Pak. J. Bot., 52(6): 2095-2099, 2020. DOI: http://dx.doi.org/10.30848/PJB2020-6(22)

COLPATE, COLPORATE AND PORATE POLLEN ISOLATED FROM THE SHALE OF BARA FORMATION, LAKHRA, SINDH, PAKISTAN

SHABAB ALI KHAN[1*], SYEDA SALEHA TAHIR[2], JAMAL UDDIN MANGI[3], NASIRUDDIN SHAIKH[4], HUMAIRA NAZ[5], FAHIM ARSHAD[6] AND NOOR-UL-AIN-SOOMRO[3]

[1]Federal Government Degree College Cantt, Hyderabad, Sindh, Pakistan.
[2]Department of Botany, Jinnah University for Women, Karachi, Pakistan
[3]Institute of Plant Science, University of Sindh, Jamshoro, Pakistan
[4]Goverement Degree College University Hyderabad, Sindh, Pakistan
[5]Centre for Pure and Applied Geology, University of Sindh, Jamshoro, Pakistan
[6]Department of Botany University of Okara, Punjab, Pakistan
[*]Corresponding email alishabab2014@yahoo.com

Abstract

The paper describes some colpate and colporate fossil pollen grains from the carbonaceous shale belonging to Bara Formation located at Lakhra, Sindh, Pakistan. Fossil pollen were compared to nearest modern equivalents. The families akin to fossil pollen grains were mainly angiospermic. Based upon palynological analyses, the environment of deposition of Bara Formation was depicted of fresh water swampy environmentad adjoining to near shore sedimentation possessing sufficient fresh water supply.

Key words: Colpate, Colporate and Porate Pollen, Angiospermic Families, Bara Formation, Sindh, Pakistan.

Introduction

The study of fossil pollen and their distribution patterns have been a useful tool in interpreting the nature, type of vegetation and the ecological conditions prevailing in the past geological periods (Traverse, 2007). Thus, it also serves as an important indicator of past geographical conditions (Traverse, 1988; Jaramillo *et al.*, 2006). Pollen described in the present research were extracted from the carbonaceous shale of Bara Formation belonging to Tertiary Period (late Paleocene Epoch) located at Lakhra, district Jamshoro, Sindh, Pakistan (Lat. 25º 30' 45"N & Long. 68º 00' 68"E).

In Sindh, the depositional condition of the Tertiary deposits at Lakhra, were analyzed by Sahito *et al*., (1986) and Nizamani *et al*., (1992). In such studies, the vegetational make-up was interpreted from the fossil plant material found in coal, since no attempt had been made to study the associated floral elements present in between the coal seams. Present work is an attempt to explore the Tertiary strata from the Sindh Province with respect to fossil flora mainly comprised of colpate, colporate and porate pollen from various shale horizons across Bara Formation, Pakistan.

Geological set up

The studied section i.e., Lakhra area is surrounded by Indus River, Kirthar Range, Fort Rani Kot and Surjan Anticline in east, west, north and south respectively (Shah, 1977; 2009). In studied section, Bara Formation is the oldest while Laki Formation is the youngest formation as shown by the stratigraphic sequence (Fig. 2).

Lithologically, Bara Formation is mainly composed of sandstone, silt stone and shale. The color of the sand stone is yellowish light pink and blackish purple, shale is light brown and grey and silt stone is interbedded with in sandstone and shale (Kazmi & Jan, 1997). Figure 1 indicates the geological mapping of Lakhra area possessing stratigraphic succession of Tertiary outcrops. At Lakhra area, the total measured thickness of Bara Formation is 20 meters.

Materials and Methods

Palynological analysis was carried out by collecting various rock samples across the stratigraphic horizons of Bara Formation from Lakhra area. Standard techniques adopted from Phipps & Playford, (1986) and Grey (1999) were firstly being devised with possible modifications in order to proceed for maceration procedure. 100 grams of each rock sample was crushed in pestle and mortar, treated with various inorganic acids (i.e., HCl, HF and HNO_3) and further subjected to preliminary microscopic observations for the recovery of palynomorphs. Oxidation of macerated sample was performed by utilizing 5% KOH. Inorganic residues were further removed through centrifugation in a heavy liquid ($ZnCl_2$). Palynomorphs after heavy liquid separation were mounted in Canada Balsam, taxonomically identified and systematically analyzed (Virmal, 1952*)*. Slides were placed at Palaeobotany Laboratory, Institute of Plant Sciences, University of Sindh, Jamshoro, Pakistan.

Systematic Description

1. *Tricolpopollenites microhenrici* Thomson & Pflug (1953)

Pollen grain light brown colored, amb ovoid, bean shaped, 37 x 56µm in size. Tricolpate, colpi 36µm long and 3µm broad at middle, gradually narrowed at both end. Exine 3 µm thick, psilate (Fig. 3).

Affinity: Fagaceae.

Remarks: The palynomorph observed during present investigations is larger in size than that described by Thomson & Pflug. (1953) reported from Tertiary sediments of North Western Krefeld, Germany.

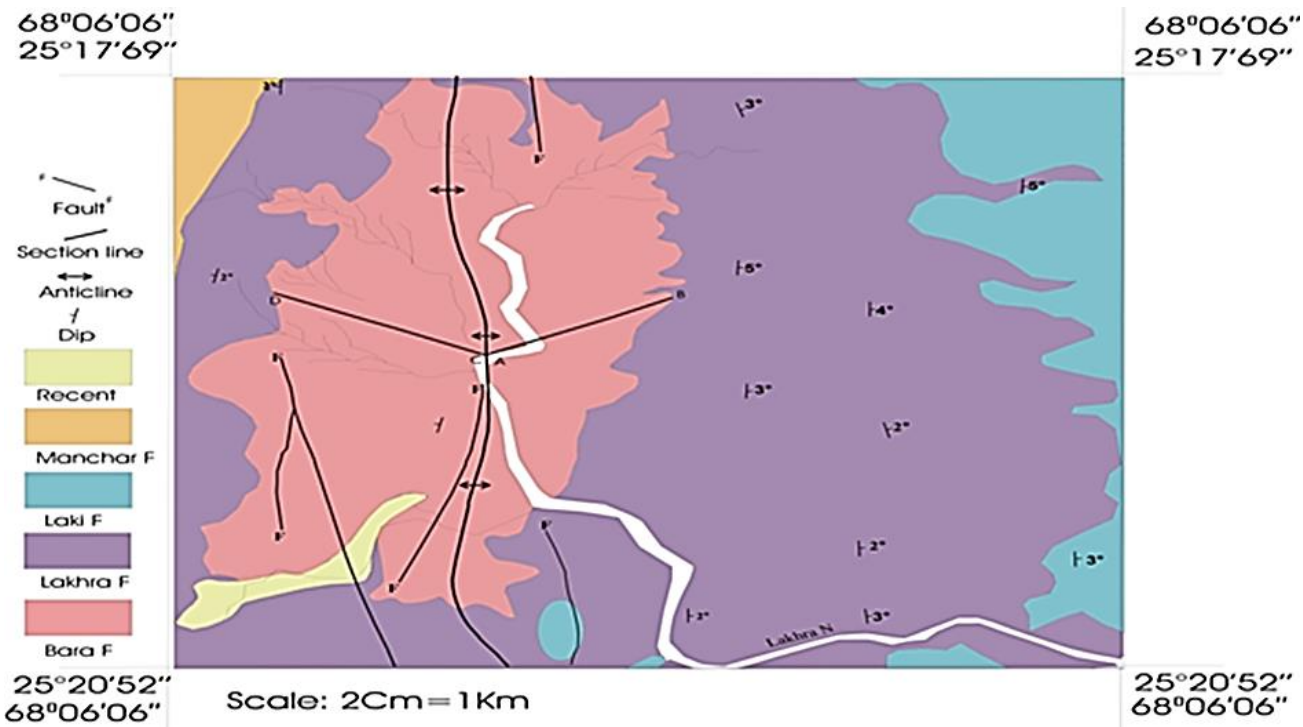

Fig. 1. Geological map of the studied Lakhra Section exhibiting early Tertiary outcrops.

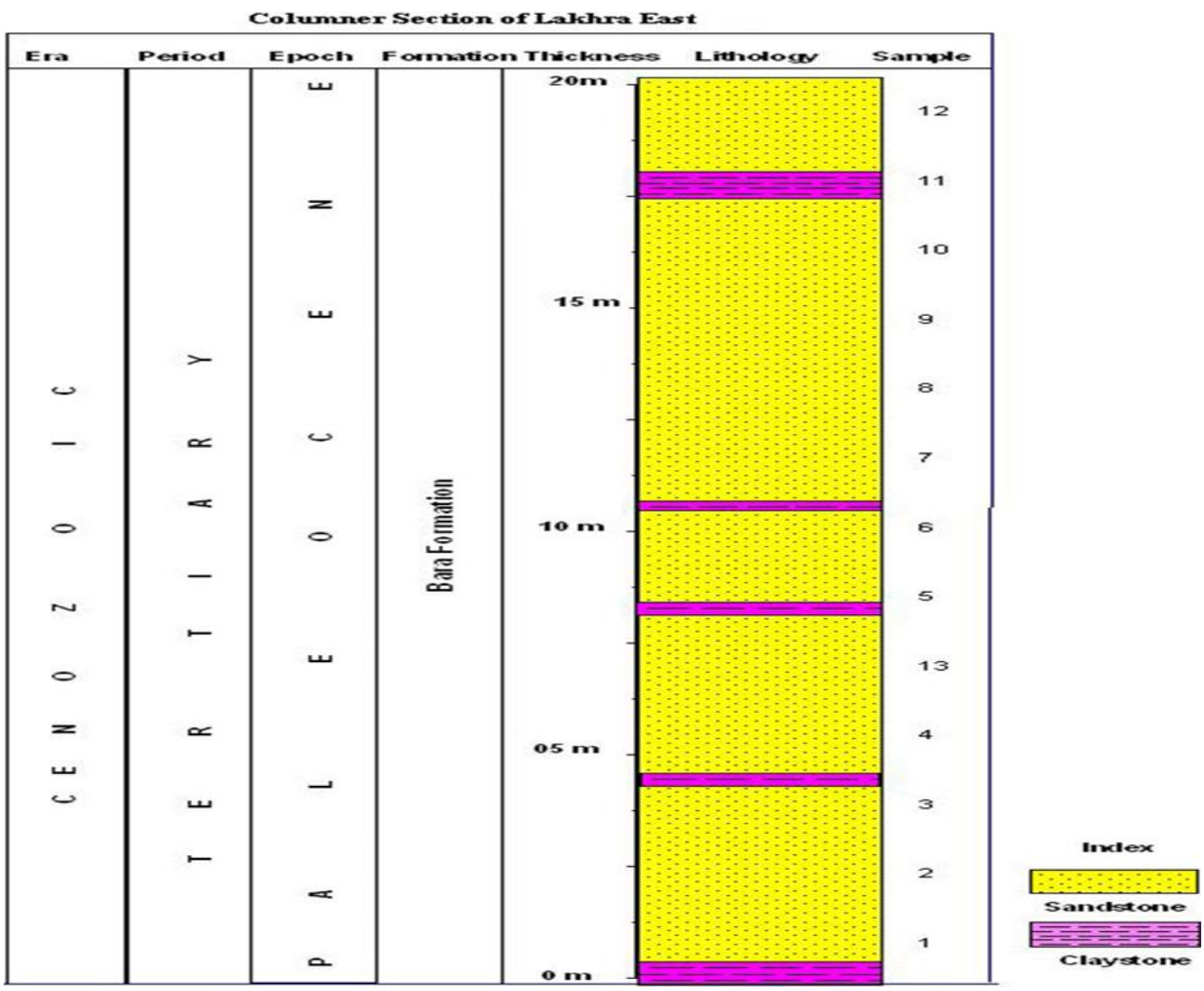

Fig. 2. Stratigraphic succession of early Tertiary outcrops (Paleocene Epoch) at Lakhra geological section.

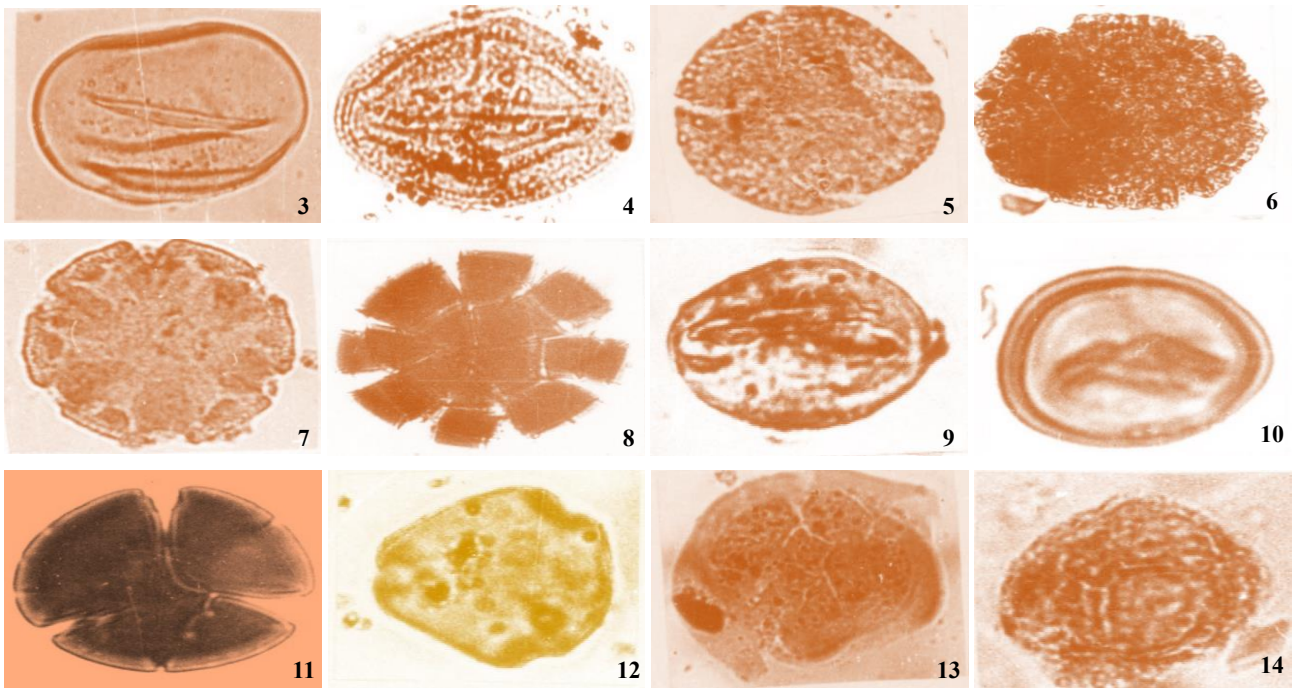

Fig. 3-14. **Colpate pollen grains: 3.** *Tricolpopollenites microhenrici* Thomson & Pflug, 1953; **4.** *Tricolpites lilliei* Couper, 1953; **5.** *Stephanocolpites tertiarus* Singh, 1974; **6.** *Retistephanocolpites williamsi* Germeraad *et al*., 1968; **7.** *Polycolpites flavatus* Sah & Kar, 1969; **8.** *Ghoshiacolpites globatus* Sah & Kar, 1969; **9.** *Araliaceoipollenites quilonensis* Rao & Ramanujam, 1982; **10.** *Sapotaceoidaepollenites obscurus* Thomson & Pflug, 1953; **11.** *Cupanieidites punctatus* Rao & Ramanujam, 1981; **12.** *Engelhardtioidites parvus* Sah & Dutta, 1966; **13.** *Droceridites spinosa* Cookson, 1947; **14.** *Droceridites parvus* Dutta & Sah, 1970

2. *Tricolpites lilliei* Couper (1953)
Pollen grain light brown colored, sub-prolate,34x47µm in size. Tricolpate, one colpus is prominent, 38µm long, extend to the poles, smooth margin, margo ends not rounded. Exine 2µm thick and exinal surface is covered by small granules (Fig. 4).
Affinity: Aceraceae.
Remarks: A close resemblance of present specimen with the pollen specimen was marked as described by Norton & Hall (1969) from upper Cretaceous, Hell Creek Formation, Montana U.S.A.

3. *Stephanocolpites tertiarus* Singh (1974)
Pollen grain brown colored, subcircular, 67x70µm in size. Tetracolpate, colpi 17µm long, narrow and sometime closed. Mesocolpia region broad. Exine 3µm thick, retipilate (Fig. 5).
Affinity: Lamiaceae.
Remarks: A large sized pollen was observed from the rock samples as compared to the specimen described by *Singh* (1974) of Tura Formation exposed at Garo Hills – Tertiary Succession, India.

4. *Retistephanocolpites williamsi* Germeraad *et al*., (1968)
Pollen grain, dark brown in colour, radially symmetrical, isopolar, amb spheroidal, 83 x 86 µmin size. Hexacolpate, Colpi short, 8µm long and 9 µmwide. Exine 3 µmthick, surface reticulate-foveolate (Fig. 6).
Affinity: Ctenolophonaceae.
Remarks: Observed pollen specimen was compared to be larger than Akli Lignite of Paleocene-Eocene age of Rajasthan, India as reported by Naskar & Baksi (1978).

5. *Polycolpites flavatus* Sah & Kar (1969)
Pollen grain brown in color, amb circular, 50x50µm in size. Hexa-brevicolpate, colpi 4 µmlong and 3µmwide at the margin of the grain. Surface finely granulated. Exine 2 µm thick. Scrobiculate structure well developed (Fig.7).
Affinity*:* Pedaliaceae.
Remarks: Open colpi and comparatively larger size of the palynomorph make it distinguishable from reported specimen from Laki sediments in Kuch Basin (Sah & Kar. 1970).

6. *Ghoshiacolpites globates* Sah & Kar (1969)
Pollen grain dark brown colored having circular amb, 73x73 µm in size. Polycolpate having 8 colpi, distinguishable, well developed, 16µm long and 8 µm wide. Mesocolpi thickened in the middle region which joins in the central region to form a star like structure. Exine 2 µm thick, exinal surface laevigate (Fig. 8).
Affinity: Lentibulariaceae.
Remarks: Specimen recovered from Bara Formation is lager in size than the specimen described by Sah & Kar (1969) reported from Laki sediments in Kutch.

7. *Araliaceoipollenites quilonensis* Rao & Ramanujam (1982)
Pollen grain brown colored, isopolar, rhomboidal equatorially, prolates, poles smoothly arched 25x36 µm in size, zonoaperturate, tricolporate, colpi 25 µm long, almost reaching poles. Ora lalogate, 3µm across. Exine 2µm thick, much thicker at poles, sexine thicker than nexine, columella distinct, surface finely punctate (Fig. 9).
Affinity: Araliaceae (Possible affinities to genera *Aralia*, *Panax* and *Heteropanax*).

Remarks: Quilon Beds of Lower to Middle Miocene age of Kerala State, South India (Rao & Ramanujam, 1982) represents smaller sized colporate pollen comparable to presently studied specimen.

8. *Sapotaceoidaepollenites obscurus* Thomson & Pflug (1953)
Pollen grain brown colored, isopolar, broadly elliptical in equatorial view, sub prolate, *17x 20 µm in size*, poles smoothly rounded, zonoaperturate, tetracolporate, colpi long, reaching to the poles with slightly thickened margins. Ora lalongate about 2 µmin size. Exine 1µmthick, surface ornamentation obscure and smooth (Fig. 10).
Affinity: Sapotaceae.
Remarks: Slightly smaller in size than the specimens observed from Tertiary sediments of Oligocene-Miocene age, *Cauvery* Basin (Venkatachala & Rawat, 1973).

9. *Cupanieidites punctatus* Rao & Ramanujam (1982)
Pollen, black in color, isopolar, amb rounded triangular with convex sides, 32x34µmin size. Tricolporate, zonoaperturate colpus margin thin, oral slightly incrassate, lalongate. Exine 2µm thick, surface of exine finely punctate (Fig. 11).
Affinity: Sapindaceae.
Remarks: The palynomorph species exhibited larger sized specimen comparable to Quilon Beds of Lower to Middle Miocene age of Kerala State, India (Rao & Ramanujam, 1982).

10. *Engelhardtioidites parvus* Sah & Dutta (1966)
Pollen grain, light yellow in color, amb triangular with slightly convex sides, 19x 30µmin size. Pores circular, 3 in number, circular shaped, 5µm in diameter and situated at the angles of the triangle, micro-papillae like structure present around pore. Exine 01µmthick, exinal surface psilate (Fig. 12).
Affinity: Juglandaceae.
Remarks: A close resemblance was observed with Lower Eocene, South Shillong Plateau, Assam, India (Dutta & Sah, 1970).

11. *Droceridites spinosa* Cookson (1947)
Pollen grain triporate, brown in colour, 70x78µm in size, sides convex, ora distinct. Exine 0.76 µm in thickness with scabrate– spinose surface (Fig. 13).
Affinity: Droseraceae.
Remarks: This specimen is larger in size than reported specimens from Paleocene Meghalaya, India (Kar & Kumar, 1986).

12. *Droceridites parvus* Dutta & Sah (1970)
Stephanoporate Pollen grains were observed as tetrahedral tetrad form, light to dark brown color, pores indistinct due topreservation in polar view and exine slightly ruptured at margin thus obscuring ora, 68x76µm in size. Exine laevigate- scabrate (Fig. 14).
Affinity: Droseraceae.
Remarks: Present specimen exhibits strike resemblance of the specimen reported from the sediments from Kollam Coast, Kerala India (Padmalal *et al.,* 2011).

Discussion

Angiospermic pollen mainly comprised of variety of colpate, colporate and porate pollen were recovered abundantly from the sedimentary outcrops of Bara Formation from the Lakhra region which is the oldest tertiary sedimentary sequence exhibiting a thickness of 20 meters (Shah, 2009). The palynoflora was preserved in fair status and palynomorphs observed during present investigations were markedly identified based upon morphographic characteristics of pollen grains. Colpate pollen morphogenera encountered from the sediments were *Tricolpopollenites microhenrici* Thomson & Pflug (1953), *Tricolpites lilliei* Couper (1953), *Stephanocolpites tertiarus* Singh (1974), *Retistephanocolpites williamsi* Germeraad *et al*. 1968, *Polycolpites flavatus* Sah & Kar (1969) and *Ghoshiacolpites globatus* Sah & Kar (1969). The colporate pollen grains were represented by *Araliaceoipollenites quilonensis* Rao & Ramanujam (1982), Cupanieidites punctatus Rao & Ramanujam (1982) and *Sapotaceoidaepollenites obscurus* Thomson & Pflug (1953), However, *Engelhardtioidites parvus* Sah & Dutta (1966), *Droceridites spinosa* Cookson (1947) and *D. parvus* Dutta & Sah, (1970) exhibited triporate–stephanoporate pollen morphoforms. By comparing the fossil palynomorphs with the modern day counterparts, angiospermic following families i.e., Fagaceae, Labiatae, Ctenolophonaceae, Pedaliaceae, Lentibulariaceae, Araliaceae, Sapotaceae, Sapindaceae, Juglandaceae and Droseraceae were investigated. Such identified floral patterns are in continuation of research aspects of already pulished literature by the Khan *et al*., (2017).

Environment is an important indicator for the distribution of species in space and time (Odum, 1961). Organization of vegetation in a specified area can also be inferred by observing the palynomorph spectrum of particular sediments in relation to other rock deposits (Shaheen *et al.,* 2016). Thus palynomorphs occurrence is a reliable tool for reconstructing the paleoclimatology as well as paleoecology of the sediments in which pollen genera were deposited (Lange, 1976). As the presence of pollen form taxa related to Ctenolophonaceae and Pedaliaceae represented tropical –subtropical climate (Deding, 1990). However, the occurrence of Araliaceae, Sapindaceae and Droseraceae families in the studied sediments inferred the occurrence of marshy mangrove vegetation preserved in the brackish water environment along the coastal belt (Coombes, 1995).

Fresh water aspects on the other hand were observed by the presence of fossil pollen forms referable to the family Lentibulariaceae (Crow, 1998), temperate fossil features related to Juglandaceae were derived from nearby upland vegetation and were moved at the time of deposition (Harrington, 1999). From overall angiospermic patterns, it was inferred that the environment was likely to be near shore with sufficient fresh water or fresh water supply occurred during depositional phase of Bara Formation.

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(Received for publication 15 November 2018)