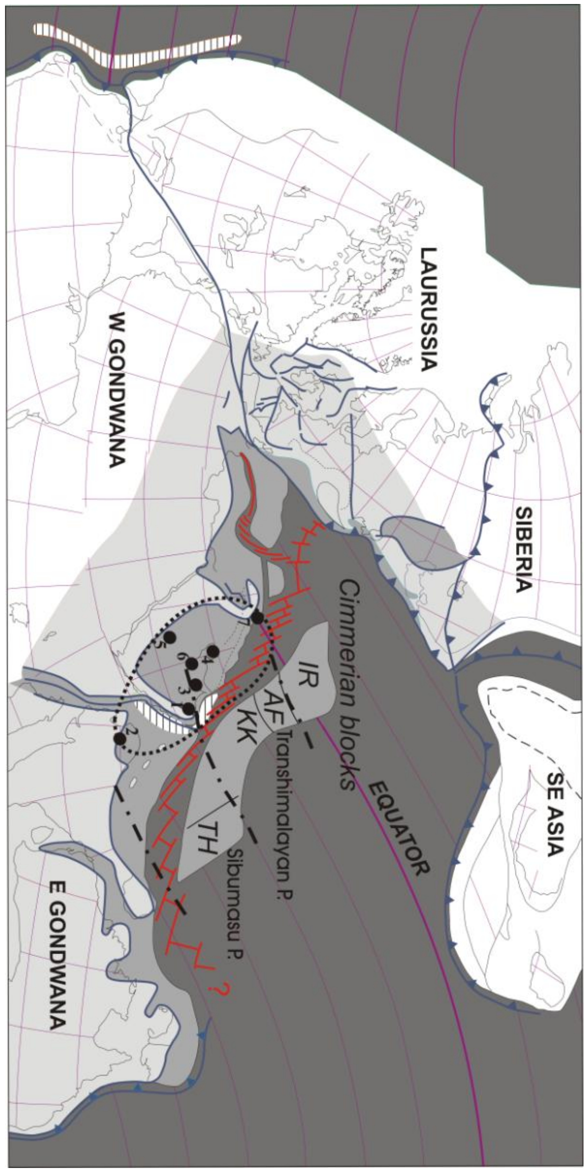

Chronostratigraphy
Palynological Biozonation
Lithostratigraphy
Southeast Turkey
North Iraq
Central Saudi Arabia
Oman
Pakistan
Middle Permian Guadalupian
Capitanian
Wordian
OSPZ6
OSPZ5
B
Gomaniibrik Formation (part)
A
Kas Formation
Chia Zairi Formation (part)
Zinner member
Clastics
Ga'ara Formation (subsurface)
Khuff Formation (part)
Basal Khuff clastics sensu Stephenson and Filatoff (2000)
?
Khuff Formation
Khuff transition section
Upper Gharif Member (part)
?
Amb Formation
Sardhai Formation

Figure6


LAURUSSIA
W GONDWANA
SIBERIA
Cimmerian blocks
IR
AF
KK
TH
Transhimalayan P.
Sibumasu P.
EQUATOR
SE ASIA
E GONDWANA