VOLUMINA JURASSICA, 2015, XIII (2): 55–80
DOI: 10.5604/17313708 .1185694

Integrated biostratigraphy of the Jurassic strata of the Wagad Uplift, Kachchh, western India

Jyotsana RAI [1], Surabhi GARG [1], Mridul GUPTA[1], Abha SINGH [1], Dhirendra K. PANDEY [2], Franz Theodor FÜRSICH [3], Matthias ALBERTI [4], Rahul GARG [1]

Key words: Jurassic, calcareous nannofossils, dinoflagellate cysts, ammonites, Oxfordian, Kimmeridgian, Wagad Uplift, Kachchh.

Abstract. An integrated study based on calcareous nannofossils, organic-walled dinoflagellate cysts, and ammonites from the Washtawa and Kanthkot formations of the Wagad Uplift have allowed a detailed documentation of the stratigraphic position of these formations within the Oxfordian and Kimmeridgian sediments of the Kachchh Basin, western India. The nannofossil assemblages from the lower part of the Nara Shale Member exposed in the Nara and Washtawa domes, the Kanthkot Ammonite Beds along the Trambau River section, and the Patasar Shale Member exposed along the Trambau River section and the Patasar Tank section in the eastern part of the Wagad Uplift belong to the NJ 14 *Cyclagelosphaera margerelli* Zone of the Early Oxfordian, the NJ 15a *Lotharingius sigillatus* Zone of the Middle Oxfordian, and the NJ 15b *Cretarhabdus conicus* of Early Kimmeridgian age, respectively. Zonation schemes, based on calcareous nannofossils, dinoflagellate cysts, and ammonites were calibrated highlighting their biostratigraphic potential. These studies may represent a reference biochronology for Oxfordian–Kimmeridgian age strata applicable to the Tethyan realm of which India was a part during Late Jurassic times.

INTRODUCTION

The marine Jurassic successions of the Kachchh Basin, western India (Fig. 1A, B), have been known globally for more than a century due to their rich and precisely datable ammonite faunas. Kachchh is a pericratonic basin which has experienced sedimentation during Mesozoic and Cenozoic times. The Mesozoic sedimentary succession comprises Upper Triassic continental sediments, Lower Jurassic (Pliensbachian) to Upper Jurassic marine sediments and Lower Cretaceous (up to Albian) marine to paralic sediments. The Mesozoic sediments crop out in the Kachchh Mainland Uplift, the northern island belt (comprising four uplifts called the Pachchham, Khadir, Bela, and Chorad islands), and the easternmost Wagad Uplift separated by the sandy sediments of the Rann (Fig. 1B).

GEOLOGY OF THE AREA

The Wagad Uplift (Fig. 1B, C) is situated in the easternmost part of the Kachchh Basin (Biswas, Deshpande, 1970). It is separated in the south from the Kachchh Mainland Uplift by a high angle fault with a regional east-west strike. It displays good exposures of Middle Jurassic (Callovian)

[1] Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow, India.

[2] Department of Geology, University of Rajasthan, Jaipur, India; e-mail: dhirendrap@hotmail.com; corresponding author.

[3] GeoZentrum Nordbayern, Fachgruppe PaläoUmwelt, Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstraße 28, 91054 Erlangen, Germany.

[4] Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Straße 10, 24118 Kiel, Germany.

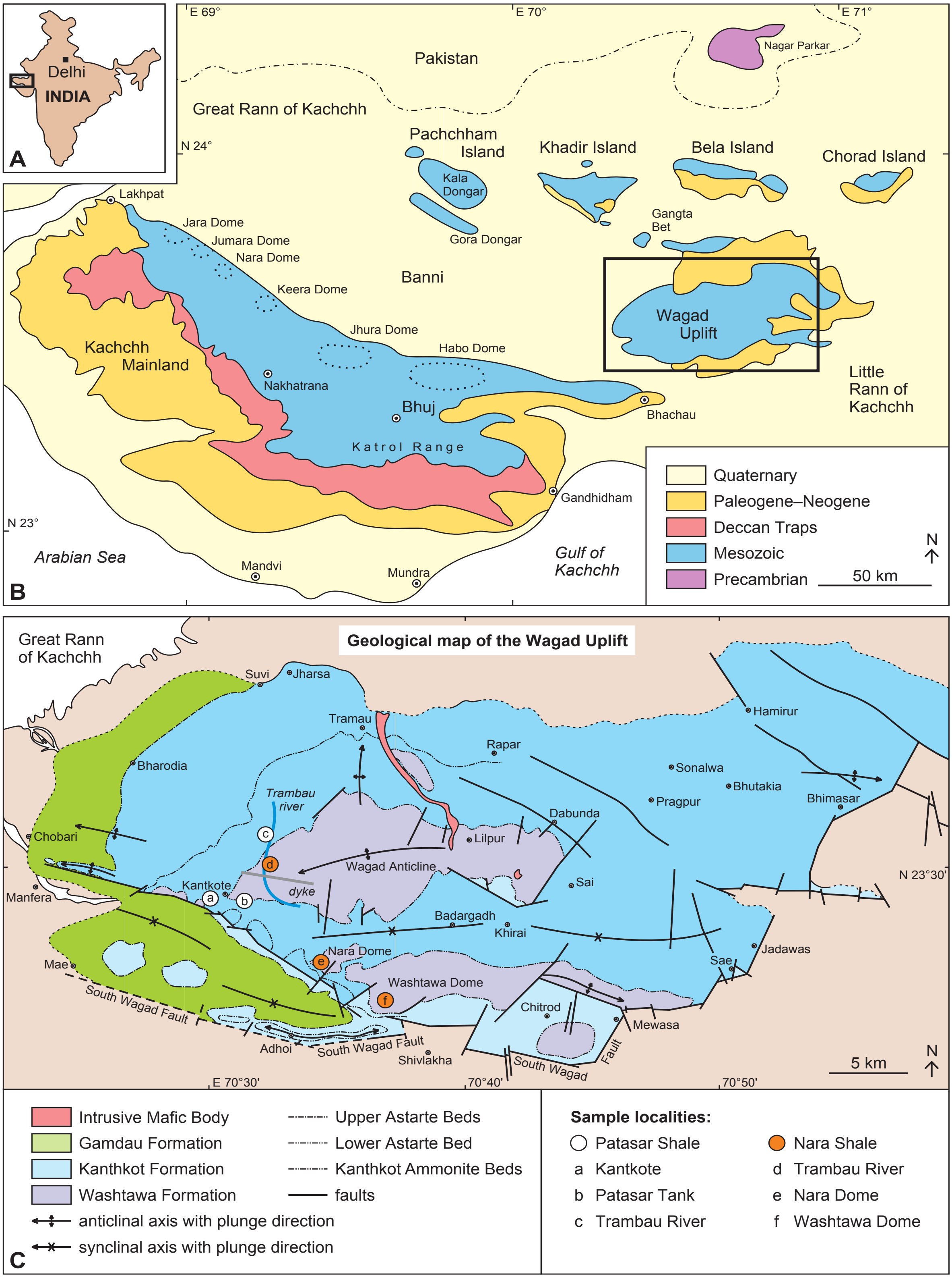


Fig. 1. A. Inset map of India. B. Geological map of the Kachchh Basin. C. Schematic map of the Wagad Uplift, Kachchh (modified after Deshpande, Merh, 1980)

to Lower Cretaceous rocks (Biswas, 1971; Deshpande, 1972; Deshpande, Merh, 1980). While Oxfordian to Kimmeridgian strata are characterized by strong condensation or stratigraphic gaps elsewhere in the basin (Alberti *et al*., 2013a), the Wagad Uplift preserves a comparatively continuous Oxfordian-Kimmeridgian succession of shallow-water sediments and thus is ideally suited for the present integrated study.

PREVIOUS STUDIES IN THE WAGAD UPLIFT

The first detailed lithostratigraphic framework of the sedimentary succession of the Wagad Uplift was provided by Deshpande (1972), followed by Biswas (1980) and other workers (*e.g*. Pandey *et al*., 2012; Fürsich *et al*., 2013). Lithostratigraphically, the Oxfordian and Kimmeridgian sediments have been grouped into the Washtawa, Kanthkot and Gamdau formations (Fig. 2). The ammonite biostratigraphy of these sediments has been improved in the recent past by the efforts of several national and international scientific co-operations (Krishna *et al*., 1995, 1998, 2009a–c; Pandey *et al*., 2012, 2013a, b). In comparison to the ammonites, data on calcareous nannofossils and dinoflagellate cysts from the Jurassic rocks of the Kachchh Basin are very limited (Krishna *et al*., 1983; Jain *et al*., 1984, 1986; Kumar, 1986a–c; Rai, 2003; Saxena, Jafar, 2008). The present study is an attempt to integrate both data on macro- and microfossils from the Wagad Uplift to attain a more precise biostratigraphic resolution.

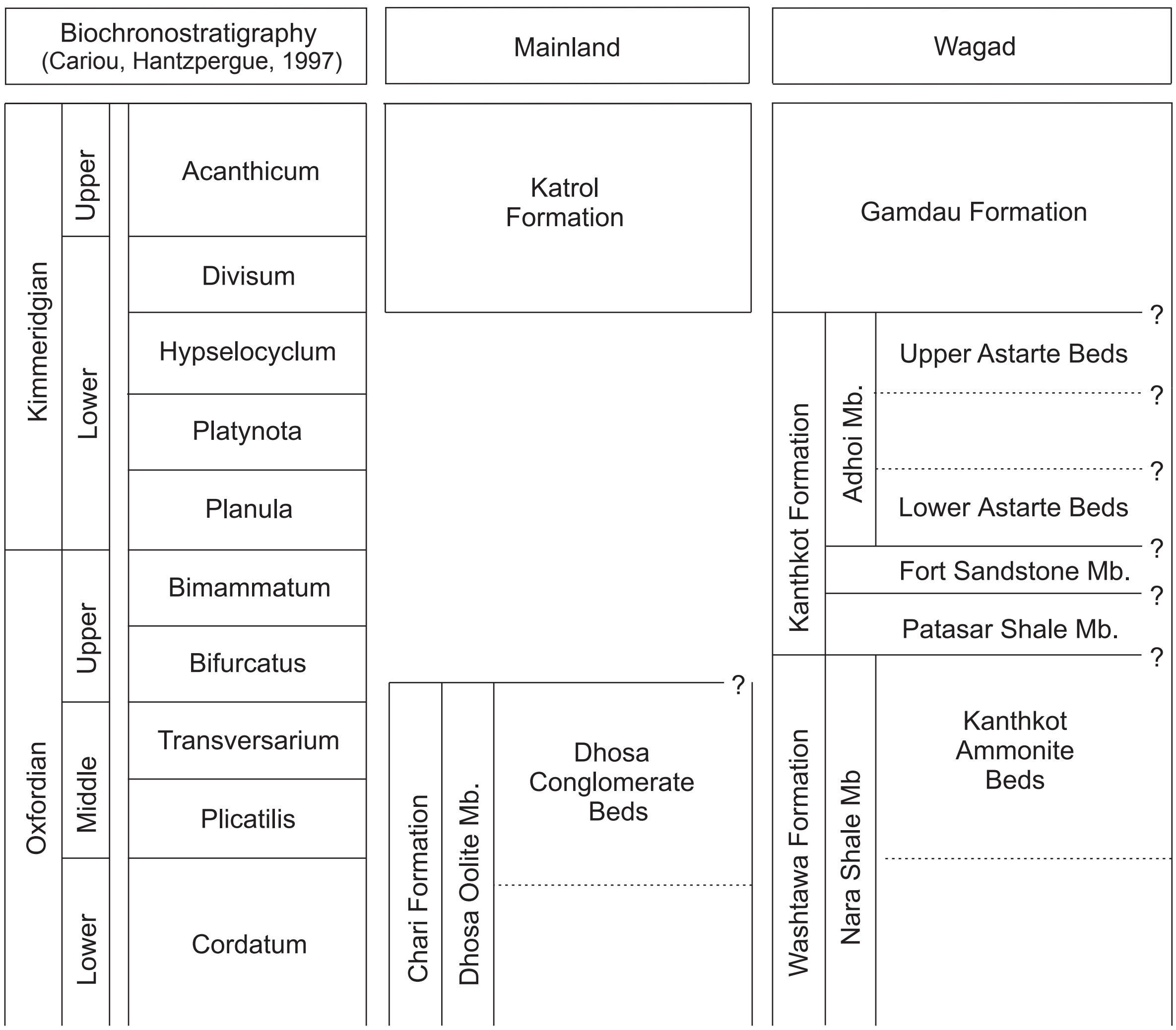


Fig. 2. Litho- and biochronostratigraphic framework for the Oxfordian and Kimmeridgian pro parte in the Kachchh Basin (modified after Pandey *et al*., 2013)

METHODS

Samples were collected from the Nara and Washtawa domes, the Trambau River section, the Patasar Tank section, and the Kantkote area during three field sessions (January-April 2012, January 2013, and December 2013–January 2014). The aim was to integrate ammonite, nannofossil, and dinocyst data to give a precise biostratigraphy and to better interpret the palaeoenvironmental conditions.

For nannofossils, two smear slides of each sample (fifty-two in number) collected from the Nara Shale Member, the Kanthkot Ammonite Beds, and the Patasar Shale Member following the procedure given in Bown, Young (1998) were studied. For dinoflagellate cysts, only samples collected from the Patasar Tank area were processed. Slides were prepared according to Wood *et al*. (1996). For biostratigraphic correlations, nannofossil zones NJ by Bralower *et al*. (1989) and Bown *et al*. (1988) were applied.

DATABLE HORIZONS IN THE WAGAD UPLIFT

WASHTAWA FORMATION, NARA SHALE MEMBER

The Nara Shale Member of the Washtawa Formation exposed in the Nara and Washtawa domes (Fig. 3A, B) has yielded nannofossils (Pls 1, 2) that have been analysed. This stratigraphic unit lacks ammonites and dinoflagellate cysts.

Kanthkot Ammonite Beds

The topmost part of the Nara Shale Member is represented by a highly ferruginous, sandy unit, rich in ammonites and belemnites, named the Kanthkot Ammonite Beds. These beds are well exposed at the base of the scarp near Kantkote village and along the Trambau River (Fig. 3C). Based on ammonites, the Kanthkot Ammonite Beds were assigned to the Middle to Upper Oxfordian (Lower Plicatilis to Lower Bifurcatus zones; Pandey *et al*., 2012). Shales associated with the well cemented sandy beds contain nannofossils (Pl. 2). The Kanthkot Ammonite Beds exposed along the Trambau River section are very rich in ammonites, gastropods, wood fragments, and plant fructifications (Pandey *et al*., 2012; Alberti *et al*., 2013b). The oldest occurrence of bennetitalean fossil flowers in India has been recorded from these strata (Rai *et al*., 2016).

KANTHKOT FORMATION, PATASAR SHALE MEMBER

The lower and middle parts of the Patasar Shale Member exposed near the Patasar Tank (Fig. 3D) have been found to contain abundant nannofossils and dinoflagellate cysts (Pls 3, 4), whereas the upper part, which is sandy and grades into the overlying Fort Sandstone Member, did not yield calcareous nannofossils and dinoflagellate cysts. So far no ammonites have been recorded from the Patasar Tank section. Along the scarp near Kantkote village, the Patasar Shale Member has yielded a rather poorly preserved fragment of an ammonite assigned to *Perisphinctes* (*Dichotomoceras*) cf. *besairiei* Collignon. Here, the Patasar Shale Member may represent the Upper Oxfordian Grossouvrei Subzone of the Bifurcatus Zone (Pandey *et al*., 2012).

RESULTS

In the course of the integrated ammonite, calcareous nannofossil, and dinoflagellate cyst studies, deposits from the above mentioned sections of the Wagad Uplift, mainly from the shales of the Washtawa and Kanthkot formations have been examined. The overlying Gamdau Formation did not yield any time-indicative macro- or microfossils. In addition ammonite data were adopted from the literature (Krishna *et al*., 1995, 1998, 2009a–c; Pandey *et al*., 2012, 2013a, b).

AMMONOID BIOSTRATIGRAPHY

Waagen (1873–1875) was the first to document ammonites from the Wagad Uplift in the Kachchh Basin followed by Spath (1927–1933). Later authors, such as Krishna *et al*. (1995, 1998, 2009a–c) and Pandey *et al*. (2012, 2013a, b), improved the biostratigraphic framework based on new collections of ammonites. Accordingly, the shales of the Washtawa Formation (Nara Shale Member, including the Kanthkot Ammonite Beds) and the Kanthkot Formation (Patasar Shale Member) range from the Middle to Upper Oxfordian (Lower Plicatilis Zone to Bifurcatus Zone; Fig. 4).

Washtawa Formation, Kanthkot Ammonite Beds

The lower part of the Kanthkot Ammonite Beds exposed southwest of Kantkote village and along the Trambau River was studied by Pandey *et al*. (2012) and assigned to the Lower Plicatilis Subzone of the Plicatilis Zone (lower Middle Oxfordian).

The central part of the Kanthkot Ammonite Beds is the most fossiliferous unit which yielded ten taxa of the genus *Perisphinctes* including several index species enabling Pandey *et al*. (2012, fig. 66) to assign these strata to the Plicatilis–Parandieri subzones of the Plicatilis–Transversarium zones (Middle Oxfordian).

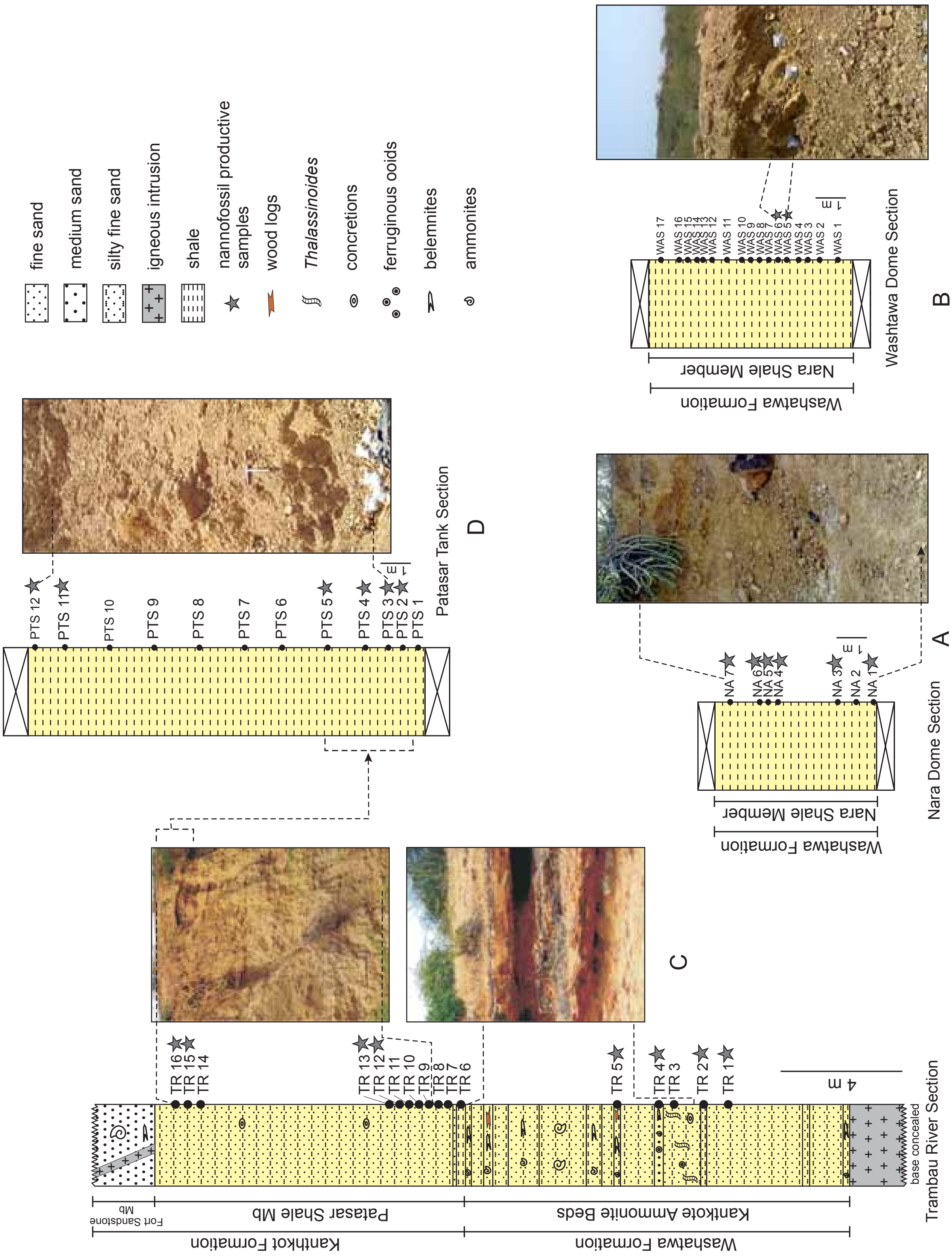


Fig. 3. Lithologs of the sections studied

A. Nara Dome section. **B.** Washtawa Dome section. **C.** Trambau River section. **D.** Patasar Tank section

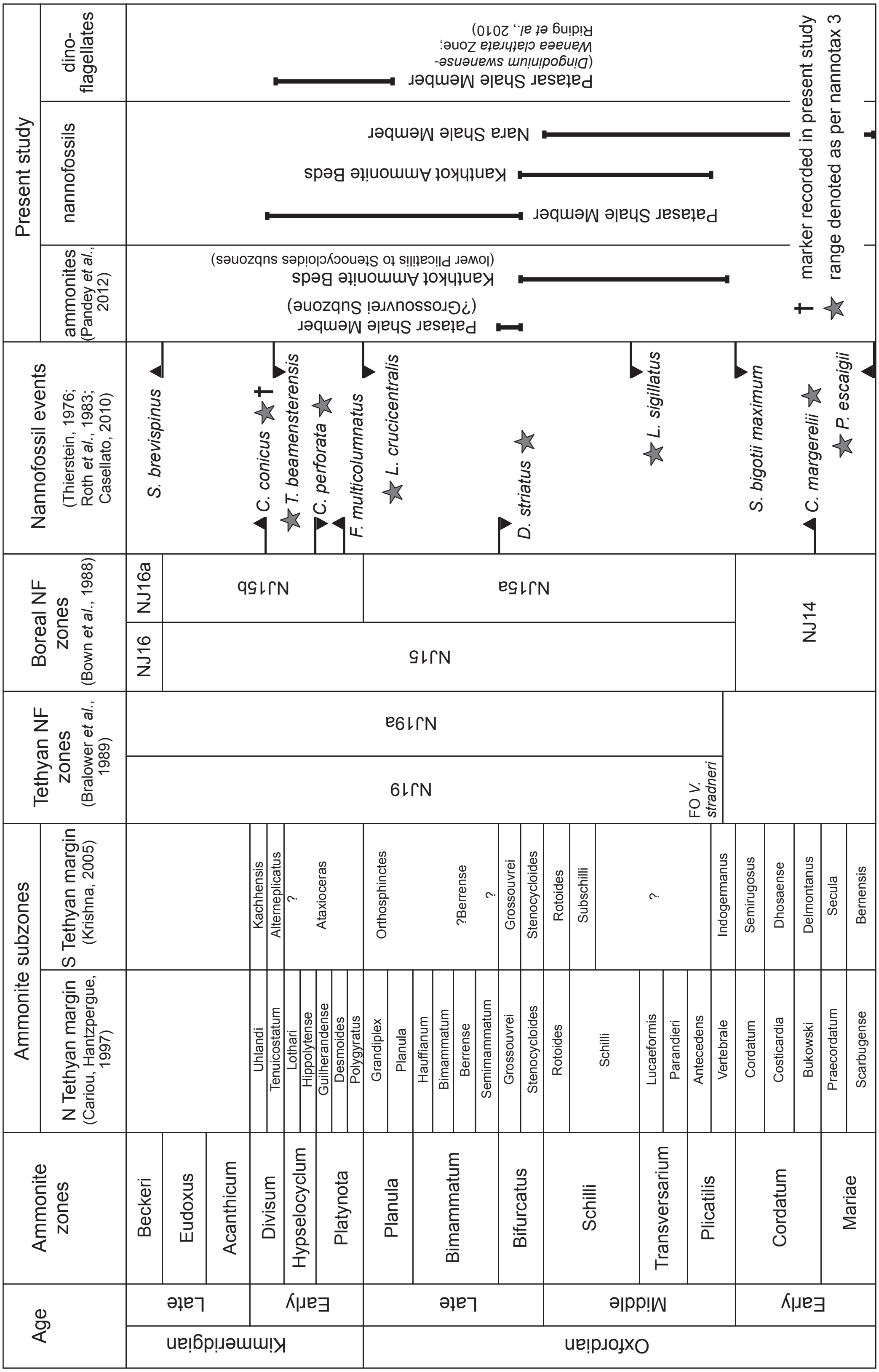


Fig. 4. Composite chart showing correlation of the standard ammonite and nannofossil zonations used in the present study

The top part of the Kanthkot Ammonite Beds present in the sections near Kantkote village and in Trambau River yielded sixteen perisphinctid taxa allowing the assignment of these levels to the Stenocycloides Subzone of the Bifurcatus Zone (lower Upper Oxfordian; Pandey *et al*., 2012).

Kanthkot Formation, Patasar Shale Member

The lower part of this member may represent the Grossouvrei Subzone of the Bifurcatus Zone (lower Upper Oxfordian). This is based on a solitary record of *P*. (*Dichotomoceras*) cf. *besairiei* Collignon from about 7 to 9 m above the highest bed of the Kanthkote Ammonite Beds near Kantkote Village (Pandey *et al*., 2012).

CALCAREOUS NANNOFOSSILS

Nara Shale Member

This member was studied at the Washtawa and Nara domes. In the Nara Dome, out of seven samples, six samples (NA 1, 3–7) have yielded nannofossils (Fig. 3A). The assemblage contains *Axopodorhabdus atavus*, *A. cylindratus*, *A. rahla*, *Biscutum dubium*, *B. finchii*, *B. novum*, *Cretarhabdus* sp., ***Cyclagelosphaera margerelii*** (FAD fide Roth *et al*., 1983 marks Early Oxfordian), *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *Ethmorhabdus gallicus*, *Hexapodorhabdus cuvillieri*, *Lotharingius barozii*, *L. contractus*, *L. crucicentralis*, *L. hauffii*, ***L. sigillatus*** (LAD fide Casellato, 2010 marks Middle Oxfordian), *Orthogonoides hamiltoniae*, *Perissocyclus plethotretus*, ***Polypodorhabdus escaigii*** (FAD fide Thierstein, 1976 marks Early Oxfordian), *Stephanolithion bigotii bigotii*, *Triscutum sullivanii*, *Tubirhabdus patulus*, *Watznaueria barnesae*, *W. britannica*, *W. manivitiae*, *Zeugrhabdotus erectus*, and ascidian spicules (Pl. 1). In the Washtawa Dome, out of 17 samples only two samples (WAS 5 and 6) have yielded nannofossils (Fig. 3B). The nannofossil assemblage includes ***Cyclagelosphaera margerelii*** (FAD fide Roth *et al*., 1983 marks Early Oxfordian), *Diazomatolithus lehmanii*, *Lotharingius hauffii*, ***L. sigillatus*** (LAD *fide* Casellato, 2010 marks Middle Oxfordian), *Schizosphaerella punctulata*, *Watznaueria britannica*, and ascidian spicules (Pl. 2). The record of ***Cyclagelosphaera margerelii*** (FAD; Early Oxfordian) and ***Polypodorhabdus escaigii*** (FAD; Early Oxfordian) suggests an Early Oxfordian age (NJ14 Zone of Bown *et al*., 1988) for the part of the Nara Shale Member exposed in the Nara and Washtawa domes stratigraphically below the Kanthkot Ammonite Beds. ***Lotharingius sigillatus*** also occurs in this assemblage but it continues from the Late Pliensbachian much below (FAD *fide* Bown, Cooper 1998, LAD *fide* Casellato, 2010 marks Middle Oxfordian; Fig. 4).

Shale intervals within the Kanthkot Ammonite Beds

Four beds within the Kanthkot Ammonite Beds at the Trambau River section (TR 1, 2, 4, and 5) have yielded a moderately diverse, slightly overgrown but datable nannofossil assemblage (Fig. 3C). The assemblage contains *Biscutum dubium*, *B. novum*, *Cretarhabdus* sp., ***Cyclagelosphaera margerelii*** (FAD *fide* Roth *et al*., 1983 marks Early Oxfordian), *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *Ethmorhabdus gallicus*, *Hexapodorhabdus cuvillieri*, *Lotharingius hauffii*, ***L. sigillatus*** (LAD fide Casellato, 2010 marks Middle Oxfordian), *Perissocyclus plethotretus*, ***Polypodorhabdus escaigii*** (FAD *fide* Thierstein, 1976 marks Early Oxfordian), *Stephanolithion bigotii bigotii*, *Triscutum sullivanii*, *Watznaueria britannica*, *W. contracta*, *W. manivitiae*, and *Zeugrhabdotus erectus* (Pl. 2). Based on the nannofossil assemblages in the under- and overlying horizons the best age suggested for these shale beds of the Kanthkot Ammonite beds is Middle Oxfordian (Fig. 4). *Cyclagelosphaera margerelii* (FAD; Early Oxfordian) and *Polypodorhabdus escaigii* (FAD; Early Oxfordian) continue upwards from underlying part of the Nara Shale Member recorded in the Nara and Washtawa domes.

Patasar Shale Member from the Trambau River section

Out of eleven samples (TR 6–TR 16) collected from the Patasar Shale Member of the Kanthkot Formation at the Trambau River section, four samples (TR 12, 13, 15, 16) contained nannofossils (Fig. 3C). The nannofossil assemblage recorded from TR 12, 13 and 15 consists of *Biscutum dorsetensis*, *B. dubium*, *B. novum*, *Cretarhabdus* sp., *Cyclagelosphaera margerelii*, *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *D. ignotus*, *Ethmorhabdus gallicus*, *Lotharingius contractus*, *L. hauffii*, ***L. sigillatus*** (LAD *fide* Casellato, 2010 marks Middle Oxfordian), *Stephanolithion bigotii bigotii*, *S. hexum*, *Triscutum tiziense*, *Watznaueria britannica*, *W. manivitiae*, and *Zeugrhabdotus erectus* which suggest a Middle Oxfordian age for this part of the Patasar Shale Member in this section (Fig. 4; Pl. 3). ***Cyclagelosphaera margerelii***, whose FAD (Roth *et al*., 1983) is much earlier in the Early Oxfordian, continues into this assemblage.

Sample number TR 16 contains *Biscutum dubium*, *B. finchii*, ***Cretarhabdus conicus*** (FAD *fide* Casellato, 2010 marks Early Kimmeridgian), *Cyclagelosphaera margerelii*, *Diazomatolithus lehmanii*, *Lotharingius contractus*, ***L. crucicentralis*** (LAD *fide* Casellato, 2010 marks Late Oxfordian), *L. hauffii*, *Stephanolithion bigotii bigotii*, *S. hexum*, *Watznaueria barnesae*, *W. britannica*, and *Zeugrhabdotus erectus* (Pl. 3). The presence of ***C. conicus*** (FAD; Early Kimmeridgian) and ***L. crucicentralis*** (LAD *fide* Casellato, 2010 marks Late Oxfordian) in this sample indicate a Late Oxfordian to Early Kimmeridgian age for the uppermost part of the Patasar Shale Member in this section (Fig. 4). The boundary between the Middle Oxfordian and Late Oxfordian in this section seems to lie between samples TR15 and TR16. ***C. margerelii*** (FAD fide Roth *et al*., 1983 marks Early Oxfordian) still continues in this nannofossil assemblage. In all possibility this uppermost part of the section, which is not very thick, represents a sedimentary condensation.

Patasar Shale Member from the Patasar Tank area

At the Patasar Tank, a thick shale succession (~15 m) is exposed along a scarp. The sediments are light to dark grey, gypsiferous in the lower part and greenish grey to khaki, silty in the upper part (Fig. 3D). The upper part is often marked by flaggy, yellowish brown siltstone alternations. Out of twelve samples, only six samples (PTS 2–5, 11 and 12) contained a highly diverse, moderately preserved nannofossil assemblage. The assemblage consists of *Axopodorhabdus cylindratus*, *Biscutum dorsetensis*, *B. dubium*, *B. finchii*, *B. novum*, ***Crepidolithus perforata*** (LAD *fide* Casellato, 2010 marks Early Kimmeridgian), ***Cretarhabdus conicus*** (FAD *fide* Casellato, 2010 marks Early Kimmeridgian), *Cyclagelosphaera margerelii*, *Diazomatolithus lehmanii*, *Discorhabdus corollatus*, *D. criotus*, *D. ignotus*, ***D. striatus*** (LAD *fide* Bown *et al*., 1988 marks Late Oxfordian), *Ethmorhabdus gallicus*, *Hexapodorhabdus cuvilieri*, *Lotharingius barozii*, ***L. crucicentralis*** (LAD *fide* Casellato, 2010 marks Late Oxfordian), *L. hauffii*, ***L. sigillatus*** (LAD *fide* Casellato, 2010 marks Middle Oxfordian), *L. velatus*, *Octopodorhabdus decussatus*, *O. praevisus*, *Podorhabdus grassei*, *Retecapsa octofenestrata*, *R. schizobrachiata*, *Staurolithites lumina*, *Stephanolithion bigotii bigotii*, *S. hexum*, *S. speciosum octum*, ***Triscutum beaminsterensis*** (LAD *fide* Casellato, 2010 marks the boundary between Early and Late Kimmeridgian), *T. sullivanii*, *T. tiziense*, *T. expansus*, *Tubirhabdus patulus*, *Umbria granulosa*, *Watznaueria barnesae*, *W. britannica*, *W. contracta*, *W. fossacincta*, *W. manivitiae*, and *Zeugrhabdotus erectus* (Pls 3, 4). Besides these zonal indices, reworked Early Jurassic nannofossils are also present in the assemblage viz. *Crucirhabdus primulus*, *Mazaganella protensa*, *Diductius constans*, and *Parhabdolithus liasicus* (Pls 3, 4).

The co-occurrence of ***Cretarhabdus conicus*** (FAD; Early Kimmeridgian), ***Lotharingius sigillatus*** (LAD; Middle Oxfordian), ***L. crucicentralis*** (LAD; Late Oxfordian), ***Discorhabdus striatus*** (LAD; Late Oxfordian), ***Crepidolithus perforata*** (LAD; Early Kimmeridgian), and ***Triscutum beamensterensis*** (LAD; boundary between Early and Late Kimmeridgian) in the above mentioned samples suggest either reworking and mixing of the Middle Oxfordian to Early Kimmeridgian species or extended stratigraphic range of some species. Contextually these shale samples in the succession at the Patasar Tank area suggest a Middle Oxfordian to Early Kimmeridgian age corresponding to the NJ 15b assemblage zonal placement of Bown *et al*. (1988). ***Cyclagelosphaera margerelii***, whose FAD (Roth *et al*., 1983) is much earlier in the Early Oxfordian, continues into this assemblage (Fig. 4; Pls 3, 4).

Based on the records of nannofossils in the two successions described above, sedimentary condensation from the Late Oxfordian to the Early Kimmeridigian can be envisaged. The record of Middle Oxfordian elements (such as *Lotharingius sigillatus*; LAD: Middle Oxfordian) from the Patasar Shale Member, which in fact has also been recorded from the underlying Kanthkot Ammonite Beds may also show repeated phases of reworking. The recorded nannofossil taxa from various sections are plotted against the sample numbers to show their distribution and the markers utilized for age assignment (Fig. 4, Table 5).

DINOFLAGELLATE CYSTS

A rich and well diversified dinoflagellate cyst (dinocyst) assemblage has been recovered from the lower part of the Patasar Shale Member (PTS 1), exposed along the Patasar Tank section (Pl. 5). The dinocyst assemblage consists of the following 32 species: *Adnatosphaeridium caulleryi*, *Aldorfia aldorfensis*, *A. dictyota dictyota*, *A. dictyota osmingtonensis*, *Apteodinium* sp., *Batiacasphaera* sp., *Broomea* sp., *Canningia* sp., *Chlamydophorella wallala*, *Circulodinium densebarbatum*, *Cleistosphaeridium* sp., *Dingodinium jurassicum*, *D. tuberosum*, *Egmontodinium polyplacophorum*, *E. torynum*, *Endoscrinium galeritum*, *E. luridum*, *Glossoidinium dimorphum*, *Gonyaulacysta jurassica*, *Leptodinium* sp. cf. *L. eumorphum*, *Lithodinia jurassica*, *Mendicodinium granulatum*, *M. microreticulatum*, *Nannoceratopsis pellucida*, *Oligosphaeridium patulum*, *Pareodinia ceratophora*, *Prolixosphaeridium anasillum*, *P. capitatum*, *Rigaudella aemula*, *R. filamentosa*, *Stiphrosphaeridium* sp., and *Tubotuberella apatela*.

The characteristic and most common species in the present assemblage include *Aldorfia dictyota dictyota*, *A. dictyota osmingtonensis*, *Dingodinium jurassicum*, *D. tuberosum*, *Endoscrinium luridum*, *Gonyaulacysta jurassica jurassica*, and *Stiphrosphaeridium dictyophorum*. The occurrence of *Egmontodinium polyplacophorum*, *E. torynum*, and *Oligosphaeridium patulum* is significant as these species have their first appearance in the Kimmeridgian (Riding, Thomas, 1992; Riding *et al*., 2010; Stover *et al*., 1996). At the same time, the occurrence of *Endoscrinium galeritum* and *E. luridum* is also very important as these two species have their last occurrence in the Early Kimmeridgian (Riding, Thomas, 1992). The present dinocyst assemblage recorded from the Patasar Tank section, indicates an Early Kimmeridgian age for the PTS 1 part of the studied interval of the Patasar Shale Member (Fig. 4).

The occurrence of nannofossils, such as *Lotharingius sigillatus* (LAD; Middle Oxfordian), *L. crucicentralis* (LAD; Late Oxfordian), and *Discorhabdus striatus* (LAD; Late Oxfordian) in the upper part of the section (PTS 11 and 12), which is stratigraphically younger to PTS 1 (assigned here to the Early Kimmeridgian on the basis of its dinoflagellate cyst assemblage), suggest either reworking and mixing of the Middle and Late Oxfordian elements to the Early Kimmeridgian species (*e.g*. ***Cretarhabdus conicus***, FAD; Early Kimmeridgian and ***Crepidolithus perforate***, LAD; Early Kimmeridgian) or extended stratigraphic range. In all probability the sedimentary succession from PTS 1 to PTS 11 & 12 represents the Early Kimmeridgian.

AGE INTERPRETATION

Krishna *et al*. (1995, 2009c) provided an ammonite biostratigraphic framework for the Wagad Uplift and assigned a late Middle Oxfordian age (Transversarium Zone, Schilli Subzone) to the Kanthkot Ammonite Beds and a Late Oxfordian (Bimammatum Zone) to early Early Kimmeridgian (Platynota Zone) interval to the overlying Kanthkot Formation exposed along the Iddurgarh-Bharodia section, near the village of Bharodia. Pandey *et al*. (2012) made further systematic collections of ammonites and assigned an early Middle Oxfordian age (Early Plicatilis Subzone of Plicatilis Zone) to the lower part of the Kanthkot Ammonite Beds, a Middle Oxfordian age (Plicatilis–Parandieri subzones of the Plicatilis–Transversarium zones) to the central part of the Kanthkot Ammonite Beds, and an early Late Oxfordian age (Stenocycloides Subzone of Bifurcatus Zone) to the top part of the Kanthkot Ammonite Beds exposed southwest of the Kantkote village and along the Trambau River section (Fig. 4). The overlying Patasar Shale Member was assigned to the ?Grossouvrei Subzone of the Bifurcatus Zone with an early Late Oxfordian age on the basis of a solitary record of *P*. (*Dichotomoceras*) cf. *besairiei* from about 7 to 9 m above the highest bed of the Kantkote Ammonite Beds near Kantkote Village. In the Bharodia section in the extreme west of the Wagad Uplift, ammonite evidence led Pandey *et al*. (2013b) to conclude a stratigraphic gap including parts of the Upper Oxfordian to lower Lower Kimmeridgian similar to that known from the Kachchh Mainland (Krishna *et al*., 2009b).

The present findings of nannofossils from the lower part of the Nara Shale Member exposed at the Nara and Washtawa domes, the Kanthkot Ammonite Beds and the Patasar Shale Member exposed along the Trambau River section and the Patasar Tank section in the eastern part of the Wagad Uplift belong to the NJ 14 *Cyclagelosphaera margerelli* Zone of the Early Oxfordian, the NJ 15a *Lotharingius sigillatus* Zone of the Middle Oxfordian, and the NJ 15b *Cretarhabdus conicus* Zone of the Early Kimmeridgian, respectively (Fig. 4). The nannofossil biostratigraphy also suggests condensation and mixing of fauna in the stratigraphic succession of the Late Oxfordian to Early Kimmeridigian. Interestingly, the dinocyst assemblage recorded from a thin horizon within the Patasar Shale Member exposed at the Patasar Tank section indicates an Early Kimmeridgian age (Fig. 4).

PALAEOBIOGEOGRAPHIC REMARKS

The dinocyst assemblage in the Patasar Shale Member contains several characteristic Late Jurassic species and shows marked similarities between Late Jurassic floras of Australasia and Indonesia as well as those recorded from India (Tethys Himalaya, Kachchh), East Africa, and Madagascar. At the same time, these assemblages also share considerable similarities with Boreal (European or northern hemisphere) assemblages. In other words, the dinocyst assemblages from India show a mixed Boreal, Tethyan and Austral aspect, a feature noted earlier by Jain *et al*. (1984), Garg *et al*. (2003), and Riding *et al.* (2010). Thus the present data set of dinoflagellate cysts tagged precisely with ammonite and nannofossil data can potentially provide important tie points between European and Australian dinoflagellate cyst assemblages.

Distribution of nannofossil taxa

Sections	Sample no.	*Axopodorhabdus atavus*	*Axopodorhabdus cylindratus*	*Axopodorhabdus rahla*	*Biscutum dorestensis*	*Biscutum dubium*	*Biscutum finchii*	*Biscutum novum*	*Crepidolithus perforata*	*Cretarhabdus conicus*	*Cretarhabdus* sp.	*Crucirhabdus primulus*	*Cyclagelosphaera margerelii*	*Diazomatolithus lehmanii*	*Diductius constans*	*Discorhabdus corollatus*	*Discorhabdus criotus*	*Discorhabdus ignotus*	*Discorhabdus striatus*	*Ethmorhabdus gallicus*	*Hexapodorhabdus cuvillieri*	*Lotharingius barozii*	*Lotharingius contractus*	*Lotharingius crucicentralis*	*Lotharingius hauffii*	*Lotharingius sigillatus*
Patasar Tank section	PTS12					R				R			A	R			R		R	F				F	F	VR
	PTS11				R	R		R	R	R			A	R						R	R				R	A
	PTS5		F		R	R	R	R	R		A	R	A	A	R	R	R	R		R	R					R
	PTS4										R			A										R	A	
	PTS3										R			A											R	A
	PTS2				VR	F					A		A	R				R		R		R	R	VR	R	VR
Trambau River section	TR16					R	R				R		R	R									R	R	R	
	TR15							R					R												R	R
	TR13				R	A					A		R	R			A			R				R		A
	TR12										R		R				R	R		R						R
	TR5		R			R		R			A		A	R			A	R		R			R		A	R
	TR4																									
	TR2												R	R												R
	TR1					R							R													R
Washtawa Dome	WAS6												R	R											R	R
	WAS5												R	R											R	R
Nara Dome	NA7		R			R	R				R		A				R			R	R	R	R		R	R
	NA6																						R			R
	NA5					R					R		A													R
	NA4					R					A		F													R
	NA3	R		R		R					R		F													R
	NA1		R								A		A	F									R	R		R

VR – 1 form/ 10 field of view, R – 1 form/ 5 field of view, F – 1 form/ 2 field of view, A – >1 form/ field of view

Table 1

against sample numbers

Lotharingius velatus	*Mazaganella protensa*	*Octopodorhabdus decussatus*	*Octopodorhabdus praevisus*	*Orthogonoides hamiltoniae*	*Parhabdolithus liasicus*	*Perissocyclus plethotretus*	*Podorhabdus grassei*	*Polypodorhabdus escaigii*	*Retecapsa octofenestrata*	*Retecapsa schizobrachiata*	*Schizosphaerella punctulata*	*Staurolithites lumina*	*Stephanolithion bigotii bigotii*	*Stephanolithion hexum*	*Stephanolithion speciosum octum*	*Triscutum beaminsterensis*	*Triscutum expanses*	*Triscutum sullivanii*	*Triscutum tiziense*	*Tubirhabdus patulus*	*Umbria granulosa*	*Watznaueria barnesiae*	*Watznaueria britannica*	*Watznaueria contracta*	*Watznaueria fossacincta*	*Watznaueria manivitiae*	*Zeugrhabdotus erectus*
		R				R							R									R	A		R	R	VR
R													R					R								F	F
	R	R			R		R		R	R		R	A		R	R	R		R	R	R	R	R		R	R	F
																				R			R			R	
																				R			R			R	
						R							R					R		VR			A	R	R	A	VR
													R	R								R	R				R
														R									R				
													R										A			R	F
														R					R				R				R
						R							R	R								A	R	R		R	
																							F				
																							F				
																							F			F	
											R												R				
											R												R				
				R									R							R			A			F	
																							A			R	
						R							R					R					A			F	
																							A			F	
						R		R					R					R					A			R	R
								R										R				R	A			F	R

CONCLUSIONS

1. This is the first synthesis of data incorporating ammonites and two microplankton groups (calcareous nannofossils and dinoflagellate cysts) from the Wagad Uplift.

2. The distribution of nannofossil assemblages within the Kanthkot Ammonite Beds fits quite well with that of ammonites proposed by earlier workers (Krishna *et al*., 1995, 2009c; Pandey *et al*., 2012, 2013b).

3. The nannofossil assemblages from the lower part of the Nara Shale Member exposed in the Nara and Washtawa domes, the Kanthkot Ammonite Beds along the Trambau River section, and the Patasar Shale Member exposed along the Trambau River section as well as the Patasar Tank section in the eastern part of the Wagad Uplift belong to the NJ 14 Cyclagelosphaera margerelli Zone of the Early Oxfordian, the NJ 15a Lotharingius sigillatus Zone of the Middle Oxfordian, and the NJ 15b Cretarhabdus conicus of the Early Kimmeridgian age, respectively.

4. The nannofossil biostratigraphy suggests condensation in the stratigraphic succession of the Late Oxfordian and Early Kimmeridgian sediments. This corresponds to the hiatus recorded from Kachchh Mainland by earlier workers based on ammonites (Pandey *et al*., 2013b).

5. The dinocyst assemblage recorded from the Patasar Shale Member exposed in the Patasar Tank section indicates an Early Kimmeridgian age.

Acknowledgements. JR and DKP express thanks to the SERC division of the DST, the funding agency for this project (SR/S4/ES-521/2010 (G)). JR, SG, MG, AS, and RG express thanks to Dr. Sunil Bajpai, Director, Birbal Sahni Institute of Palaeobotany, Lucknow, for allowing the use of the existing facilities, constant encouragement and permission to publish this work (Permission no.-BSIP/RDCC/Publication no. 58/2014-15). Help rendered by Drs. Vandana Prasad, Biswajeet Thakur, and Mr. Premraj in the lab from time to time is duly acknowledged. Academic help by way of discussions and supply of rare reprints on Jurassic nannofossils by Dr. Sreepat Jain, Delhi, and Dr. Sudeep Kanungo, University of Utah, USA, need heartfelt thanks. JR, AS, DKP, FTF, and MA thank Valsamma Fürsich for assistance in the field. Authors also extend thanks to the two anonymous reviewers for critical reviewing and comments for the improvement of the manuscript.

REFERENCES

ALBERTI M., FÜRSICH F.T., PANDEY D.K., 2013a — Deciphering condensed sequences: A case study from the Oxfordian (Upper Jurassic) Dhosa Oolite Member of the Kachchh Basin, western India. *Sedimentology*, **60**: 574–598.

ALBERTI M., NÜTZEL A., FÜRSICH F.T., PANDEY D.K., 2013b — Oxfordian (Late Jurassic) gastropods from the Kachchh Basin, western India. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **270**: 275–300.

BISWAS S.K., 1971 — A note on the Geology of Kutch, Gujarat. *Quarterly Journal, Geological, Mining and Metallurgical Society, India*, **43**, 4: 223–235.

BISWAS S.K., 1980 — Mesozoic rock-stratigraphy of Kutch, Gujarat. *Quarterly Journal Geological, Mining and Metallurgical Society, India*, **49**, 3/4: 1–51 (for 1977).

BISWAS S.K., DESPANDE S.V., 1970 — Geological and tectonic map of Kutch. *Bulletin of the Oil and Natural Gas Commission, India*, **7**, 2: 115–123.

BOWN P.R., COOPER M.K.E., 1998 — Jurassic. *In*: Calcareous nannofossil biostratigraphy (Ed. P.R. Bown): 16–28. British Micropalaeontological Society Series, Chapman & Hall, London.

BOWN P.R., COOPER M.K.E., LORD A.R., 1988 — A calcareous nannofossil biozonation scheme for the early to mid Mesozoic. *Newsletters on Stratigraphy*, **20**: 91–114.

BOWN P.R., YOUNG J.R., 1998 — Techniques. *In*: Calcareous nannofossil biostratigraphy (Ed. P.R. Bown): 16–28. British Micropalaeontological Society Series, Chapman & Hall, London.

BRALOWER T.J., MONECHI S., THIERSTEIN H.R., 1989 — Calcareous nannofossil zonation of the Jurassic-Cretaceous boundary interval and correlation with the geomagnetic polarity timescale. *Marine Micropaleontology*, **14**: 153–235.

CARIOU E., HANTZPERGUE P., 1997 — Biostratigraphie du Jurassique ouest-européen et méditerranéen: zonations parallèles et distribution des invertébrés et microfossils. *Bulletin du Centre Recherches Elf Exploration Production Mémoire*, **17**: 1–422.

CASELLATO C.E., 2010 — Calcareous nannofossil biostratigraphy of Upper Callovian–Lower Berriasian successions from the Southern Alps, North Italy. *Rivista Italiana di Paleontologia e Stratigrafia*, **116**: 357–404.

DESHPANDE S.V., 1972 — Geology of Wagad Hills, Eastern Kutch with special reference to stratigraphy and structure [unpublished Ph.D. Thesis]. M.S. University, Baroda.

DESHPANDE S.V., MERH S.S., 1980 — Mesozoic sedimentary model of Wagad Hills, Kutch, western India. *Journal of the Geological Society of India*, **21**: 75–83.

FÜRSICH F.T., ALBERTI M., PANDEY D.K., 2013 — Stratigraphy and palaeoenvironments of the Jurassic rocks of Kachchh. Field guide. *Beringeria, Special Issue*, **7**: 1–174.

GARG R., ATEEQUZZAMAN K., KRISHNA J., JAIN K.P., 2003 — Biostratigraphic potential of dinoflagellate cysts recovered from the Late Jurassic ammonites of the Tethys Himalaya, India. *Journal of the Palaeontological Society of India*, **48**: 41–58.

JAIN K.P., GARG R., KUMAR S., SINGH I.B., 1984 — Upper Jurassic dinoflagellate biostratigraphy of Spiti Shale (Formation), Malla Johar area, Tethys Himalaya, India. *Journal of the Palaeontological Society of India*, **29**: 67–83.

JAIN K.P., JANA B.N., MAHESHWARI H.K., 1986 — Fossil floras of Kutch Part VI. Jurassic dinoflagellates. *Palaeobotanist*, **35**, 1: 73–84.

KRISHNA J., 2005 – Update on Kachchh Jurassic ammonoid zonation: summarised intra-basinal to global perspectives. *In*: Supplementary Publication (eds D.S.N. Raju *et al*.): 63–68. Association of Petroleum Geologists, India.

KRISHNA J., PATHAK D.B., PANDEY B., 1995 — Ammonoid age control in the Mesozoic succession of Wagad outside the Mainland Kachchh. *Geophytology*, **26**, 1: 63–68.

KRISHNA J., PATHAK D.B., PANDEY B., 1998 — Development of Oxfordian (early Upper Jurassic) in the most proximally exposed part of the Kachchh Basin at Wagad outside the Kachchh Mainland. *Journal of the Geological Society of India*, **52**: 513–522.

KRISHNA J., PANDEY B., OJHA J.R., 2009a — *Gregoryceras* in the Oxfordian of Kachchh (India): Diverse eventful implications. *Géobios*, **42**: 197–208.

KRISHNA J., PANDEY B., PATHAK D.B., 2009b — Characterization of *Dichotomoceras* in the Oxfordian of Kachchh. *Journal of the Geological Society of India*, **74**: 469–479.

KRISHNA J., PANDEY B., OJHA J.R., PATHAK D.B., 2009c — Reappraisal of the age framework, correlation, environment and nomenclature of Kachchh Mesozoic lithostratigraphic units in Wagad. *Journal of Scientific Research, Banaras Hindu University, Varanasi*, **53**: 1–20.

KRISHNA J., SINGH I.B., HOWARD J.D., JAFAR S.A., 1983 — Implications of new data on Mesozoic rocks of Kachchh, western India. *Nature*, **305**: 790–792.

KUMAR A., 1986a — A dinocyst assemblage from the Middle Member (Lower Kimmeridgian–Tithonian) of the Jhuran Formation, Kachchh, India. *Review of Palaeobotany and Palynology*, **48**: 377–407.

KUMAR A., 1986b — Distribution of dinocysts in the Jurassic rocks of Kachchh, India. *Journal of the Geological Society of India*, **29**: 594–602.

KUMAR A., 1986c — Additional dinocysts and acritarchs from the Middle Member (Lower Kimmeridgian-Tithonian) of the Jhuran Formation, Kachchh, India. *Revista Española de Micropalentologia*, **19**: 239–249.

PANDEY D.K., ALBERTI M., FÜRSICH F.T., 2012 — Ammonites of the genus *Perisphinctes* Waagen, 1869 from the Oxfordian of Kachchh, western India. *Revue de Paléobiologie, Genève*, **31**, 20: 483–587.

PANDEY D.K., ALBERTI M., FÜRSICH F.T., 2013a — Ammonites from the Oxfordian Bifurcatus Zone strata of Gangta Bet, Kachchh, western India. *Journal of the Palaeontological Society of India*, **58**: 139–174.

PANDEY D.K., ALBERTI M., FÜRSICH F.T., GŁOWNIAK E., OLÓRIZ F., 2013b — Ammonites from the Oxfordian-Kimmeridgian boundary and the Lower–Upper Kimmeridgian of Kachchh, western India. *Volumina Jurassica*, **11**: 97–146.

RAI J., 2003 — Early Callovian nannofossils from Jara Dome, Kachchh, western India. *Journal of the Geological Society of India*, **61**: 283–294.

RAI J., PRAKASH N., PANDEY D.K., FÜRSICH F.T., ALBERTI M., SINGH A., GARG S., SWAMI N., 2016 — A Middle Oxfordian (Jurassic) flora from the Kachchh Basin, western India, with the earliest record of Bennettitaleans from the subcontinent. *Journal of the Palaeontological Society of India* [in press].

RIDING J.B., MANTLE D.J., BACKHOUSE J., 2010 — A review of the chronostratigraphical ages of Middle Triassic to Late Jurassic dinoflagellate cyst biozones of the northwest shelf of Australia. *Review of Palaeobotany and Palynology*, **162**: 543–575.

RIDING J.B., THOMAS J.E., 1992 — Chapter 2. Dinoflagellate cysts of the Jurassic System. *In*: A stratigraphic index of dinoflagellate cysts (Ed. A.J. Powell): 7–98. Chapmann and Hall, London.

ROTH P.H., MEDD A.W., WATKINS D.K., 1983 — Jurassic calcareous nannofossil zonation, an overview with new evidence from Deep Sea Drilling Project Site 534. *Initial Reports Deep Sea Drilling Project*, **14**: 421–85.

SAXENA R., JAFAR S.A., 2008 — Middle Jurassic calcareous nannofossils from type Jumara Formation, Kachchh, Western India. *Journal of the Geological Society of India*, **72**: 495–509.

SPATH L.F., 1927–1933 — Revision of the Jurassic cephalopod fauna of Kachh (Cutch). Parts I –VI. *Memoirs of the Geological Survey of India, Palaeontologia Indica, new series*, **9**, 2: 1–130.

STOVER L.E., BRINKHUIS H., DAMASSA S.P., de VERTEUIL L., HELBY R.J., MONTEIL E., PARTRIDGE A.D., POWELL A.J., RIDING J.B., SMELROR M., WILLIAMS G.L., 1996 — Chapter 19. Mesozoic-Tertiary dinoflagellates, acritarchs and prasinophytes. *In*: Palynology: principles and applications (eds J. Jansonius, D.C. McGregor), 2: 641–750. American Association of Stratigraphic Palynologists Foundation, Dallas, Texas, U.S.A.

THIERSTEIN H.R., 1976 — Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Marine Micropaleontology*, **1**: 325–362.

WAAGEN W., 1873–1875 — Jurassic fauna of Kutch. The Cephalopoda. *Memoirs of the Geological Survey of India, Paleontologia Indica, series*, **9**, 1: 1–247.

WOOD G.D., GABRIEL A.M., LAWSON J.C., 1996 — Chapter 3. Palynological techniques – processing and microscopy. *In*: Palynology: principles and applications (eds J. Jansonius, D.C. McGregor), 1: 29–50. American Association of Stratigraphic Palynologists Foundation, Dallas, Texas, U.S.A.

Appendix 1

LIST OF TAXA

Genus *Axopodorhabdus* Wind et Wise in Wise, Wind, 1977
Axopodorhabdus atavus (Grün *et al*., 1974) Bown, 1987
Axopodorhabdus cylindratus (Noël, 1965) Wind et Wise in Wise, Wind, 1977
Axopodorhabdus rahla (Noël, 1965) Grün et Zweili, 1980
Genus *Biscutum* Black in Black, Barnes, 1959
Biscutum dorsetensis (Varol et Girgis, 1994) Bown in Bown, Cooper, 1998
Biscutum dubium (Noël, 1965) Grün in Grün *et al*., 1974
Biscutum finchii Crux, 1984
Biscutum novum (Goy in Goy *et al*., 1979) Bown, 1987
Genus *Crepidolithus* Noël, 1965
Crepidolithus perforata (Medd, 1971) Grün et Zweili, 1980
Genus *Cretarhabdus* Bramlette et Martini, 1964
Cretarhabdus sp.
Cretarhabdus conicus Bramlette et Martini, 1964
Genus *Crucirhabdus* Rood *et al*., 1973
Crucirhabdus primulus Rood *et al*., 1973
Genus *Cyclagelosphaera* Noël, 1965
Cyclagelosphaera margerelii Noël, 1965
Genus *Diazomatolithus* Noël, 1965
Diazomatolithus lehmanii Noël, 1965
Genus *Diductius* Goy in Goy *et al*., 1979
Diductius constans Goy in Goy *et al*., 1979
Genus *Discorhabdus* Noël, 1965
Discorhabdus corollatus Noël, 1965
Discorhabdus criotus Bown, 1987
Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Discorhabdus striatus Moshkovitz et Ehrlich, 1976
Genus *Ethmorhabdus* Noël, 1965
Ethmorhabdus gallicus Noël, 1965
Genus *Hexapodorhabdus* Noël, 1965
Hexapodorhabdus cuvillieri Noël, 1965
Genus *Lotharingius* Noël, 1973
Lotharingius barozii Noël, 1973
Lotharingius contractus Bown et Cooper, 1989
Lotharingius crucicentralis (Medd, 1971) Grün et Zweili, 1980
Lotharingius hauffii Grün et Zweili in Grün *et al*., 1974
Lotharingius sigillatus (Stradner, 1961) Prins in Grün *et al*., 1974
Lotharingius velatus Bown et Cooper, 1989
Genus *Mazaganella* Bown, 1987
Mazaganella protensa Bown, 1987
Genus *Octopodorhabdus* Noël, 1965
Octopodorhabdus decussatus (Manivit, 1959) Rood *et al*., 1971
Octopodorhabdus praevisus Noël, 1965
Genus *Orthogonoides* Wiegand, 1984
Orthogonoides hamiltoniae Wiegand, 1984
Genus *Parhabdolithus* Deflandre in Grassé 1952
Parhabdolithus liasicus Deflandre in Grassé, 1952
Genus *Perissocyclus* Black, 1971
Perissocyclus plethotretus (Wind et Cepek, 1979) Crux, 1989
Genus *Podorhabdus* Noël, 1965
Podorhabdus grassei Noël, 1965
Genus *Polypodorhabdus* Noël, 1965
Polypodorhabdus escaigii Noël, 1965
Genus *Retecapsa* Black, 1971
Retecapsa octofenestrata (Bralower in Bralower *et al*., 1989) Bown in Bown, Cooper, 1998
Retecapsa schizobrachiata (Gartner, 1968) Grün in Grün, Allemann, 1975
Genus *Schizosphaerella* Deflandre et Dangeard, 1938
Schizosphaerella punctulata Deflandre et Dangeard, 1938
Genus *Staurolithites* Caratini, 1963
Staurolithites lumina Bown in Bown, Cooper, 1998
Genus *Stephanolithion* Deflandre, 1939
Stephanolithion bigotii bigotii Deflandre, 1939
Stephanolithion hexum Rood et Barnard, 1972
Stephanolithion speciosum octum Rood et Barnard, 1972
Genus *Triscutum* Dockerill, 1987
Triscutum beaminsterensis Dockerill, 1987
Triscutum expanses (Medd, 1979) Dockerill, 1987
Triscutum sullivanii de Kaenel et Bergen, 1993
Triscutum tiziense de Kaenel et Bergen, 1993
Genus *Tubirhabdus* Rood *et al*., 1973
Tubirhabdus patulus Rood Hay et Barnard, 1973 *ex* Prins, 1969
Genus *Umbria* Bralower et Thierstein in Bralower *et al*., 1989
Umbria granulosa Bralower et Thierstein in Bralower *et al*., 1989
Genus *Watznaueria* Reinhardt, 1964
Watznaueria barnesae (Black in Black, Barnes, 1959) Perch-Nielsen, 1968
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964
Watznaueria contracta (Bown et Cooper, 1989) Cobianchi *et al*., 1992
Watznaueria fossacincta (Black, 1971) Bown in Bown, Cooper, 1989
Watznaueria manivitiae Bukry, 1973
Genus *Zeugrhabdotus* Reinhardt, 1965
Zeugrhabdotus erectus (Deflandre in Deflandre, Fert, 1954) Reinhardt, 1965
Ascidian spicule

Plates

PLATE 1

Nannofossil assemblage of the Nara Shale Member from the Nara Dome

Fig. 1. *Axopodorhabdus atavus*
Fig. 2. *Axopodorhabdus cylindratus*
Fig. 3. *Axopodorhabdus rahla*
Fig. 4. *Biscutum dubium*
Fig. 5. *Biscutum finchii*
Fig. 6. *Biscutum novum*
Fig. 7. *Cretarhabdus* cf. *C. conicus*
Fig. 8a, b. *Cyclagelosphaera margerelii*
Fig. 9. *Diazomatolithus lehmanii*
Fig. 10. *Discorhabdus criotus*
Fig. 11. *Ethmorhabdus gallicus*
Fig. 12. *Hexapodorhabdus cuvillieri*
Fig. 13. *Lotharingius barozii*
Fig. 14a, b. *Lotharingius contractus*
Fig. 15. *Lotharingius crucicentralis*
Fig. 16. *Lotharingius hauffii*
Fig. 17a, b. *Lotharingius sigillatus*
Fig. 18a, b. *Orthogonoides hamiltoniae*
Fig. 19. *Perissocyclus plethotretus*
Fig. 20a, b. *Polypodorhabdus escaigii*
Fig. 21–23. *Stephanolithion bigotii*
Fig. 24. *Triscutum sullivanii*
Fig. 25. *Tubirhabdus patulus*
Fig. 26. *Watznaueria barnesae*
Fig. 27. *Watznaueria britannica*
Fig. 28a, b. *Watznaueria manivitiae*
Fig. 29. *Zeugrhabdotus erectus*
Fig. 30. Ascidian spicule

Wagad Uplift, Washtawa Formation, Nara Shale Member

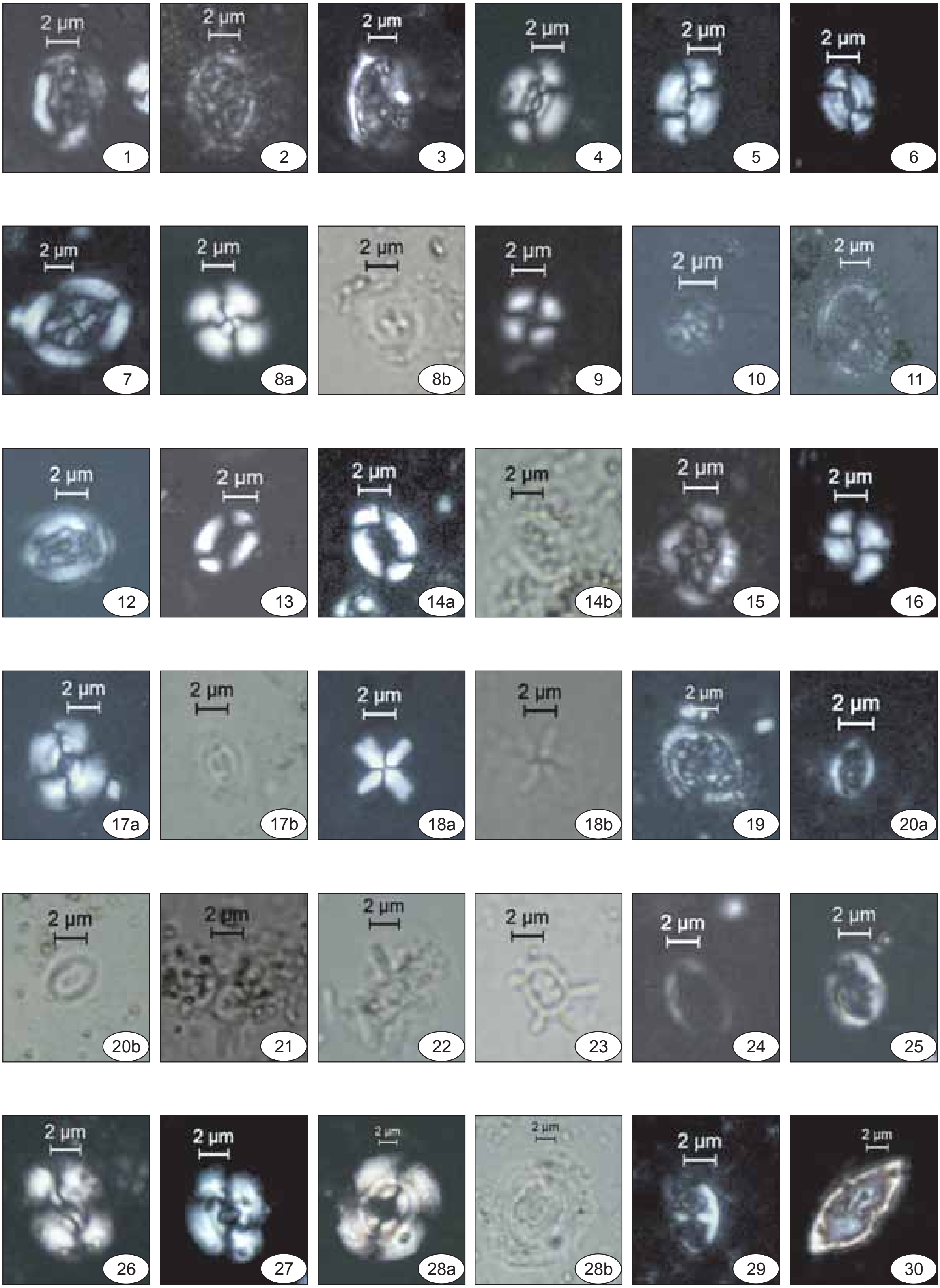

1
2
3
4
5
6
7
8a
8b
9
10
11
12
13
14a
14b
15
16
17a
17b
18a
18b
19
20a
20b
21
22
23
24
25
26
27
28a
28b
29
30

PLATE 2

Nannofossil assemblage of the Nara Shale Member from the Washtawa Dome and Kanthkot Ammonite Beds of the Trambau River section

Fig. 1a–c. *Cyclagelosphaera margerelii*
Fig. 2a–c. *Diazomatolithus lehmanii*
Fig. 3a–c. *Lotharingius hauffii*
Fig. 4a–c. *Lotharingius sigillatus*
Fig. 5a–c. *Schizosphaerella punctulata*
Fig. 6a, b. *Watznaueria britannica*
Fig. 7. Ascidian spicule
Fig. 8. *Biscutum dubium*
Fig. 9. *Biscutum novum*
Fig. 10. *Cretarhabdus* cf. *C. conicus*
Fig. 11. *Cyclagelosphaera margerelii*
Fig. 12. *Diazomatolithus lehmanii*
Fig. 13. *Discorhabdus criotus*
Fig. 14. *Ethmorhabdus gallicus*
Fig. 15. *Hexapodorhabdus cuvillieri*
Fig. 16. *Lotharingius hauffii*
Fig. 17. *Lotharingius sigillatus*
Fig. 18. *Perissocyclus plethotretus*
Fig. 19. *Polypodorhabdus escaigii*
Fig. 20. *Stephanolithion bigotii*
Fig. 21. *Triscutum sullivanii*
Fig. 22. *Watznaueria britannica*
Fig. 23. *Watznaueria contracta*
Fig. 24. *Watznaueria manivitae*
Fig. 25. *Zeugrhabdotus erectus*

Figs 1–7. Wagad Uplift, Washtawa Formation, Nara Shale Member, Washtawa Dome
Figs 8–25. Wagad Uplift, Washtawa Formation, Nara Shale Member, Kanthkot Ammonite Beds, Trambau River section

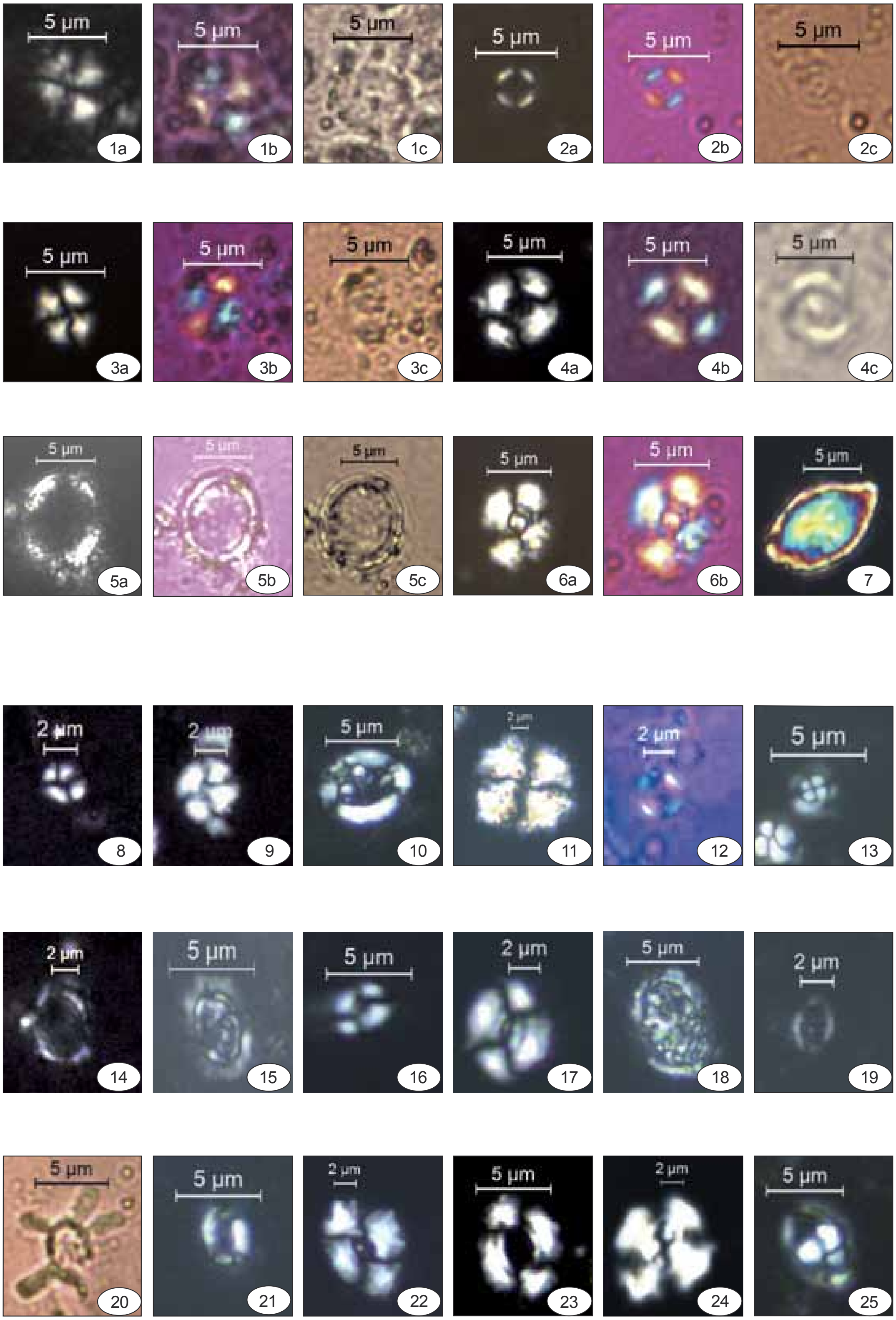

5 µm
1a
5 µm
1b
5 µm
1c
5 µm
2a
5 µm
2b
5 µm
2c
5 µm
3a
5 µm
3b
5 µm
3c
5 µm
4a
5 µm
4b
5 µm
4c
5 µm
5a
5 µm
5b
5 µm
5c
5 µm
6a
5 µm
6b
5 µm
7
2 µm
8
2 µm
9
5 µm
10
2 µm
11
2 µm
12
5 µm
13
2 µm
14
5 µm
15
5 µm
16
2 µm
17
5 µm
18
2 µm
19
5 µm
20
5 µm
21
2 µm
22
5 µm
23
2 µm
24
5 µm
25

PLATE 3

Nannofossil assemblage of the Patasar Shale Member from the Trambau River section and Patasar Tank area

Fig. 1. *Biscutum dorsetensis*
Fig. 2. *Biscutum dubium*
Fig. 3. *Biscutum finchii*
Fig. 4. *Biscutum novum*
Fig. 5, 6. *Cretarhabdus conicus*
Fig. 7. *Cretarhabdus* cf. *C. conicus*
Fig. 8. *Cyclagelosphaera margerelii*
Fig. 9. *Diazomatolithus lehmanii*
Fig. 10. *Discorhabdus criotus*
Fig. 11. *D. ignotus*
Fig. 12. *Ethmorhabdus gallicus*
Fig. 13. *Lotharingius contractus*
Fig. 14. *Lotharingius crucicentralis*
Fig. 15. *Lotharingius hauffii*
Fig. 16a, b. *Lotharingius sigillatus*
Fig. 17. *Stephanolithion bigotii*
Fig. 18. *Stephanolithion hexum*
Fig. 19. *Triscutum tiziense*
Fig. 20. *Watznaueria barnesae*
Fig. 21. *W. britannica*
Fig. 22. *W. manivitiae*
Fig. 23. *Zeugrhabdotus erectus*
Fig. 24. *Axopodorhabdus cylindratus*
Fig. 25. *Biscutum dorsetensis*
Fig. 26. *Biscutum dubium*
Fig. 27. *Biscutum finchii*
Fig. 28. *Biscutum novum*
Fig. 29. *Crepidolithus perforata*
Fig. 30a, b. *Cretarhabdus conicus*
Fig. 31. *Crucirhabdus primulus*
Fig. 32. *Cyclagelosphaera margerelii*
Fig. 33. *Diazomatolithus lehmanii*
Fig. 34. *Diductius constans*

Wagad Uplift, Kanthkot Formation, Patasar Shale Member
Figs 1–23 – Trambau River section, Figs 24–34 – Patasar Tank Area

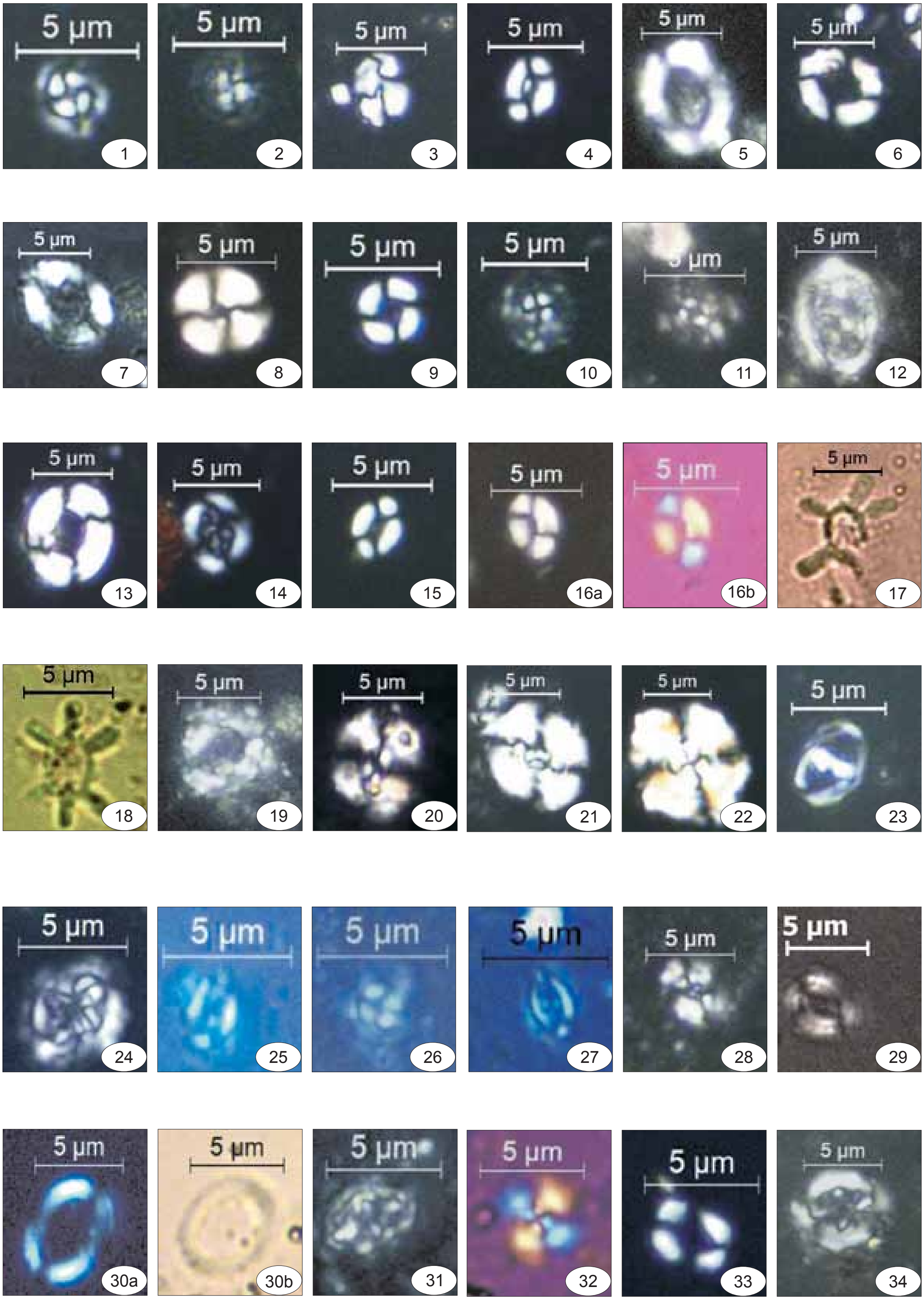

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16a
16b
17
18
19
20
21
22
23
24
25
26
27
28
29
30a
30b
31
32
33
34
5 µm

PLATE 4

Nannofossil assemblage of the Patasar Shale Member from the Patasar Tank area

Fig. 1. *Discorhabdus corollatus*
Fig. 2. *Discorhabdus criotus*
Fig. 3. *Discorhabdus ignotus*
Fig. 4. *Discorhabdus striatus*
Fig. 5. *Ethmorhabdus gallicus*
Fig. 6. *Hexapodorhabdus cuvillieri*
Fig. 7. *Lotharingius barozii*
Fig. 8a, b. *Lotharingius crucicentralis*
Fig. 19. *Lotharingius hauffii*
Fig. 10. *Lotharingius sigillatus*
Fig. 11. *Lotharingius velatus*
Fig. 12. *Mazaganella protensa*
Fig. 13. *Octopodorhabdus decussatus*
Fig. 14. *Octopodorhabdus praevisus*
Fig. 15. *Parhabdolithus liasicus*
Fig. 16. *Podorhabdus grassei*
Fig. 17. *Retecapsa octofenestrata*
Fig. 18. *Retecapsa schizobrachiata*
Fig. 19. *Staurolithites lumina*
Fig. 20. *Stephanolithion bigotii*
Fig. 21. *Stephanolithion hexum*
Fig. 22. *Stephanolithion speciosum octum*
Fig. 23a, b. *Triscutum beaminsterensis*
Fig. 24. *Triscutum expansus*
Fig. 25. *Triscutum sullivanii*
Fig. 26. *Triscutum tiziense*
Fig. 27. *Tubirhabdus patulus*
Fig. 28. *Umbria granulosa*
Fig. 29. *Watznaueria barnesae*
Fig. 30. *Watznaueria britannica*
Fig. 31. *Watznaueria contracta*
Fig. 32. *Watznaueria fossacincta*
Fig. 33. *Watznaueria manivitiae*
Fig. 34. *Zeugrhabdotus erectus*

Wagad Uplift, Kanthkot Formation, Patasar Shale Member

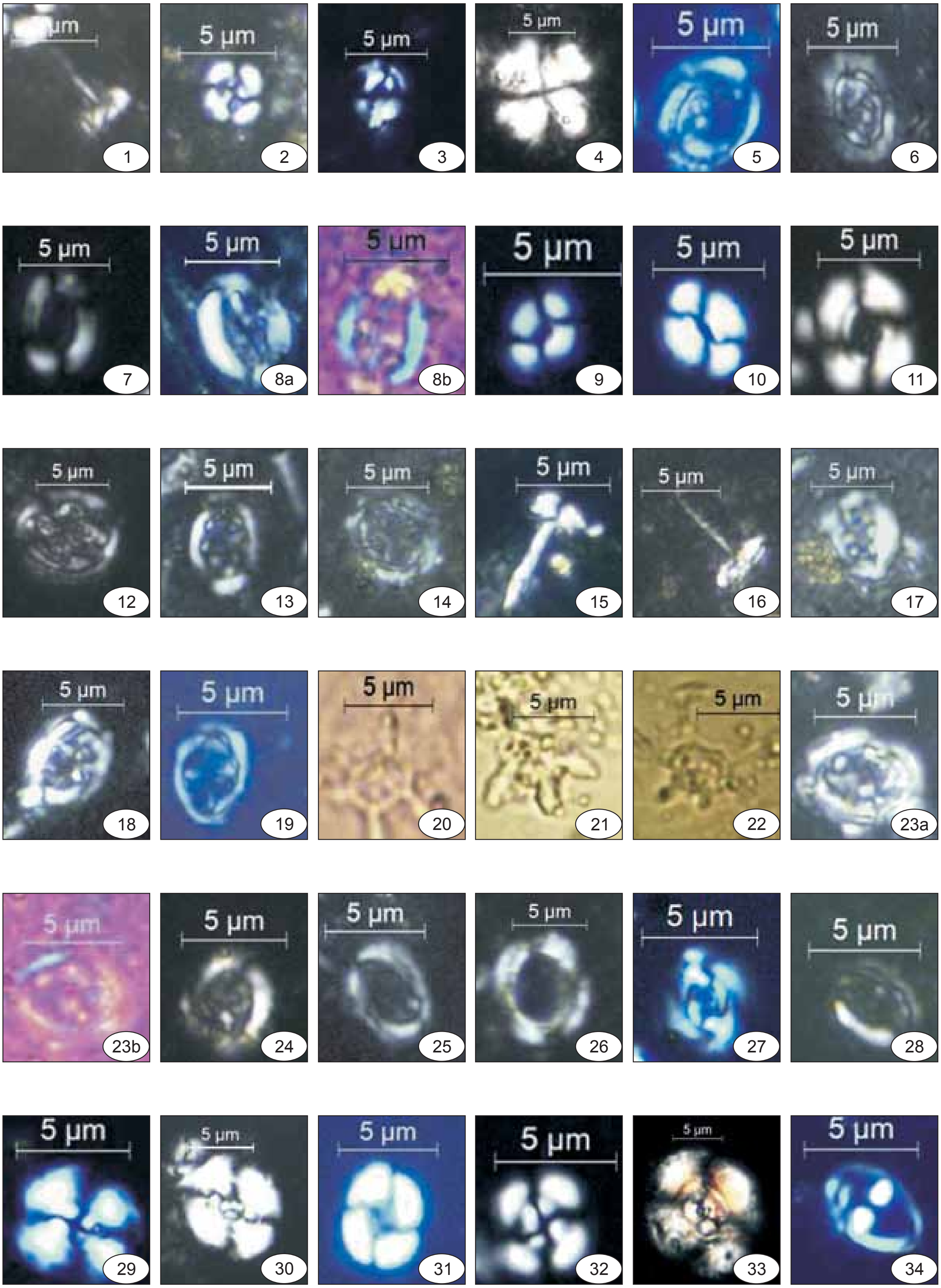
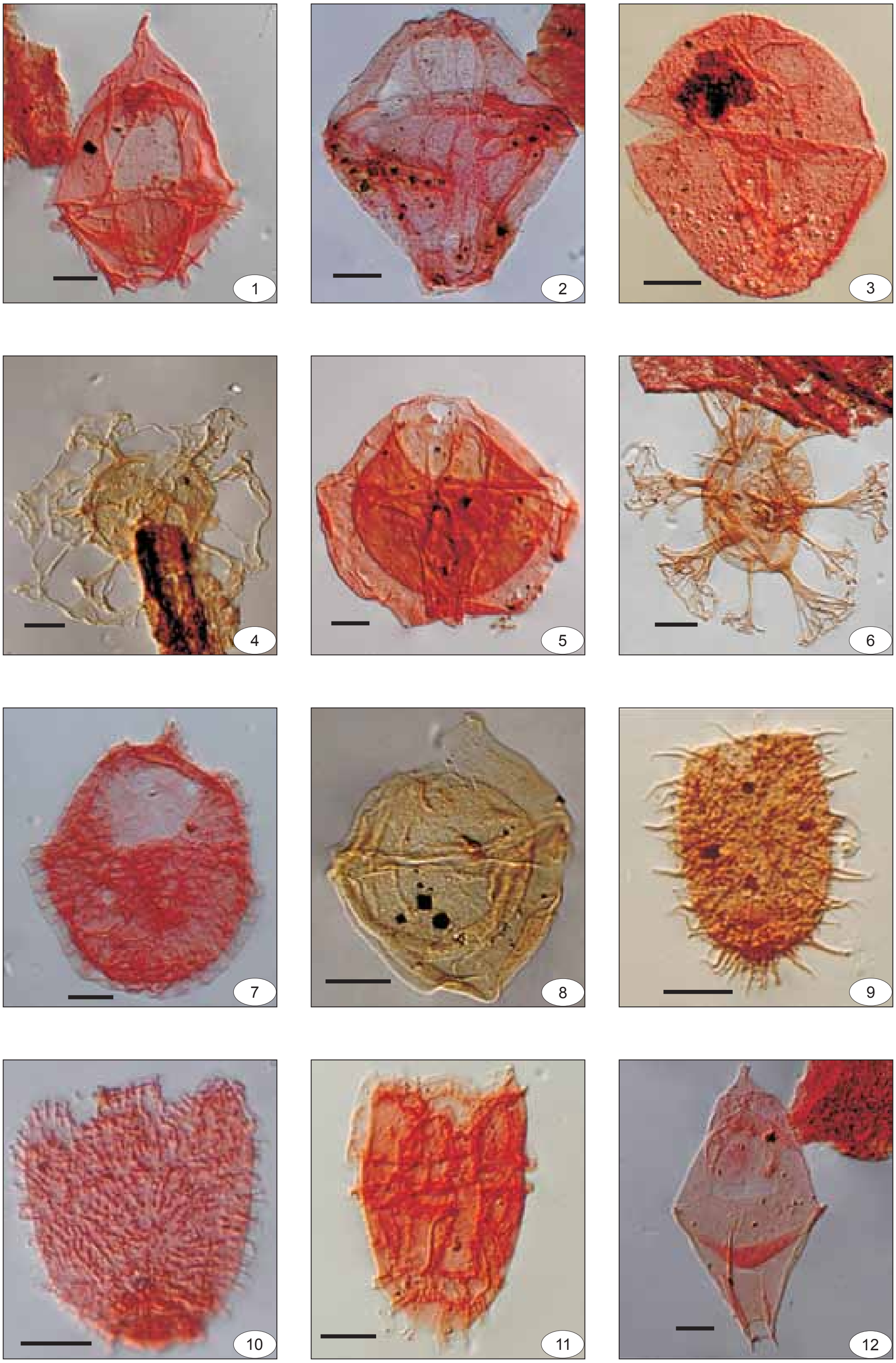

1
2
3
4
5
6
7
8a
8b
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23a
23b
24
25
26
27
28
29
30
31
32
33
34

PLATE 5

Dinoflagellate cyst assemblage from the Patasar Tank area

Fig. 1. *Gonyaulacysta jurassica jurassica*
Fig. 2. *Endoscrinium galeritum*
Fig. 3. *Mendicodinium granulatum*
Fig. 4. *Rigaudella filamentosa*
Fig. 5. *Endoscrinium luridum*
Fig. 6. *Oligospheridium patulum*
Fig. 7. *Aldorfia dictyota*
Fig. 8. *Dingodinium jurassicum*
Fig. 9. *Prolixosphaeridium anasillum*
Fig. 10. *Chlamydophorella wallala*
Fig. 11. *Egmontodinium polyplacophorum*
Fig. 12. *Tubotuberella apatela*

Wagad Uplift, Kanthkot Formation, Patasar Shale Member
Scale bar 20 μm


1
2
3
4
5
6
7
8
9
10
11
12