Rivista Italiana di Paleontologia e Stratigrafia | volume 119 | no. 1 | pp. 3-17 | March 2013

AN UPPER VISÉAN (ASBIAN-BRIGANTIAN) AND SERPUKHOVIAN CORAL SUCCESSION AT DJEBEL OUARKZIZ (NORTHERN TINDOUF BASIN, SOUTHERN MOROCCO)

SERGIO RODRÍGUEZ [1], IAN SOMERVILLE [2], ISMAIL SAID [1] & PEDRO CÓZAR [3]

Received: June 29, 2012; accepted: November 23, 2012

Key words: Mississippian, Upper Viséan, Serpukhovian, biostratigraphy, palaeogeography, rugose corals, Tindouf Basin, Morocco.

Abstract. The Djebel Ouarkziz Formation, located in the northern part of the Tindouf Basin, in western Algeria and southern Morocco, is composed mainly of shales with interbedded limestones, dolostones and sandstones. The limestone beds are relatively thin, but are laterally persistent, and can be followed along strike for tens of kilometres. We have identified 19 limestone beds in three main sections; one logged along the road from Assa to Zag, a second in the Tinguiz-Remz Valley, 15 km to the east, and a third section 10 km west of the Assa-Zag road section. Rugose coral assemblages are recorded in most limestone beds, but the stratigraphically higher beds become more diverse. However, many rugose genera and species are persistent throughout much of the succession. The oldest coral assemblages are Asbian in age and the youngest coral assemblages indicate a Serpukhovian age, as confirmed by foraminiferal biostratigraphy. The first appearance of rugose corals shows a different pattern than that in northern Moroccan basins; some common genera that first appear in the Asbian and lower Brigantian in northern Morocco and Europe, appear much later, in the upper Brigantian or Serpukhovian in the Djebel Ouarkziz. The genus *Kizilia*, which is rare in the Upper Viséan in northern Moroccan basins, is, however, abundant in the Tindouf Basin. Interestingly, the occurrence of the genus *Lonsdaleia* in the Serpukhovian from Djebel Ouarkziz poses a palaeogeographic problem because of its absence in northern Moroccan basins (except as transported elements in Serpukhovian conglomerates). Similarly, *Actinocyathus* in the Serpukhovian in the Tindouf Basin is not present north of the Anti-Atlas Mountains. A possible coral migration route to the Tindouf Basin may be from the northeast via the Béchar Basin in Algeria, similar to that already inferred for foraminifers and calcareous algae.

Riassunto. La Formazione Djebel Ouarkziz, situata nella parte settentrionale del Bacino di Tindouf, nel nord-ovest dell'Algeria e nel sud del Marocco, è costituita in prevalenza da argilliti, con intercalazioni di calcari, dolomie e arenarie. Sebbene alcuni strati calcarei siano piuttosto sottili (in alcuni casi meno di un metro), essi sono molto persistenti lateralmente e possono essere seguiti da est a ovest per decine di km. Noi abbiamo individuato 19 strati calcarei in tre sezioni principali, una lungo la strada da Assa a Zag, la seconda nella valle di Tinguiz-Remz, 15 km più a est, e la terza sezione 8 km ad ovest della sezione di Assa-Zag. Le associazioni di coralli Rugosa divengono più diversificate negli strati più alti, con numerose prime comparse. Le associazioni a coralli più antiche sono di età Asbiana e quelle più giovani sono di età Serpukhoviana. La prima comparsa dei coralli Rugosa mostra un composizione diversa da quella che si osserva nei bacini del Marocco settentrionale. Alcuni generi, che sono comuni nell'Asbiano e nel Brigantiano inferiore del Marocco settentrionale e in Europa, compaiono per la prima volta molto più tardi nel Brigantiano o nel Serpukhoviano della Formazione Djebel Ouarkziz. Il genere *Kizilia*, che è scarso nel Viséano superiore nei bacini del Marocco settentrionale è invece abbondante nel Bacino di Tindouf. Ugualmente interessante è la presenza del genere *Lonsdaleia* nel Serpukhoviano di Djebel Ouarkziz, perché pone un problema paleogeografico in quanto esso è assente nei bacini del Marocco settentrionale (eccetto che come elementi inclusi nei conglomerati di tale età). Ugualmente, *Actinocyathus* nel Serpukhoviano del Bacino di Tindouf non è presente a nord della catena dell'Anti-Atlante. Una via di migrazione possibile per i coralli verso il Bacino di Tindouf può essere attraverso il Bacino di Béchar in Algeria, così come si suppone per i foraminiferi e le alghe calcaree.

Introduction

The Tindouf Basin is a large syncline which crosses the border between western Algeria and southern Morocco, south of the Anti-Atlas Mountains, and extends for more than 500 km from east to west and 300 km from north to south (Fig. 1). The Carboniferous outcrops in the Tindouf Basin are extensive. In the northern part of the Basin, they occur along the Djebel

---

[1] Departamento de Paleontología, Instituto de Geociencias y Facultad de Ciencias Geológicas, CSIC,UCM, c/José Antonio Novais, 2, 28040 Madrid, Spain. E-mail: sergrodr@geo.ucm.es; ismsaid@gmx.fr

[2] UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland.

[3] Instituto de Geociencias (CSIC, UCM), c/ José Antonio Novais 2, 28040 Madrid, Spain. E-mail: p.cozar@igeo.ucm-csic.es

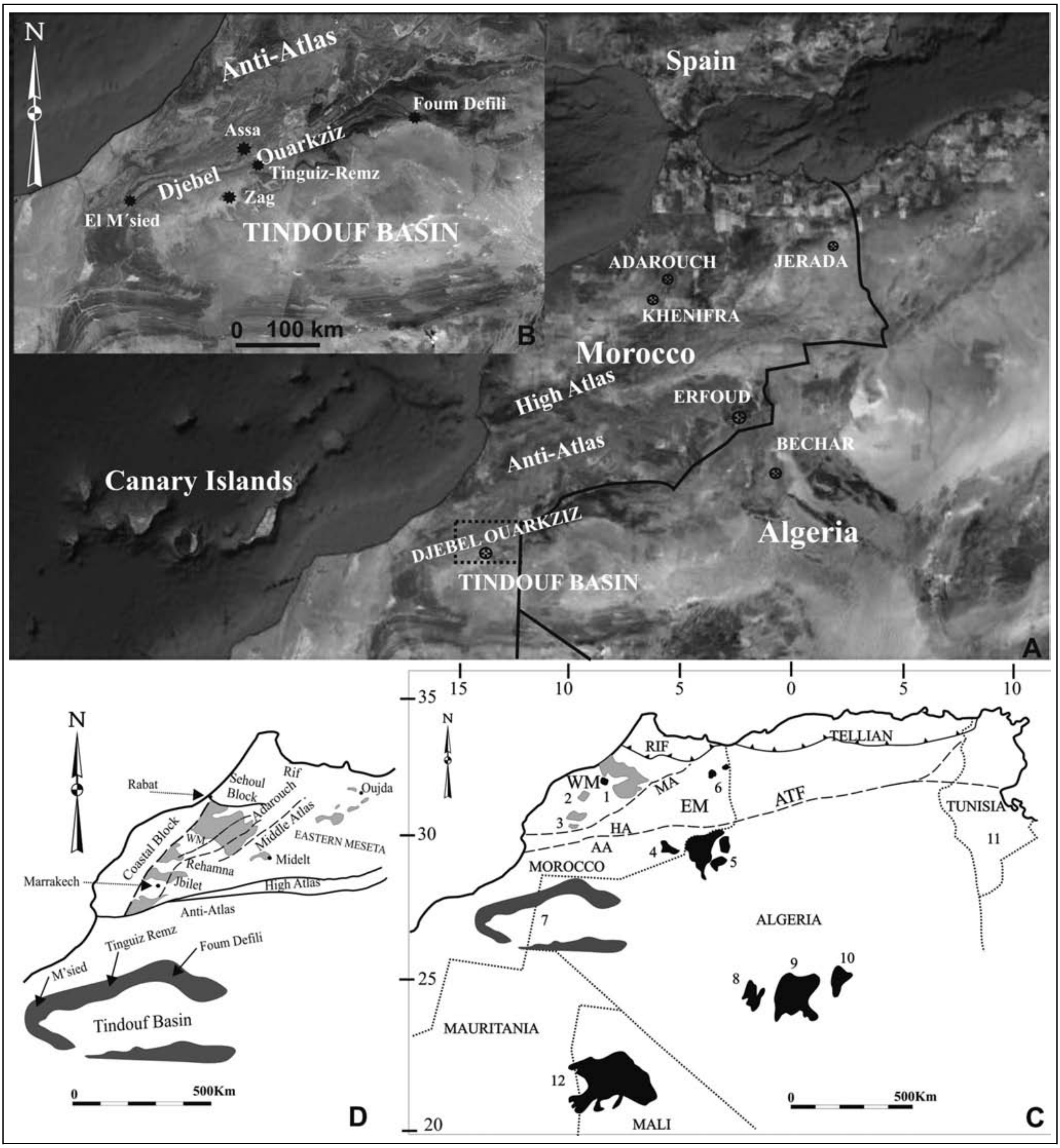

Fig. 1 - Location of the studied outcrops in Djebel Ouarkziz region. A) General location of the Tindouf Basin. B) Detail of the Tindouf Basin, with location of main geographical localities. Based on Google Earth. C) Location of the main Carboniferous outcrops and basins in Morocco, Algeria, Mali and subsurface in Tunisia, 1. Central Meseta (Azrou-Khenifra), 2. Rehamna, 3. Jebilet, 4. Tafilalt, 5. Béchar, 6. Jerada, 7. Tindouf, 8. Reggane, 9. Ahnet, 10. Mouydir, 11. subsurface Carboniferous (number is situated in the map were the boreholes intersected Carboniferous rocks in Tunisia), 12. Taoudenni, AA Anti-Atlas, ATF Atlas Transform Fault, EM Eastern Meseta, HA High Atlas, MA Middle Atlas, WM Western Meseta. D) Detail of the Variscides and Tindouf Basin in Morocco, pale grey areas are Carboniferous outcrops, dark grey is the Tindouf Basin outcrop (modified from Somerville et al. in press).

Ouarkziz, a mountain range that runs along strike for more than 350 km, from ENE to WSW, crossing the Algeria-Morocco border (Figs 1, 2). The Tindouf Basin stratigraphy was originally described in the Algerian part of the Basin (Conrad 1972; Fabre 1976; Conrad in Wagner et al. 1985), but the lithological sequence is quite similar in the Moroccan part of the basin (Mamet et al. 1966). Five formations have been distinguished in the Carboniferous succession from the northern part of the Basin (Conrad 1972; Conrad in Wagner et al. 1985): Djebel Tazout Formation (at the base), Betaina Formation, Djebel Ouarkziz Formation (subdivided infor-

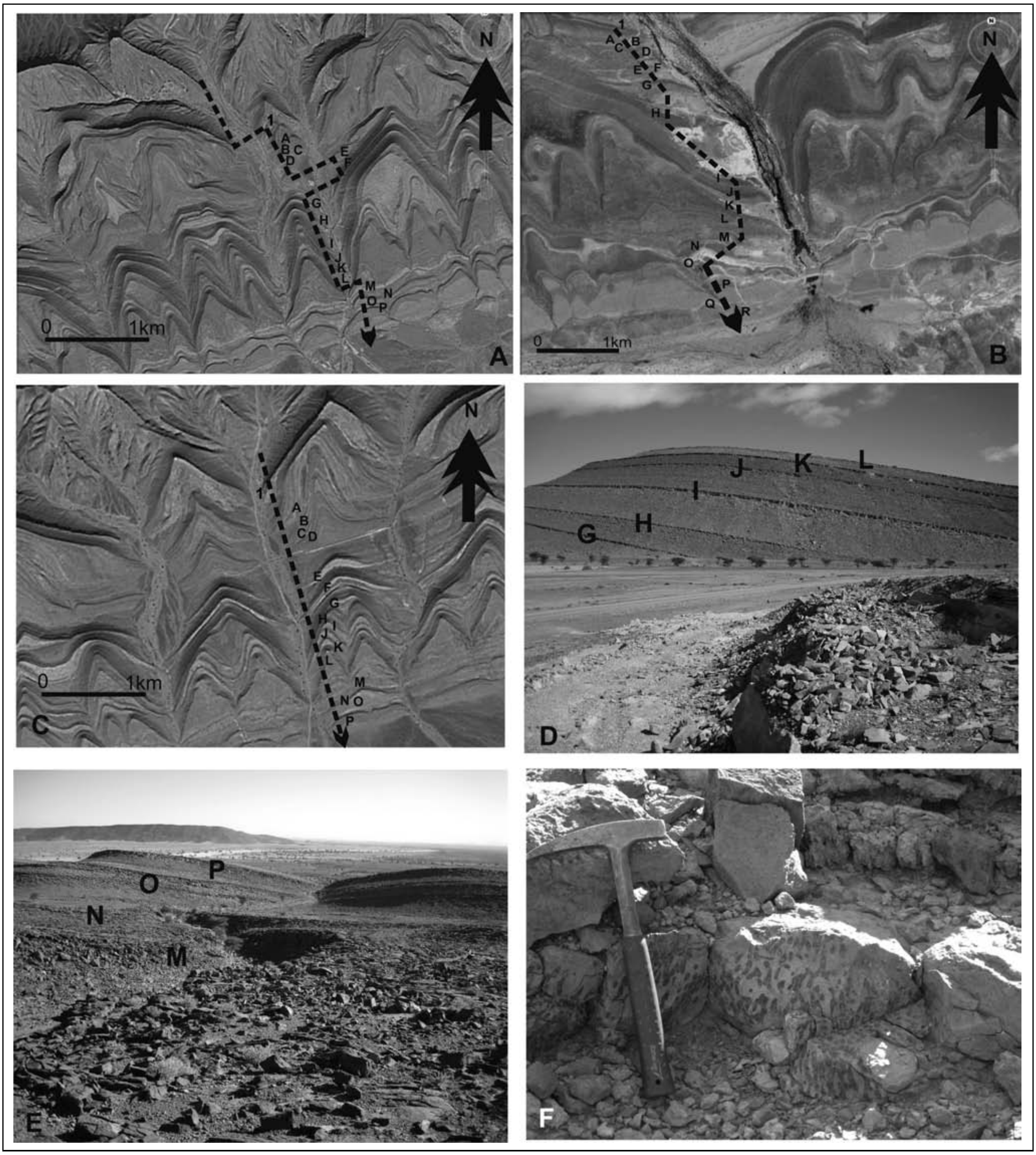

Fig. 2 - A) Location of limestone bed 1 (top of Betaina Fm.) and Beds A-P (lower member, Djebel Ouarkziz Fm.) in section 2 along the road from Assa (northwards) to Zag (southwards). B) Location of limestone beds 1 (top of Betaina Fm.) and Beds A-R (lower member, Djebel Ouarkziz Fm. in section 3, along the Tinguiz-Remz valley. C) Location of limestone bed 1 (top of Betaina Fm) and Beds A-P (lower member, Djebel Ouarkziz Fm.) in section 1, 10 km west of Assa-Zag road. D) Limestone beds G to L in the road section 2 from Assa to Zag. Note that all limestone beds are coral-bearing, apart from the oolitic limestone (bed J). E) Coral-bearing limestone beds M to P in the wadi section west of the main valley section in Tinguiz Rems (section 3). F) In situ *Siphonodendron* colonies in bed A. Hammer length = 32 cm. Aerial views based on Google Earth.

mally into lower, middle and upper members), the Djebel Reouina Formation and the Merkala Formation (last two formations constitute the so-called Betana beds).

Semenoff-Tian-Chansky (1974) described some solitary rugose corals from the Tindouf Basin. Those corals were collected in the Algerian part of the northern Tindouf Basin at Foum Defili (Fig. 1B), in the eastern Djebel Ouarkziz. Unfortunately, the stratigraphical location of the described corals is imprecise and the assemblage quite poor. A summary of solitary and co-

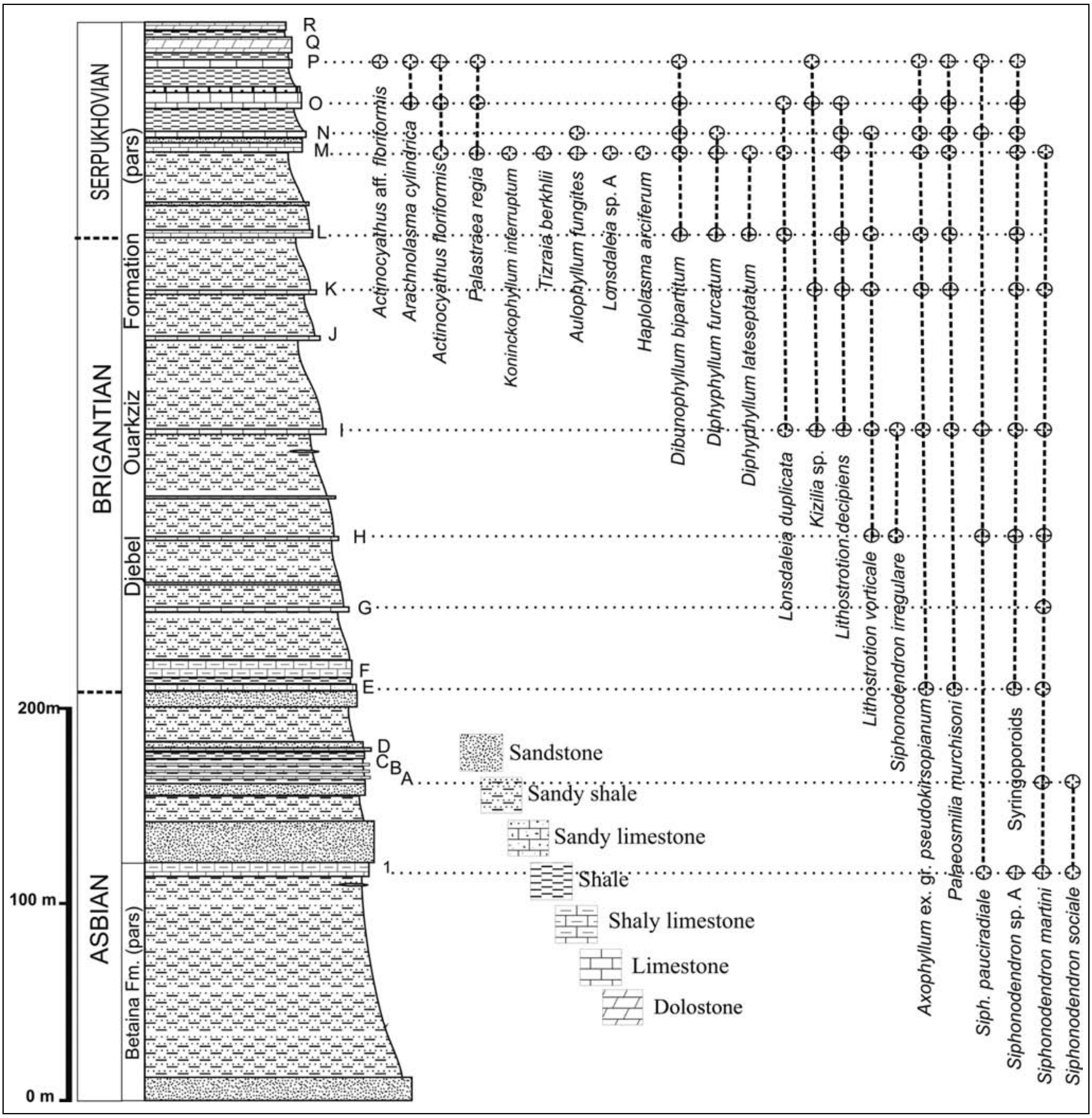

Fig. 3 - Coral distribution in the combined sections along the road from Assa to Zag (section 2), western track (section 1), and in the Tinguiz-Remz Valley (section 3) east of Assa-Zag road.

lonial rugose corals was subsequently documented (Semenoff-Tian-Chansky 1985) from the northern Tindouf Basin, but no taxa were illustrated. Aretz (2011a) described *Lithostrotion vorticale* from the lower beds and *Dibunophyllum bipartitum* from the upper beds of the Djebel Ouarkziz Formation in Algeria.

The corals collected for this study occur in the uppermost beds of the Betaina Formation and in the lower member of the Djebel Ouarkziz Formation (Figs 3, 4). The Betaina Formation is composed of sandstones and shales and regarded as Asbian in age by Mamet et al. (1966) based on the presence of the goniatite *Beyrichoceras micronotum* Phillips, 1836. The Djebel Ouarkziz Formation is composed mainly of red, purple and green shales with interbedded limestones, dolostones and sandstone beds. The formation is composed of purer carbonates to the northeast of the syncline, and it passes into sandstones to the southwest. Thus, close to El M'sied, at the western end of Djebel Ouarkziz (Fig. 1B), limestone beds are rarely observed. The Djebel Ouarkziz Formation has been dated as upper Viséan to Bashkirian by means of foraminifers and brachiopods

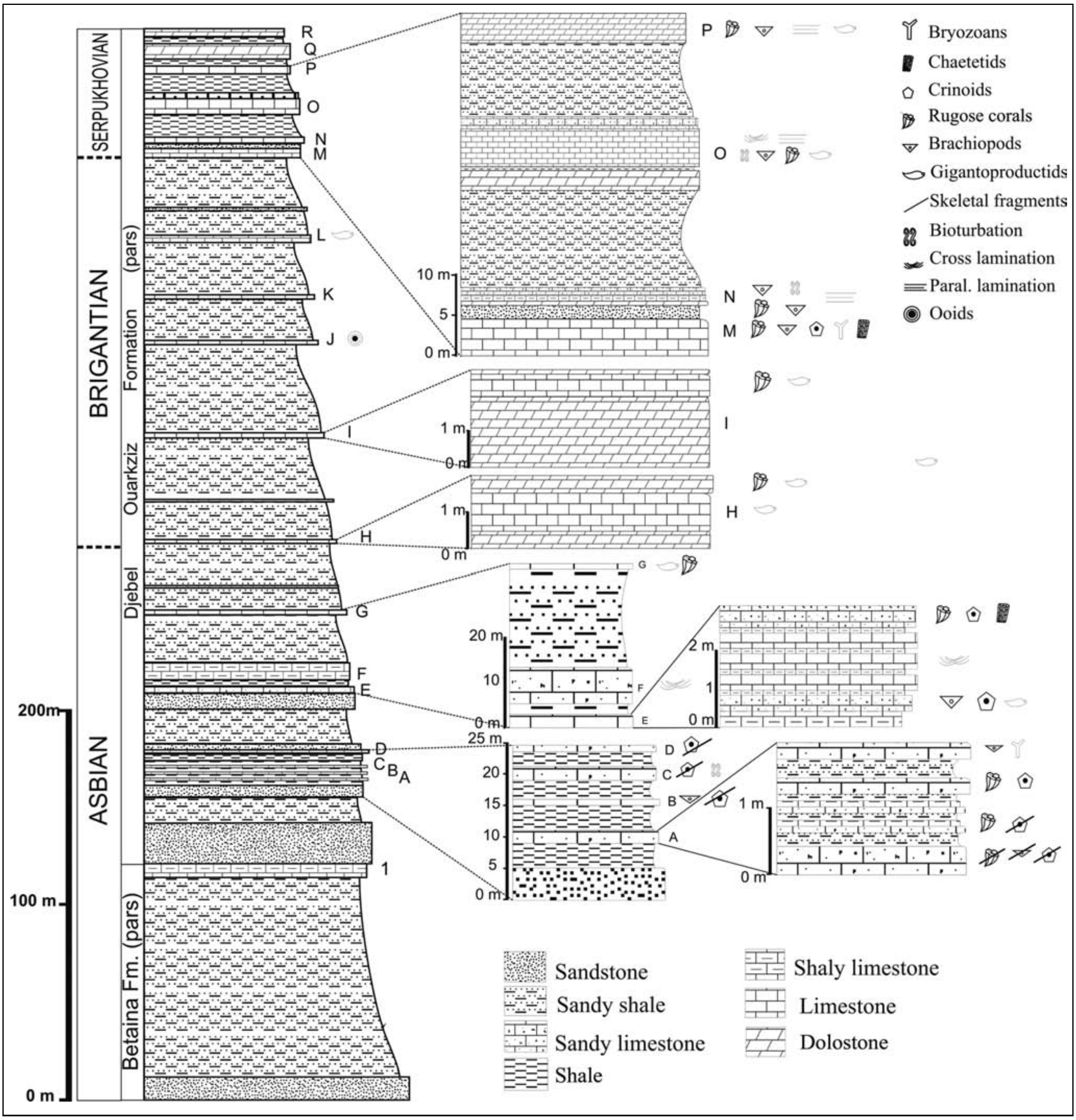

Fig. 4 - Stratigraphical log combining sections at the road from Assa to Zag and at Tinguiz-Remz, with details of the most important coral-bearing limestone beds.

(Lys 1979). The boundary between the Betaina Fm. and Djebel Ouarkziz Fm. is placed in the area of Tinguiz-Remz at the base of a 20-m-thick sandstone bed (the second sandstone bed above the base of the log in Fig. 3) which forms a prominent scarp. Approximately 6 m below this sandstone is recorded the first limestone bed (Bed 1) (Fig. 3). Although some of the limestone beds in the succession are quite thin (less than 1 m in some cases), they are laterally very persistent and can be followed along strike east-west for tens of kilometres (Fig. 2). We have identified 19 persistent limestone beds labelled 1 (uppermost Betaina Fm.) and beds A to R (lower member of the Djebel Ouarkziz Fm.) in three main sections; one logged along the road from Assa to Zag (Section 2; coordinates 28° 24' 20" N, 9° 24' 04" W; Fig. 2A, D), a second one in the Tinguiz-Remz Valley, 15 km to the east (Section 3; 28° 26' 06" N, 9° 13' 43" W; Fig. 2B), which also includes a wadi section (dry valley) one kilometre to the southwest for the upper part of the succession (28° 24' 58" N, 9° 13' 43" W; Fig. 2E), and a third section 10 km west of the Assa-Zag section in a trail which passes through the mountain

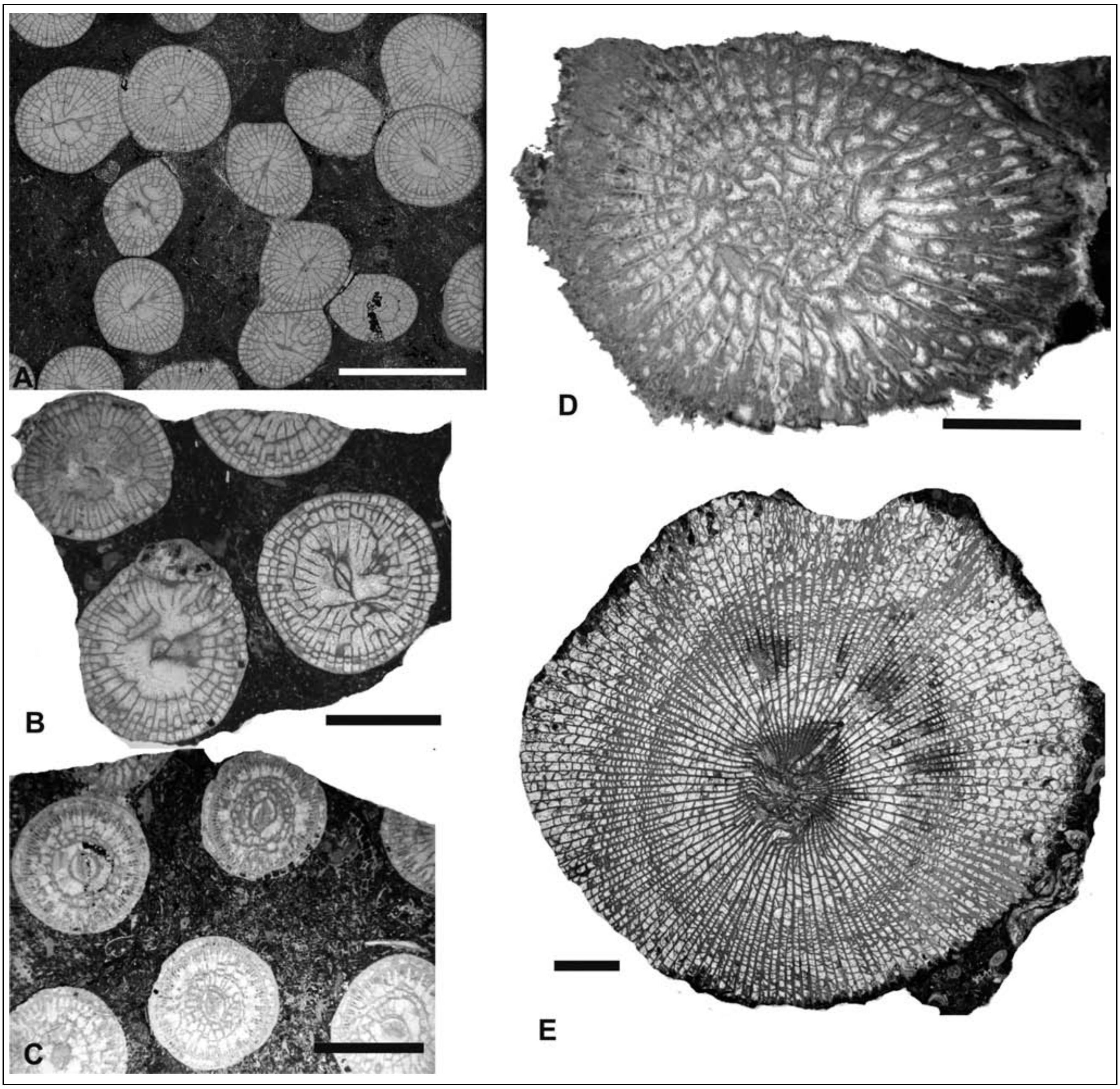

Fig. 5 - Corals first appearing in beds 1 to E. A) *Siphonodendron* sp. A, TUI/-A-11. B. *Siphonodendron sociale* (Phillips, 1836), TUI/A-5. B) Transverse section. C) *Siphonodendron martini* (Milne-Edwards & Haime, 1851), TUI/-A-3. D) *Axophyllum* ex. gr. *pseudokirsopianum* Semenoff-Tian-Chansky, 1974, TUI/E-6. E) *Palaeosmilia murchisoni* Milne-Edwards & Haime, 1848, TUI/E-3. Scale bars = 5 mm.

range (Section 1; 28° 21' 20" N, 9° 29' 04" W; Fig. 2C). The Djebel Ouarkziz Formation logged in all three sections is over 430-m thick (Figs 3, 4), although the upper part of the formation above bed R (> 200 m thick, according to data in Mamet et al. 1966) is discontinuously exposed beneath the flat wadi deposits south of Tinguiz Remz (Fig. 2B) and in the western section. The coral assemblages collected from most of the limestone beds are remarkably similar in all three logged sections, with the same rugose genera and species recorded at each horizon (Fig. 3).

The main aims of this paper are: (i) to document the Mississippian coral faunas of the Djebel Ouarkziz Mountains, (ii) to establish precise ages of the rugose coral assemblages and the range of individual taxa using foraminiferal biostratigraphy, and (iii) to analyse the palaeogeographic setting of the Tindouf Basin coral faunas in southern Morocco and compare it with that of the northern Moroccan basins and the Western Palaeotethys region.

All the coral specimens collected from the top of the Betaina Fm. and lower member of the Djebel Ouarkziz Fm. in the Tindouf Basin, are reposited in Departamento de Paleontología, Universidad Complutense de Madrid (UCM) and catalogued as TUI-A to TUI-P.

Coral occurrences

The first beds in which corals are recorded is in the uppermost part of the Betaina Formation, which mainly consists of fine-grained siliciclastics, but shows some thin carbonate beds in its upper part. Those marly limestone beds (20-cm thick) contain brachiopods, crinoids and gastropods, as well as conspicuous large in situ colonies of *Siphonodendron pauciradiale* (McCoy, 1849), *S. sociale* (Phillips, 1836)*, S. martini* (Milne-Edwards & Haime, 1851) and *Siphonodendron* sp. A (bed 1, Fig. 5A). The unidentified species shows similar dimensions to *S. irregulare*, but the number of major septa is closer to that of *S. martini*. The colonies form a biostrome which can be recognised in all three sections.

Near the base of the Djebel Ouarkziz Formation, several horizons containing corals have been identified (limestone bed A; 1.5-m thick, Fig. 4). The first horizon contains only fragments of coral branches, but the second horizon, a brown sandy limestone, shows the coral colonies in growth position (Fig. 2F). The coral assemblage here is dominated by *Siphonodendron martini* (Fig. 5C) and *S. sociale* (Fig. 5B), together with the tabulate coral *Syringopora* sp. Foraminifers recorded from bed A readily indicate an Asbian age, based on the the occurrence of *Archaediscus* spp., many of them at *angulatus* stage, and *Globoendothyra globulus* (von Eichwald, 1860). The presence of *Pseudoendothyra sublimis* (Schlykova, 1951) and *Nodasperodiscus* sp. suggest a probable late Asbian age (see Cózar & Somerville 2004; Cózar et al. 2008).

Limestone beds B to D are thin bioclastic beds containing brachiopods, crinoids and bryozoans, but corals were not recorded (Fig. 4). Limestone bed B shows abundant brachiopod shells parallel to the stratification showing a random distribution of the convex side. Limestone bed C is a sandy limestone with wave ripples. It shows intense bioturbation, with vertical burrows and horizontal tracks, mainly at the top of the bed. These correspond to the "*Cancellophycus*" beds of Mamet et al. (1966). Limestone bed D is essentially a crinoid-rich limestone. The occurrence of the foraminifer *Archaediscus karreri grandis* Conil & Lys, 1964 in bed B suggests an uppermost late Asbian age, which is confirmed in bed D by the presence of *Neoarchaediscus* spp.

The limestone bed E (3.2-m thick, Fig. 4) is located about 36 m above bed D. It contains alternating layers of sandy and shaly crinoidal limestones (Fig. 4). Gigantoproductid brachiopods are common in some of the beds. The crinoidal layer at the top contains the solitary corals *Axophyllum* ex gr. *pseudokirsopianum* Semenoff-Tian-Chansky, 1974 (Fig. 5D) and *Palaeosmilia murchisoni* Milne-Edwards & Haime, 1848 (Fig. 5E) and colonial corals (*Siphonodendron martini* and syringoporoids; Fig. 3), as well as common chaetetid sponges. Above a thin shale interval, 3 m of marly limestones occur (bed F, Fig. 4), succeeded by 9 m of mudstones with thin interbedded fine-grained limestones showing strong cross-lamination and ripples. No corals have been recorded from this interval. Foraminiferal assemblages suggest that the base of the Brigantian should be situated in this bed E, mostly by the occurrence of common species of *Neoarchaediscus*.

Limestone bed G (2.1-m thick, Fig. 4) shows ripples and cross lamination. At the top, large gigantoproductid brachiopods occur, along with small colonies of *Siphonodendron martini*, the single coral species recorded in this limestone bed (Fig. 3). The latter can be observed attached growing in an upright position on the inverted brachiopod shells.

Limestone bed H (2.1-m thick) shows several concentrations of gigantoproductid shells, many inverted in a convex-up orientation. Near the top of the bed, coral colonies occur in growth position, some attached to the upper surface of brachiopods, in a similar manner to bed G (Fig. 7A). The coral assemblage shows a clear diversification with the first occurrence of fasciculate *Siphonodendron irregulare* (Phillips, 1836), and the cerioid *Lithostrotion vorticale* (Parkinson, 1808) (Fig. 6B-C). Colonial corals dominate this bed; solitary corals have been not recorded (Fig. 3). This suite of taxa is typical of the late Asbian, but does extend into the Brigantian (Poty 1981; Rodríguez & Somerville 2007).

Diversification increases significantly in the next limestone bed (bed I; 3.2-m thick, mostly dolomitised, apart from a one-metre thick interval near the top), with 10 species recorded. In this bed *Lonsdaleia duplicata* (Martin, 1809), *Lithostrotion decipiens* (McCoy, 1849), *Kizilia* sp. (Fig. 6D-F) and a gregarious axophyllid make their first appearances. The abundance of corals increases also in this bed, where a large concentration of solitary corals (*Palaeosmilia murchisoni, Kizilia* sp., *Axophyllum* ex gr. *pseudokirsopianum*) is recorded at the top. The presence of *Lonsdaleia* and *Kizilia* suggest a probable Brigantian age.

Bed J is an oolitic limestone, 2.5-m thick, which is mostly dolomitised and did not provide any corals. The coral assemblage recorded in bed K (1.65-m thick) is broadly similar to that of bed I, not only in its diversity, but also in the abundance and distribution of corals in the bed. In this bed *Lonsdaleia* is absent but syringoporoid colonies become abundant (Fig. 7B), as well as large colonies of *Lithostrotion decipiens* up to 50 cm in diameter. However, solitary corals are the most dominant taxa, with common *Palaeosmilia* and *Axophyllum.* Foraminifers recorded from bed J and K suggest a uppermost late Brigantian age, including *Janischewskina* sp., *Neoarchaediscus* aff. *postrugosus* (Reitlinger, 1949), *Planospirodiscus taimyricus* (Sossipatrova, 1962),

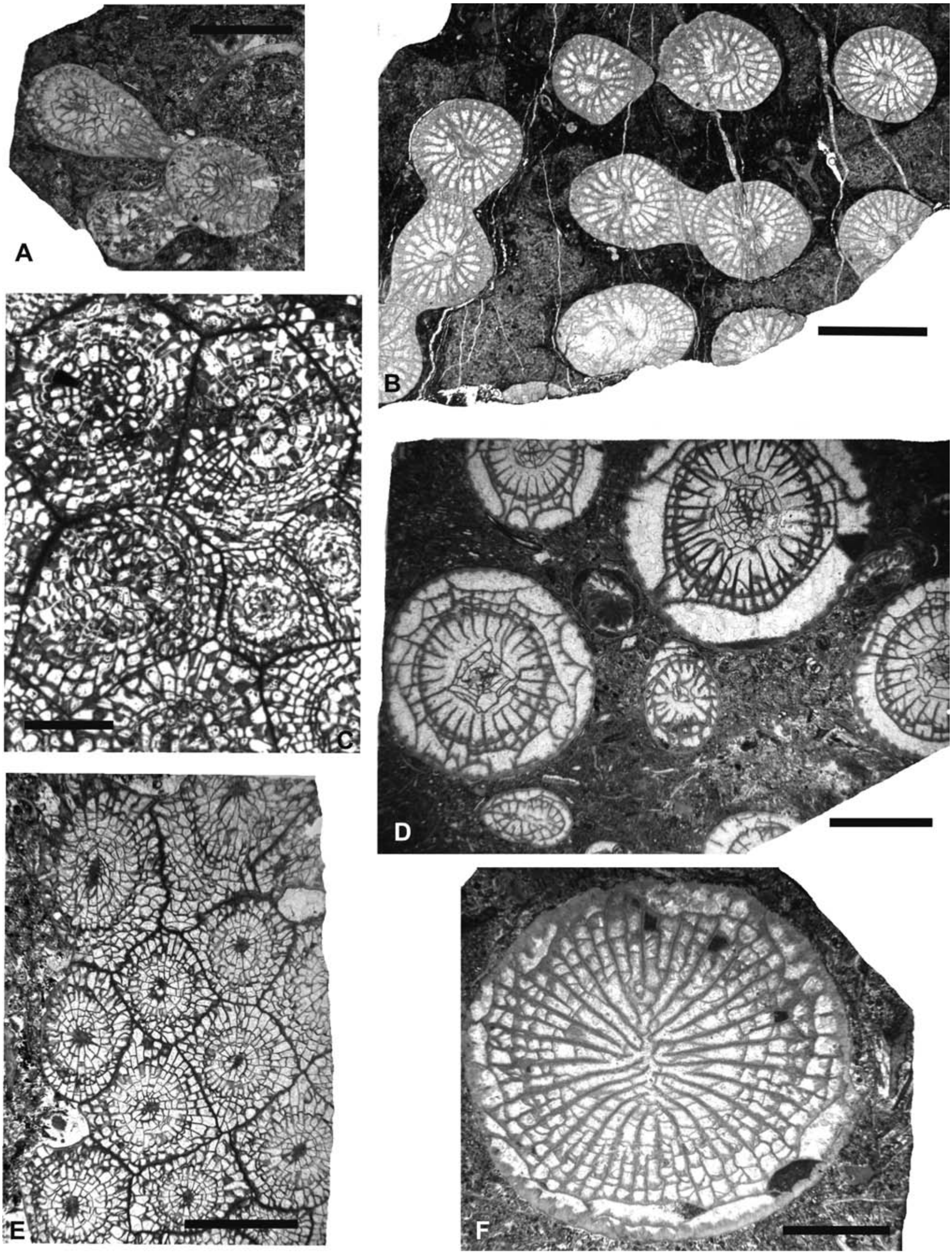

Fig. 6 - Corals first appearing in beds H and I. A) *Siphonodendron pauciradiale* (McCoy, 1849), TUI/H1. B) *Siphonodendron irregulare* (Phillips, 1836), TUI/H-2. C) *Lithostrotion vorticale* (Parkinson, 1808), TUI/I-12. D) *Lonsdaleia duplicata* (Martin, 1809), TUI-M-6. E) *Lithostrotion decipiens* (McCoy, 1849), TUI-M-13. F) *Kizilia* sp., TUI-M-27. Scale bars = 5 mm.

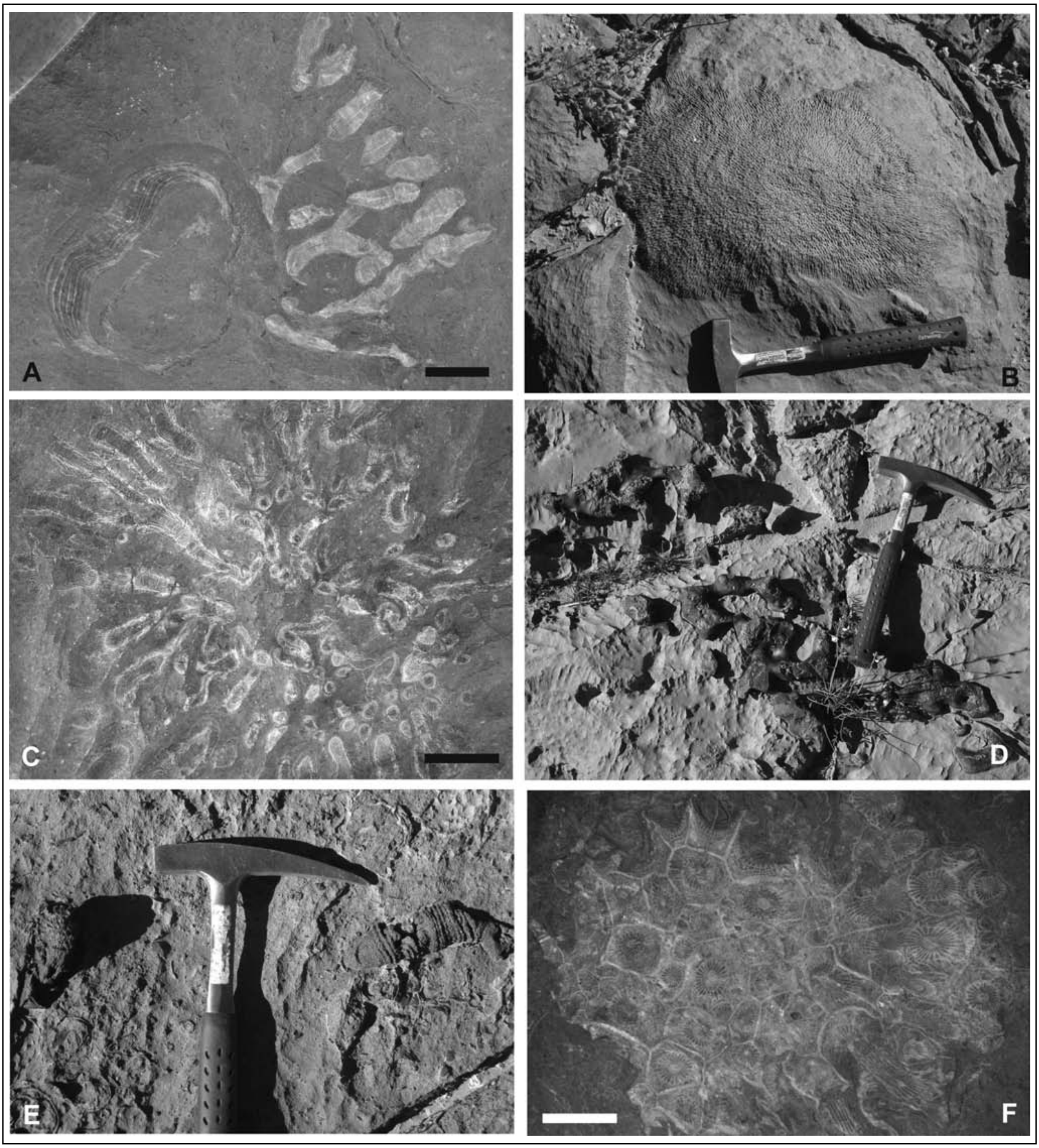

Fig. 7 - Corals at outcrop. A) Detail of bed H, with a *Siphonodendron* colony in growth position, attached to a gigantoproductid shell (Scale bar = 2 mm). B) Large colony of syringoporoids in bed K. C) Colony of *Diphyphyllum furcatum* Hill, 1940 in bed M (scale bar = 5 cm). D) Silicified *Thalassinoides* in bed N. E) Silicified solitary corals in bed O. F) Colony of *Actinocyathus* in bed P (scale bar = 2 mm). Length of the hammer = 32 cm.

Biseriella sp., with *Climacammina* sp. first recorded in bed K (see Cózar & Somerville 2004; Somerville & Cózar 2005; Cózar et al. 2008).

The first occurrence of *Diphyphyllum furcatum* Hill, 1940 (Fig. 7C), *Diphyphyllum lateseptatum* McCoy, 1849, (Fig. 8A) and *Dibunophyllum bipartitum* (McCoy, 1849) (Fig. 8B) is recorded in bed L (Fig. 3), 3.3-m thick limestone, containing abundant gigantoproductids. Corals occur mainly at the top of the bed, dominated by solitary taxa. Interestingly, this is the only limestone bed in which *Siphonodendron* is not recorded. These taxa are typical of the Brigantian (Rodríguez & Somerville 2007), but they can also extend into the Serpukhovian (Brand 2011). Notable, is the first occur-

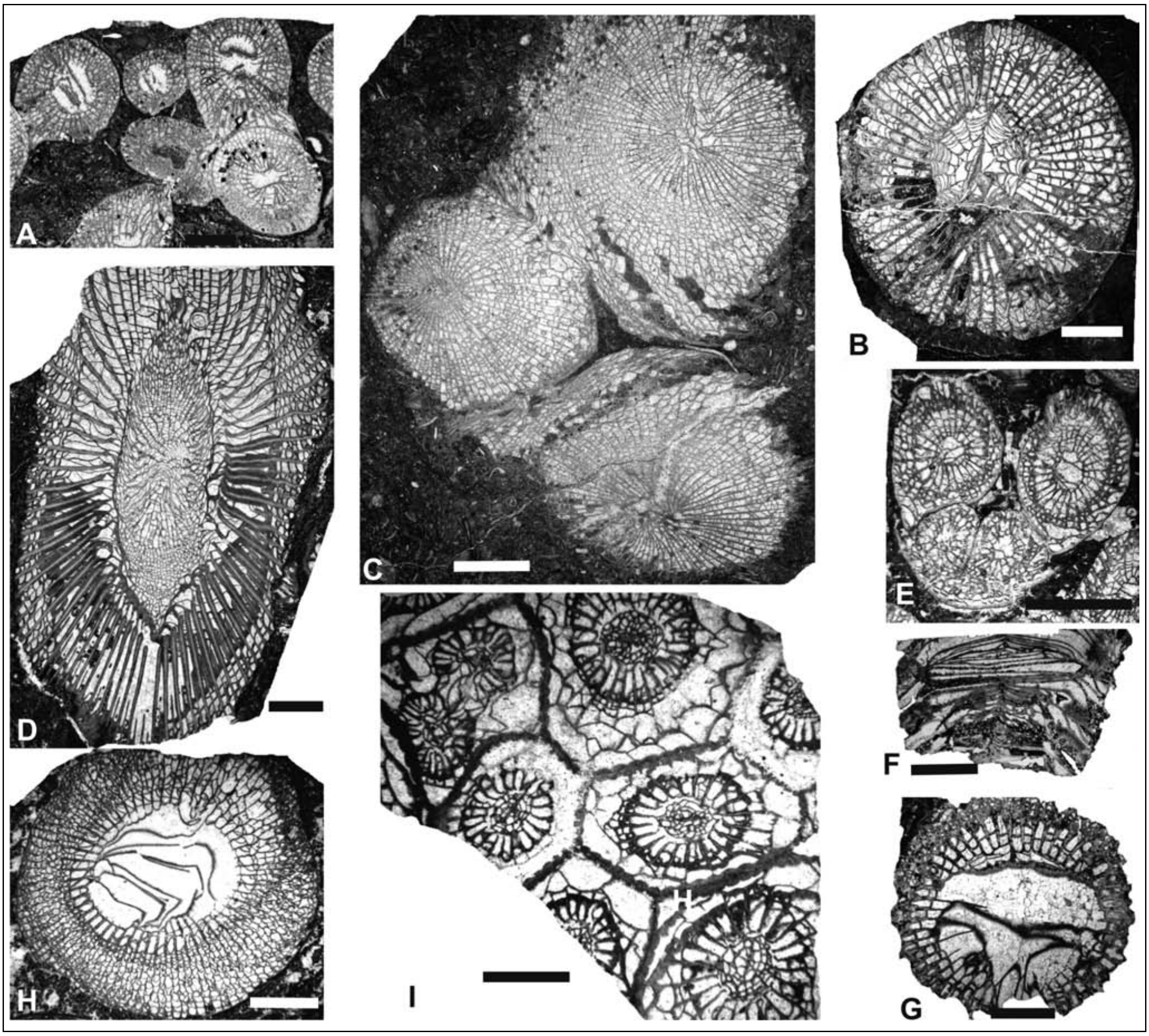

Fig. 8 - Corals first appearing in beds L-P. A) *Diphyphyllum lateseptatum* McCoy, 1849, TUI-L-1. B) *Dibunophyllum bipartitum* (McCoy, 1849), TUI-L-11. C) *Palastraea regia* (Phillips, 1836), TUI-M-11. D) *Aulophyllum fungites* (Fleming, 1828), TUI-M-2. E) *Tizraia berkhlii* Said & Rodríguez, 2007, TUI-M-40. F-G) *Koninckophyllum interruptum* (Thomson & Nicholson, 1876), TUI-O-3. F. Longitudinal section. G. Transverse section. H) *Haplolasma arciferum* Semenoff-Tian-Chansky, 1974, TUI-M-8. I) *Actinocyathus floriformis* (Martin, 1809), TUI-P-2. Scale bars = 5 mm.

rence of the foraminifers *Eostaffella pseudostruvei* Rauzer-Chernoussova & Beljaev in Rauzer-Chernoussova et al., 1936, *E. mutabilis* Rauzer-Chernoussova in Rauzer-Chernoussova et al., 1951, *E. mirifica* Brazhnikova in Brazhnikova et al., 1967, *E. postproikensis* Vdovenko in Brazhnkova et al., 1967, *Bradyina cribrostomata* Rauzer-Chernoussova & Reitlinger in Rauzer-Chernoussova & Fursenko, 1937, *Insolentitheca* sp. and *Endothyranopsis plana* Brazhnikova in Brazhnikova et al., 1967, which indicate a Serpukhovian age (see Cózar et al. 2008, 2011).

Limestone beds M to P (Fig. 4) show strong dolomitization and many of the corals recorded in this interval are silicified. Bed M (4.5-m thick) shows a high abundance and diversity of corals, including the first occurrences of *Actinocyathus floriformis* (Martin, 1809), *Lonsdaleia* sp. A, *Palastraea regia* (Phillips, 1836), *Aulophyllum fungites* (Fleming, 1828), *Tizraia berkhlii* Said & Rodríguez, 2007, *Koninckophyllum interruptum* (Thomson & Nicholson, 1876) and *Haplolasma arciferum* Semenoff-Tian-Chansky, 1974 (Fig. 8C-I). Chaetetids are also common in that bed. Bed M has the largest number of genera present (13), comprising a similar number of colonial (7) and solitary (6) taxa. This assemblage is typical of the Brigantian and early Serpukhovian (Rodríguez & Somerville 2007; Said et al. 2011).

Limestone bed N (2.2-m thick, Fig. 4) shows a similar coral assemblage to that of bed M, but has slightly fewer genera and species (Fig. 3). Bed N exhibits common silicified *Thalassinoides* burrows (Fig. 7D), and solitary corals are also commonly silicified (Fig. 7E). The last occurrences of *Diphyphyllum* spp., *Siphonodendron martini*, *Lonsdaleia* sp. and *Lithostrotion vorticale* are recorded also in that bed.

Limestone bed O (7.5-m thick, Fig. 4) shows the first occurrences of the solitary coral *Arachnolasma cylindrica* Yu, 1934. The upper part of the bed is strongly laminated and shows truncation by vertical burrows. The top of the bed shows abundant gigantoproductid brachiopods and solitary corals, mostly silicified. Limestone bed P (3.5-m thick) shows a similar assemblage as bed O, with common *Actinocyathus floriformis* (Fig. 7F) and rare *Actinocyathus* aff. *floriformis*. Foraminifers recorded from beds O and P (*Brenckleina* sp., *Eosigmoilina* sp., *Neoarchaediscus akchimensis* (Grozdilova & Lebedeva, 1954), *Eostaffellina* of the group *E.* "*paraprotvae*" Rauzer-Chernoussova, 1948) suggest a probable late Serpukhovian age (see Cózar et al. 2008, 2011).

Corals are absent in limestone beds Q and R, which are mainly laminated micrites and show pervasive dolomitization. The middle and upper members of the Djebel Ouarkziz Formation (above bed R) are poorly exposed and comprise mostly lime mudstones. However, there is a record of the "*Lithostrotion* cf. *junceum* beds" at the top of the Formation (Mamet et al. 1966). Semenoff-Tian-Chansky (1985) and Legrand-Blain et al. (1989) reported a biostrome at the top of the upper Serpukhovian beds in the Tindouf Basin, below the *Titanaria* brachiopod marker bed (see also Somerville et al. in press), which can also be recognized at the same level in the Taoudenni, Reggane and Ahnet basins to the east (Fig. 9). The biostrome is characterised by the presence of small clusters of a small *Siphonodendron* species referred to as *Siphonodendron* sp. A, or 'close to *S. pauciradiale*' by these authors, but it was not illustrated. Interestingly, Semenoff-Tian-Chansky (1985) recorded also, large specimens of *Lonsdaleia* close to *L. sarytschevae* Dobrolubova, 1958 and *Axophyllum*? *coronatum* (Fabre, 1955) from the same bed, neither of which were illustrated.

Discussion

The coral assemblages from the uppermost part of the Betaina Formation and the Djebel Ouarkziz Formation show distinctive characteristics, as well as some unusual peculiarities:

1) The occurrence of a *Siphonodendron* species in the lowest limestone bed (bed 1) shows a similar corallite diameter to *S. irregulare* (c. 4 mm), but the number of septa (23-25) are comparable to those of *S. martini*. The latter species ranges through the lower member of the Djebel Ouarkziz Formation and is regarded as one of the commonest *Siphonodendron* species in North African basins (Aretz 2010, 2011a). The biostrome containing *Siphonodendron* sp. A (bed 1) can be traced for at least 25 kilometres, because it occurs as large colonies below a prominent thick sandstone ridge in the three studied sections (Fig. 3). The different relationships in the number of septa/diameter could be due to ecological factors, such as a higher siliciclastic input into limestones. This was highlighted in a study on *Siphonodendron* colonies in sandy limestones in Viséan rocks in the UK (Nudds & Day 1997). Alternatively, it could simply represent an independent species, which has adapted to a widespread sandy carbonate substratum associated with the Asbian marine transgression in the Basin. It may be possibly endemic to the Tindouf Basin, although, similar specimens of *Siphonodendron* have been recently reported in coeval late Asbian rocks of NW Turkey (Denayer 2011).

2) The coral assemblages have a low diversity in the lower limestone beds (1 and A-H), typically with 1-5 species (Fig. 3). This diversity, however, increases progressively up through the Djebel Ouarkziz Formation, being highest in beds M to P, with a maximum in bed M (14 genera and 16 species). This results, in part, from the continued presence of many taxa in the upper beds, although in bed M, several new taxa first appear in the same horizon (Fig. 3). This could be explained by migration from other areas in the Palaeotethys and adjustment to improving environmental conditions in the Tindouf Basin during the Brigantian and Serpukhovian. Prior to this time, during the Asbian, the depositional setting of the underlying Betaina Fm. was possibly deeper water and had a high siliciclastic influx with common trace fossils, moulds of brachiopods, crinoids and goniatites recorded. However, a low diversity assemblage of undissepimented solitary corals has been recorded by us near the base of the formation (unpublished data). Consequently, corals only could develop widely when conditions changed to shallower water carbonate sedimentation with less siliciclastic input. Then, the migrating corals could establish there and persist with the improving 'cleaner' carbonate sedimentation on the platform. The coral migration was probably pulsed, with new taxa arriving along with surviving taxa with each transgressive event, leading to an increasing diversity during the Brigantian and especially in the Serpukhovian, when assemblages reached their peak.

3) Rugose coral associations (RCA) which were described for the upper Viséan coral assemblages in the western Palaeotethys (Somerville & Rodríguez 2007) can be recognised also in the Tindouf Basin succession. This is because most of the upper Viséan (Asbian-Brigantian) taxa extend into the Serpukhovian. The biostrome in bed 1 is distinctive because of its relatively low

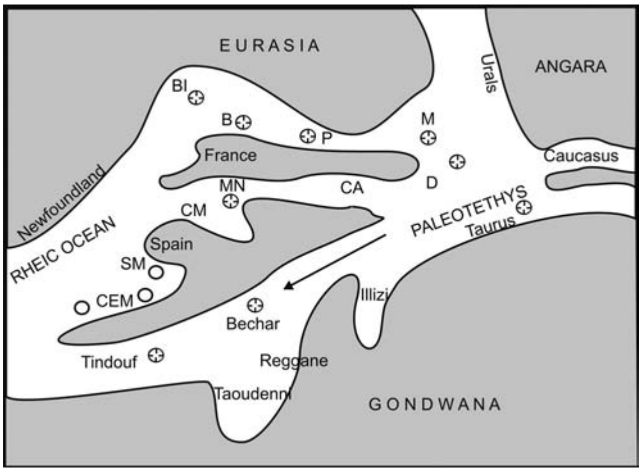

Fig. 9 - Palaeogeographic distribution of *Lonsdaleia* in the Brigantian. Coral symbols = occurrences of *Lonsdaleia* in the Viséan. Open circles = areas of absence of *Lonsdaleia* in the Viséan. Arrow = possible migration route for *Lonsdaleia*. B = Belgium, BI = British Isles, CA = Carnic Alps, CEM = Central and Eastern Morocco, CM = Cantabrian Mountains, D = Donetz Basin, M = Moscow Basin, MN = Montaigne Noire, P = Poland, SM = Sierra Morena. Based on Krainer & Vachard (2002).

diversity, dominated by up to 4 species of *Siphondendron* and the abundant in situ colonies. It is closest to RCA7 of Somerville & Rodríguez (2007), although *Lithostrotion* is not recorded. Bed E is typical of RCA2 where solitary corals are dominant in a low diversity assemblage. Bed H is representative of RCA3 with common colonial taxa (mostly *Siphonodendron*) and absence of solitary corals. Bed I and beds L-P can all be assigned to RCA4 because of their high diversity (>8 taxa). Moreover, some beds, e.g. M, O and P have abundant solitary and colonial rugose taxa. Bed K, on the other hand, differs by the lower number of taxa in the assemblage and by the dominance of solitary corals, and is referred to RCA2. It is, however, more diverse than the assemblage in Bed E.

4) The occurrence of the genus *Lonsdaleia* that has never been recorded in situ in Viséan rocks from the northern basins of Morocco or of Sierra Morena (SW Spain) (Said et al. 2007; Aretz & Herbig 2010; Aretz 2010; Fig. 9), but is common in Western European basins, such as the Montagne Noire (Aretz 2002b), Belgium (Poty 1981), British Isles (Mitchell 1989; Rodríguez & Somerville 2007), and Russia (Hecker 1997, 2001). The only record of *Lonsdaleia* in northern Moroccan basins is from pebbles in a Serpukhovian conglomerate at Koudiat Mohamed ben Sidi Mohamed, near Rabat, in the western part of the Central Meseta, but the source area is unknown. It is difficult to explain this distribution of *Lonsdaleia* from a palaeogeographic point of view, because the most direct migration route between the Tindouf Basin and Western Europe should be via northern Morocco and southern Europe, as suggested by Legrand-Blain et al. (1989: fig. 4) based on an analysis of the coeval brachiopod faunas.

From a palaeoecological perspective, the absence of the genus *Lonsdaleia* in intermediate areas could be explained if this taxon required a specific ecological niche, which was not present in those areas. However, this is not the case, as in basins from northern Morocco and SW Spain corals are found in many different environments (Said et al. 2007, 2011; Aretz & Herbig 2010; Rodríguez & Falces 1992). Most corals present in the Djebel Ouarkziz assemblages occur also in those basins; *Lonsdaleia* and *Actinocyathus* are the only significant taxa absent in those regions. However, there are records of *Actinocyathus* in transported limestone blocks of the Marbella Limestone Formation in southern Spain of Serpukhovian to Bashkirian age (Herbig & Mamet 1985; Herbig 1986).

If the corals occurring in the Tindouf Basin did not migrate there from the north, one of the most likely routes could be from the northeast and east, through other North African basins, such as the Béchar Basin (Fig. 9). This hypothesis could be confirmed with a more detailed search for those genera in that basin. Previous studies (Semenoff-Tian-Chansky 1985) and recently published data in Aretz (2011a) from the central Saharan basins demonstrates the dominance of Aulophyllidae, Palaeosmiliidae, Cyathopsidae and Lithostrotionidae. However, colonial Axophyllidae (*Lonsdaleia* and *Actinocyathus*) were not reported from the Béchar Basin. Nevertheless, a possible marine connection between Tindouf and Béchar is inferred based on the palaeogeographical reconstruction of Krainer & Vachard (2002, fig. 8), resulting from a study of Serpukhovian microfossils (foraminifers and calcareous algae).

5) The abundance of the genus *Kizilia* in Upper Viséan and Serpukhovian beds in the Tindouf Basin is noteworthy. This genus is common in the Serpukhovian, but has been rarely recorded in the Upper Viséan of Western Europe (Poty 1981; Denayer et al. 2011). However, it occurs in the Brigantian limestones from Djebel Ouarkziz and becomes abundant before the end of the Viséan. It also occurs in the Upper Viséan from northern basins in Morocco (e.g. Azrou-Khenifra Basin), but it is scarce there (Somerville et al. 2011; Said et al. in press).

6) In the Tindouf Basin there is a different sequence of first occurrences of rugose corals compared to the same taxa in other areas of the Western Palaeotethys. For instance, the genera *Tizraia, Aulophyllum, Arachnolasma, Koninckophyllum* and *Palastraea,* which are common from the Brigantian in the Azrou-Khenifra Basin (Said et al. 2007, 2011; Rodríguez et al. 2010), all occur for the first time in the Serpukhovian in the Tindouf Basin. Similarly, *Dibunophyllum* and *Diphyphyllum* are common in late Asbian-early Brigantian rocks

from northern Moroccan basins (Said et al. 2007, 2011; Rodríguez et al. 2010), but in the Djebel Ouarkziz they have their first occurrence in late Brigantian rocks. None of the rugose genera recorded in the Djebel Ouarkziz Formation is endemic to Tindouf; they all have wide geographical distributions. Consequently, all of these taxa probably migrated to the Tindouf Basin at different times, following the main tropical currents in the Palaeotethys, from east to west (northeast to southwest in this case; Fig. 9). The anomalous first occurrences of the different species can be explained as: (i) a result of a chance combination of current variations, (ii) occurrence of species in the source areas, located closer to the equator (e.g. Western Europe, Russian Platform) and (iii) the capability of coral planulae to be transported along the northern border of Gondwana. The latter mechanism was also suggested by Semenoff-Tian-Chansky (1974) who referred to the 'slow migration of favourable biotopes'.

Also, it is interesting to note, that all the solitary taxa in the northern Tindouf Basin (*Aulophyllum, Arachnolasma, Koninckophyllum, Haplolasma*) are recorded in the Serpukhovian in Algeria (Semenoff-Tian-Chansky 1974, table 3), whose first appearance is, in every case, later than in most other parts of the Western Palaeotethys (cf. Fedorowski 1981; Poty 1981; Mitchell 1989; Rodriguez & Somerville 2007). Those corals occur typically in the upper Viséan from the British Isles, Belgium, France, Spain, Poland, Russia, etc.

Most of the differences between the assemblages from northern Morocco and SW Spain could be explained by different palaeolatitudes, but the assemblages from the Djebel Ouarkziz Formation show greater similarities with those from NW Europe, as previously noted by Semenoff-Tian-Chansky (1985) (see Poty 1981; Mitchell 1989; Aretz 2002a, 2011b; Rodríguez & Somerville 2007; Somerville et al. 2007). An alternative explanation for the differences in the assemblages could be accounted for by a combination of sedimentological and palaeoecologic factors related to sea-level oscillations in a mixed carbonate-siliciclastic sequence. The succession in the Djebel Ouarkziz Formation shows some similarity with the successions described from the Brigantian in northern Britain (cyclothems, mainly composed of intervals of shales and sandstones with thin limestone intercalations; Holliday et al. 1975; Burgess & Mitchell 1976; Johnson & Nudds 1996; Cózar & Somerville 2004). In contrast, it is very different from the successions in SW Spain (Cózar & Rodríguez 1999) and northern Morocco, north of the Anti-Atlas Mountains (Said et al. 2007; Cózar et al. 2008, 2011; Aretz & Herbig 2008; Aretz 2010; Somerville et al. 2011), where the formations are predominantly carbonate and contain large mud mounds.

Conclusions

(i) A continuous late Asbian to late Serpukhovian succession is recorded in the northern Tindouf Basin. This sequence, which mainly belongs to the Djebel Ouarkziz Formation, is mostly composed of shales alternating with sandstones, thin limestones and dolostones.

(ii) Corals are recorded in most limestone beds and show a progressive increase in diversity; typically 1-5 species in the lower part of the formation, 7-16 in the higher limestone beds. Bed M has the highest diversity with 14 genera and 16 species.

(iii) Two genera, *Lonsdaleia* and *Actinocyathus,* present in the Tindouf Basin, are unknown from northern Moroccan basins, but are common in NW Europe and Russia in the Upper Viséan and Serpukhovian. Also, *Kizilia* is common in the Tindouf Basin, but is scarce in the Azrou-Khenifra Basin and elsewhere in Europe.

(iv) Several taxa appear later (in the Serpukhovian) in the Tindouf Basin compared to other basins in Morocco and Europe. These include *Palastraea regia, Tizraia berkhlii, Actinocyathus floriformis* and *Aulophyllum fungites*, which typically first occur in the Brigantian.

(v) Palaeogeographic reconstructions based on the distribution of rugose corals is difficult because of (a) the isolated position of the Tindouf Basin in Saharan Morocco compared to other Moroccan basins north of the Anti-Atlas Mountains, (b) the absence elsewhere in Morocco of several key taxa (*Actinocyathus* and *Lonsdaleia*), and (c) the later arrivals of taxa in the Serpukhovian compared to other Moroccan basins.

(vi) The simple north-to-south marine corridor from southern Europe to the Sahara as envisaged by previous workers is complicated by the absence of key taxa in northern Morocco. Thus, there must have been at times some partial isolation of basins in northern Morocco and southern Spain. A possible migration route to the Tindouf Basin may lie to the northeast in the Béchar Basin. Furthermore, it has also to be considered that the later arrival of marine trangressions in the Tindouf Basin may, in part, explain the first appearance of coral taxa in the Serpukhovian which are first recorded elsewhere in the Upper Viséan.

Acknowledgements. The authors are grateful to Olga Kossovaya and Tetsuo Sugiyama for providing constructive reviews which helped improve the manuscript. We also express our thanks to Lucia Angiolini for her editorial expertise and useful comments. Field work was carried out thanks to the collaboration of the Department of Mine Development of the Ministère de l'Energie et des Mines of Morocco. Field work was founded by the Spanish Ministerio de Innovación y Ciencia (research project CGL2009-10340/BTE) and Santander-UCM Research group 910231. This paper is a contribution to the IGCP 596.

REFERENCES

Aretz M. (2002a) - Habitatanalyse und Riffbildungspotential kolonialer rugoser Korallen im Unterkarbon (Mississippium) von Westeuropa. *Koln. F. Geol. Paläont.*, 10(2002): 1-155.

Aretz M. (2002b) - Rugose corals and associated carbonate microfossils from the Brigantian (Mississippian) of Castlesec (Montagne Noire, Southern France). *Geobios*, 35: 187-200.

Aretz M. (2010) - Rugose corals from the upper Viséan (Carboniferous) of the Jerada Massif (NE Morocco): taxonomy, biostratigraphy, facies and palaeobiogeography. *Palaeont. Z.*, 84(3): 323-344.

Aretz M. (2011a) - Corals from the Carboniferous of the central Sahara (Algeria): the collection of "Marie Legrand-Blain". *Geodiversitas*, 33(4): 581-624.

Aretz M. (2011b) - Palaeobiogeographical analysis for the late Viséan corals in the Variscan Realm of Western Europe and Northern Africa. Abstract Volume, 11th International Symposium on Fossil Cnidaria and Sponges, Liege, August 19-29, 2011. *Koln. F. Geol. Paläont.*, 19: 12-13.

Aretz M. & Herbig H.-G. (2008) - Microbial-sponge and microbial-metazoan buildups in the late Viséan basin-fill sequence of the Jerada Massif (Carboniferous, NE Morocco). *Geol. J.*, 43(2-3): 307-336.

Aretz M. & Herbig H.-G. (2010) - Corals from the Viséan of the central and southern part of Azrou-Khénifra Basin (Carboniferous, Central Moroccan Meseta). In: Kossovaya O. & Somerville I.D. (Eds) - X Coral Symposium, St. Petersburg. *Palaeoworld*, 19(3-4): 295-304.

Brand P.J. (2011) - The Serpukhovian and Bashkirian (Carboniferous, Namurian and basal Westphalian) faunas of northern England. *Proc. Yorkshire Geol. Soc.*, 58: 1-24.

Brazhnikova N.E. Vakarchuk G. I., Vdovenko M. V., Vinnichenko L. V., Karpova M. A., Kolomiets Ya. I., Potievskaya P. D., Rostovtseva L. F. & Shevchenko G.D. (1967) - Microfaunal marker-horizons from the Carboniferous and Permian deposits of the Dniepr-Donets Depression. *Ak. Nauk Ukrainskoi SSR, Inst. Geol. Nauk, Trudy, Izdatelstvo "Naukova Dumka"*, Kiev, 224 pp. [in Russian].

Burgess I. & Mitchell M. (1976) - Viséan lower Yoredale limestones on the Alston and Askrigg blocks, and the base of the D2 zone in northern England. *Proc. Yorkshire Geol. Soc.*, 40: 613-630.

Conil R. & Lys M. (1964) - Matériaux pour l'étude micropaléontologique du Dinantien de la Belgique et de la France (Avesnois). Partie 2, foraminifères. *Mém. Inst. Géol. Univ. Louvain*, 23: 1-296.

Conrad J. (1972) - L'age et les modalités de la regresión carbonifère au bord nord du Bassin de Tindouf. *C. R. Acad. Sc. Paris*, 274: 1780-1783.

Cózar P. & Rodríguez S. (1999) - Propuesta de nueva nomenclatura para las unidades del Carbonífero Inferior del Sector Norte del Área del Guadiato (Córdoba). *Bol. Geol. Min.*, 110: 237-254.

Cózar P. & Somerville I. D. (2004) - New algal-foraminiferal evidence for the recognition of the Asbian-Brigantian boundary in northern England. *Proc. Yorkshire Geol. Soc.*, 55(1): 43-65.

Cózar P., Vachard D, Somerville I.D., Berkhli M., Medina-Varea P., Rodríguez S. & Said I. (2008) - Late Viséan–Serpukhovian foraminiferans and calcareous algae from the Adarouch region (central Morocco), North Africa. *Geol. J.*, 43(4): 463-485.

Cózar P., Said I., Somerville I.D., Vachard D., Medina-Varea P., Rodríguez S. & Berkhli M. (2011) - Potential foraminiferal markers for the Visean–Serpukhovian and Serpukhovian–Bashkirian boundaries - A case-study from central Morocco. *J. Paleont.*, 85: 1105-1127.

Denayer J. (2011) - Mississippian Lithostrotionidae from Zonguldak and Bartin (NW Turkey). In: Aretz M., Delculée S., Denayer J. & Poty E. (Eds) - Abstracts 11th Symposium on Fossil Cnidaria and Sponges. *Köln. F. Geol. Paläont.*, 19(2011): 34.

Denayer J., Poty E. & Aretz M. (2011) - Uppermost Devonian and Dinantian rugose corals from Southern Belgium and surrounding areas. In: Aretz M. & Poty E. (Eds) - Field Guides 11th International Symposium on Fossil Cnidaria and Porifera, Liège 2011. *Köln. F. Geol. Pälaont.,* 20: 151-201.

Dobrolyubova T. A. (1958) - Lower Carboniferous colonial tetracorals of the Russian Platform. Transactions of the Palaeontological Institute, Academy of Sciences, USSR, 70: 1-226, Moscow [in Russian].

Eichwald E. von (1860) - Lethaea Rossica ou Paléontologie de la Russie, première section de l'anncienne période. E. Schweizerbart, Stuttgart, 1: 1-681.

Fabre J. (1955) - Deux polypiers du Viséen dupérieur de Tindouf (Sahara N.W.): *Caninophyllum archiaci* (M.E. et H) var. *densa* n. var. et *Carcinophyllum coronatum* nov. sp. *Ann. Soc. Géol. Nord*, 75: 8-15.

Fabre J. (1976) - Introduction à la géologie du Sahara algérien. S.N.E.D., Alger, 422 pp.

Fleming J. (1828) - A history of British animals. Bel & Bradfute, Edinburgh, 565 pp.

Fedorowski J. (1981) - Carboniferous corals: distribution and sequence. *Acta Palaeontol. Pol.*, 26(2): 87-160.

Grozdilova L.P. & Lebedeva N.S. (1954) - Foraminifers of the Lower Carboniferous and Bashkirian Stage of the Middle Carboniferous of the Kolva-Vishera area. *Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-razvedochnogo Instituta (VNIGRI), Mikrofauna SSSR Sbornik 7*, Nov. Ser., 81: 4-235 [in Russian].

Hecker M. (1997) - Rugosa coral faunas from Upper Viséan (Asbian-Brigantian) buildups and adjacent platform limestones, Kingscourt, Ireland. *Bol. R. Soc. Española Hist. Nat., (Sec. Geol.),* 92 (1-4): 35-47.

Hecker M. (2001) - Lower Carboniferous (Dinantian and Serpukhovian) rugose coral zonation of the East European Platform and Urals, and correlation with Western Europe. *Bull. Tohoku Univ. Mus.*, 1: 298-310.

Herbig H.-G. (1986) - Rugosa und Heterocorallia aus Obervise′-Geröllen der Marbella-Formation (Betische Kordilliere, Südspanien). *Palaeont. Z.*, 60: 189-225.

Herbig H.-G. & Mamet B. L. (1985) - Stratigraphy of the limestone boulders, Marbella Formation (Betic Cordillera, Southern Spain). In: C. R. 10ème Cong. Int. Strat. Géol. Carbon., 1: 199-212, Madrid.

Hill D. (1938-1940) - A monograph on the Carboniferous rugose corals of Scotland. Palaeontological Society of London Monograph, Pt 1 (1-78), Pt 2 (79-114), Pt 3 (115-204).

Holliday D., Burgess I.C. & Frost D.V. (1975) - A recorrelation of the Yoredale Limestones (Upper Viséan) of the Alston Block with those of the Northumberland Trough. *Proc. Yorks. Geol. Soc.*, 40: 319-334.

Johnson G.A.L. & Nudds J.R. (1996) - Carboniferous biostratigraphy of the Rookhope Borehole, Co. Durham. *Trans. R. Soc. Edinburg, Earth Sc.*, 86: 181-226.

Krainer K. & Vachard D. (2002) - Late Serpukhovian (Namurian A) Microfacies and Carbonate Microfossils from the Carboniferous of Nötsch (Austria). *Facies*, 46: 1-24.

Legrand-Blain M., Conrad J., Coquel R., Lejal-Nicol A., Lys M., Poncet J. & Semenoff-Tian-Chansky P. (1989) - Carboniferous Palaeobiogeography of North Africa. In: C. R. 11ème Cong. Int. Strat. Géol. Carbon., Beijing 1987, 4: 216-230, Beijing.

Lys M. (1979) - Micropaléontologie (Foraminifères) des formations marines du Carbonifère saharien. In: 8émé Cong. Int. Strat. Carbon., Moscow, 1975, 2: 37-47, Moscow.

Mamet B., Choubert G. & Hottinger L. (1966) - Note sur le Carbonifère du Djebel Ouarkziz. Etude du passage Viséen au Namurien d'après les Foraminifères. *Not. Mem. Serv. Géol. Maroc*, 198(27): 7-21.

Martin W. (1809) - *Petrificata derbiense*; or figures and descriptions of petrifications collected in Derbyshire, 28 pp., D. Lyon, Wigan.

McCoy F. (1849) - On some new genera and species of Palaeozoic Corals and Foraminifera. *Ann. Mag. Nat. Hist.*, Series 2, 3: 1-20, 119-136.

Milne-Edwards H. & Haime J. (1848) - Recherches sur les polypiers, Premier général. *Ann. Sci. Nat.*, 9: 37-89.

Milne-Edwards H. & Haime J. (1851-1855) - Monographie des polypiers fossils des terrains palaeozoiques, précédée d'un tableau general de la classification des Polypes. Archives du Museum d'Histoire Naturelle de Paris, Paris, 502 pp.

Mitchell M. (1989) - Biostratigraphy of Viséan (Dinantian) rugose coral faunas from Britain. *Proc. Yorks. Geol. Soc.*, 47: 233-247.

Nudds J.R. & Day (1997) - Rugosa coral faunas from Upper Viséan (Asbian-Brigantian) buildups and adjacent platform limestones, Kingscourt, Ireland. *Bol. R. Soc. Española Hist. Nat.*, (*Sec. Geol.*), 92(1-4): 35-47.

Parkinson L. (1808) - Organic remains of a former world. *Zoophytes*, 2: 1-286.

Phillips J. (1836) - Illustration of the geology of Yorkshire. Part II. The Mountain Limestone district: 1-253, London.

Poty E. (1981) - Recherches sur les Tétracoralliaires et les Hétérocoralliaires du Viséen de la Belgique. *Meded. Rijks Geol. D.*, 35: 1-161.

Rauser-Chernoussova D. M. (1948) - Some new species of foraminifers from Lower Carboniferous deposits of the Moscow Basin. *Ak. Nauk SSSR, Trudy Inst. Geol. nauk, Geol. Ser.* 19, 62: 227-238 [In Russian].

Rauser-Chernoussova D. M. & Fursenko A.V. (1937) - Guide to Foraminifers from the Oil-Bearing Regions of the USSR, Part I. ONTI, NKTP, SSSR, Glavnaya Redaktsiya Gorno-Toplivnoy Literatury, Leningrad and Moscow, 320 pp. [in Russian].

Rauser-Chernoussova D.M., Belyaev G. & Reitlinger E.A. (1936) - Upper Paleozoic foraminifers of the Pechora region. *Akademiya Nauk SSSR, Trudy Polyarnoy Komissii*, 28:159-232 [in Russian].

Rauser-Chernoussova D. M. Kireeva G.D., Leontovich L.E., Grizlova N.D., Safanova T.P. & Chernova. E.I. (1951) - Middle Carboniferous fusulinids from the Russian Platform and surrounding areas. *Ak. Nauk SSSR, Inst. Geol. Nauk*, 380 pp. [in Russian].

Reitlinger E.A. (1949) - Smaller foraminifers in the lower part of the Middle Carboniferous of the Middle Urals and Kama River area. *Izvestiya Akademii Nauk SSSR, Seriya Geologicheskaya*, 6: 149-164 [in Russian].

Rodríguez S. & Falces S. (1992) - Corales rugosos. In: Rodríguez S. (Ed.) - Analisis paleontológico y sedimentológico de la Cuenca Carbonífera de los Santos de Maimona (Badajoz). *Col. Paleont.*, 44: 159-218, Madrid.

Rodríguez S. & Somerville I.D. (2007) - Comparisons of rugose corals from the Upper Viséan of SW Spain and Ireland: implications for improved resolutions in late Mississippian coral biostratigraphy. In: Hubmann B. & Piller W. E. (Eds) - Fossil Corals and Sponges. Proc. 9th Int. Symp. Fossil Cnid. Por., Graz 2003. *Schrift. Erdwissensch. Kom.*, 17: 275-305.

Rodríguez S., Somerville I.D., Said I. & Cózar P. (2010) - Tiouinine: un arrecife franjeante con la estructura preservada en el Misisípico de Marruecos. In: III Congreso Ibérico de Paleontología: 265-268, Lisbon.

Said I. & Rodríguez S. (2007) - A new genus of coral (Rugosa) from the Adarouch area (Brigantian, NE Central Morocco). *Col. Paleontología*, 57: 23-35.

Said I., Rodríguez S. & Berkhli M. (2007) - Preliminary data on the coral distribution in the Upper Visean (Mississippian) succession from Adarouch area (NE Central Morocco). In: Hubmann B. & Piller W. E. (Eds) - Fossil Corals and Sponges. Proc. 9th Int. Symp. Fossil Cnid. Por., Graz 2003. *Schrift. Erdwissensch. Kom.*, 17: 353-364.

Said I., Rodríguez S., Somerville I.D. & Cózar P. (2011) - Environmental study of coral assemblages from the upper Viséan Tizra Formation (Adarouch area, Morocco) - implications for Western Palaeotethys biogeography. *N. J. Geol. Paläont.*, Abt., 261(1): 101-118.

Said I., Somerville I.D., Rodríguez S. & Cózar P. (in press) - Mississippian coral assemblages from the Khenifra area, Central Morocco: biostratigraphy, biofacies, palaeoecology and palaeobiogeography. *Gondwana Res.* (accepted).

Schlykova T. I. (1951) - Foraminifery vizeiskogo i namurskogo yarusov nizhenego Karbona zapadnogo Kryla Podmoskovn kotloviny [Foraminifers of the Visean and Namurian stages from the western part of the Moscow basin]. Trudy VNIGRI, 56: 109-178 [in Russian].

Semenoff-Tian-Chansky P. (1974) - Recherches sur les Tétracoralliaires du Carboniférе du sahara Occidental. *Ed. Cent. Nat. Rech. Sc.. Sér. 6, Sc. Terre,* 30: 1-316.

Semenoff-Tian-Chansky P. (1985) - Corals. In: Wagner R.H., Winkler Prins C.F. & Granados L.F. (Eds) - The Carboniferous of the World, II, Australia, Indian subcontinent, South Africa, South America and North Africa. IUGS Publication 20: 374-381, 431-435. Instituto Geológico y Minero de España/ Empresa Nacional Adaro de Investigaciones Mineras, S.A, Madrid.

Somerville I.D. & Cózar P. (2005) - Late Asbian to Brigantian (Mississippian) foraminifera from southest Ireland: comparison with northern England assemblages. *J. Micropalaeont.*, 24: 131-144.

Somerville I.D. & Rodríguez S. (2007) - Rugose coral associations from the Upper Viséan of Ireland., Britain and SW Spain. In: Hubmann, B. & Piller, W. E. (Eds) - Fossil Corals and Sponges. Proc. 9th Int. Symp. Fossil Cnid. Por., Graz 2003. *Schrift. Erdwissensch. Kom.,* 17: 329-351.

Somerville I.D., Cózar P. & Rodríguez S. (2007) - Late Viséan rugose coral faunas from south-eastern Ireland: composition, depositional setting and palaeoecology of *Siphonodendron* biostromes. In: Hubmann B. & Piller W. E. (Eds) - Fossil Corals and Sponges. Proc. 9th Int. Symp. Fossil Cnid. Por., Graz 2003. *Schrift. Erdwissensch. Kom.,* 17: 307-328.

Somerville I.D., Rodríguez S., Said I. & Cozar P. (2011) - Mississippian microbial mounds and coral reefs from Central Morocco. ICCP 2011 Perth 3-8 July, 2011, Abstract: 116.

Somerville I.D., Cozar P., Said I., Vachard D., Medina-Varea P. & Rodríguez S. (in press) - Palaeobiogeographical constraints on the distribution of foraminifers and rugose corals in the Carboniferous Tindouf Basin, S. Morocco. *J. Palaeogeogr.*

Sossipatrova G. P. (1962) - Foraminifers from Upper Paleozoic deposits of Taimyr. Nauchno-Issledovatel'skii Institut Geologii Arktiki (NIIGA), 30: 35-72.

Thompson J. & Nicholson H.A. (1876) - Contribution to the study of the chief generic types of the Palaeozoic corals. *Ann. Mag. Nat. Hist.*, Series 4, 17(6): 451-462.

Wagner R. H., Winkler Prins C.F. & Granados L.F. (1985) - The Carboniferous of the World, II Australia, Indian Subcontinent, South Africa, South America & North Africa. 447 pp., Instituto Geológico y Minero, Madrid.

Yu C.C. (1934) - Lower Carboniferous corals of China. *Palaeontologica Sinica*, 12(3) (1933): 1-211.