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LATE DEVONIAN-TOURNAISIAN CONODONTS FROM THE EASTERN KHYBER REGION, NORTH-WEST PAKISTAN

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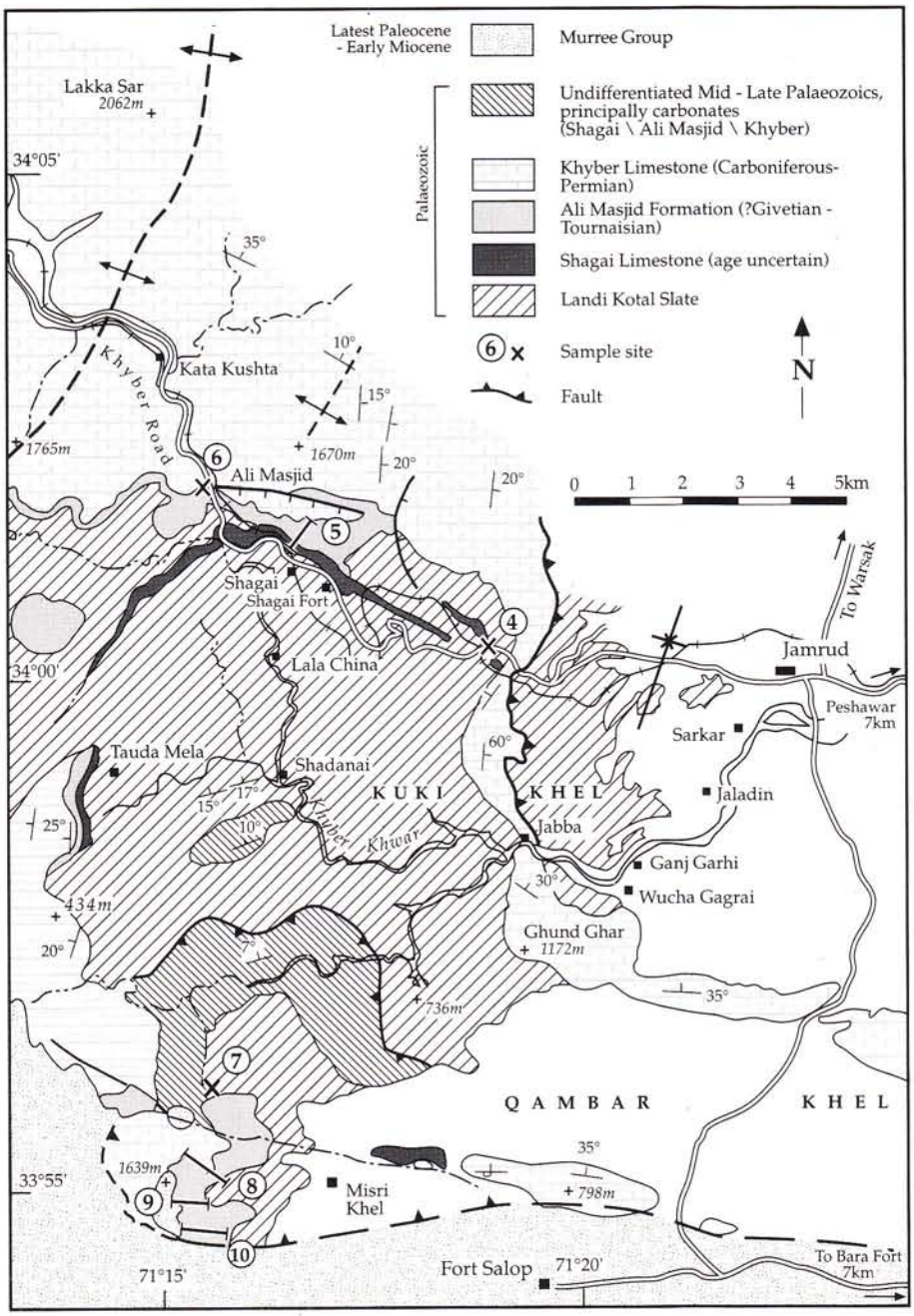

Fig. 1 - Geology of the south-eastern part of the Khyber region, North-West Frontier Province, Pakistan, simplified from an air-photo interpretation of the geology by (Stauffer, 1968a) with minor modification from subsequent traverses (Shah et al., 1980). Location of sampled sections provided by S.M.I. Shah.

Key-words: Conodonts, biochronology, South Khyber Agency, northwest Pakistan, Late Devonian, Frasnian, Famennian, Early Carboniferous, Tournaisian.

Riassunto. Vengono illustrate in questo articolo 26 tra specie e sottospecie di conodonti provenienti da 226 campioni raccolti lungo 4 sezioni stratigrafiche misurate nella Ali Masjid Formation nella South Khyber Agency del nord-ovest Pakistan e ne viene documentata la distribuzione.

Tali dati indicano che, almeno nell'area considerata, l'unità in questione è distribuita tra la Middle *crepida* Zone (Famenniano inferiore) sino ad almeno la Early *crenulata* Zone (Tournesiano medio): Tuttavia una fauna nella parte inferiore di una sezione ha prodotto conodonti indicativi della Late *falsiovalis* Zone (Frasniano inferiore). Vengono ipotizzate due lacune maggiori, la prima tra la Late *falsiovalis* Zone e la Middle *crepida* Zone, e tra la Late *expansa* Zone e la Early *duplicata* Zone. La distribuzione dei conodonti si accorda bene con le correlazioni litostratigrafiche tra le sezioni misurate.

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Abstract. Conodonts (62 species and subspecies) from acid-leaching of 226 samples from four sections through the Ali Masjid Formation west of Misri Khel in the former South Khyber Agency, north-west Pakistan, are documented by illustrations and distributional data. These indicate that most of this unit, at least in that area, spans the interval Middle *crepida* Zone (low in the Famennian) to at least Early *crenulata* Zone (mid-Tournaisian), though a fauna from low in one of the sections produced conodonts indicative of the Late *falsiovalis* Zone (early Frasnian). Two major hiatuses are inferred: between the Late *falsiovalis* and Middle *crepida* zones, and between the Late *expansa* and Early *duplicata* zones. Coherence of the conodont biostratigraphy accords with lithologic alignments between the sections.

Introduction.

This report constitutes the first documentation of Late Devonian conodont faunas from Pakistan. Conodonts of this age have been reported from several localities in north-western Pakistan (Talent et al., 1982; Pogue et al., 1992) and adjacent Afghanistan (K.J. Müller in Dürkoop et al., 1967, and in Dürkoop, 1970) but no documentation of these faunas has been presented. Late Devonian conodonts have been reported from several localities in India and Nepal and, though documentation was presented, all reports have been demonstrated to be spurious, and to have been based on North American material (see Talent et al., 1988; Talent, 1989).

The sampled sections forming the basis of the present report are located in the south-eastern part of the former Khyber Agency in the border regions of the North-West Frontier Province of Pakistan, close to the Afghan border (Figs 1, 2). That the geology and palaeontology of the former Khyber Agency was neglected was primarily due to the region being prone to pay-back homicide and, on occasion, protracted inter-communal blood-feuds. It is a region where tribal law and the dictates of local patriarchs (*maliks*) take precedence over the law of Pakistan. Though a region where honour and bloodshed are interwoven, it is also an area where, under appropriate auspices, the traveller may be the focus of hospitality rarely equalled elsewhere in the world. Limestone boulders up to 250-500 kg with Permian (or "Permo-Carboniferous") and\or "lower Silurian" fossils were long known to occur in watercourses west of Peshawar, particularly in the vicinity of Jamrud (Fig. 1); the boulders were assumed to have been derived from farther west in the southern Khyber region (Vicary, 1851, p. 45; Oldham, 1893, p. 141; Hayden, 1900, p. 111; Shah et al., 1980, pp. 7, 8). That the Permian (or "Permo-Carboniferous") boulders may have come from the Bazar valley, from outcrops now referred to the Khyber Limestone, had already been suggested by Hayden (1900). It was not until 1968 that the source of boulders bearing Devonian fossils was identified as a Devonian (late Givetian-Famennian)-Early Carboniferous (Tournaisian) sequence now referred to as the Ali Masjid Formation (or Group), specifically occurrences in the mountains west of Tauda Mela and Misri Khel (Fig. 1), about 13 km west-southwest and south respectively of Jamrud (Shah, 1969; Shah et al., 1980). The occurrence west of Misri Khel is the primary focus of this report. It falls within K.W. Stauffer's (1968a) air-photo interpretation of the geology of the Khyber region *sensu lato*; this represented a fundamental advance in knowledge of the geology of the region. There had been only two prior

PLATE 1

Fig. 1 a,b - *Apatognathus varians varians* Branson and Mehl. SB27. MU 15045. With a lateral limb and incomplete apical denticle. Respectively oblique lateral view showing flared outer margin of the basal cavity and outer view; x 80.

Fig. 2 - *Apatognathus varians varians* Branson and Mehl. SB27. MU 15047. With broken lateral limb, inner view showing *en echelon* denticle arrangement and long outer margin of basal cavity; x c.120.

Fig. 3 - *Apatognathus varians varians* Branson and Mehl. SB27. MU 15046. With a broken lateral process in oblique view showing tall apical denticle; x 80.

Fig. 4 a,b - *Apatognathus varians klapperi* Druce. SB27. MU 15048. With distal portion of both lateral processes broken. Respectively inner lateral view showing bi-cuspid apical denticulation and a single row of denticles on left process and outer view showing small denticle inserted between main cusp and enlarged lateral denticle; x 80.

Fig. 5 - *Bispathodus stabilis* Branson and Mehl. SM29C. MU 15064. With large basal cavity and slightly depressed posterior tip, in lateral view; x 45.

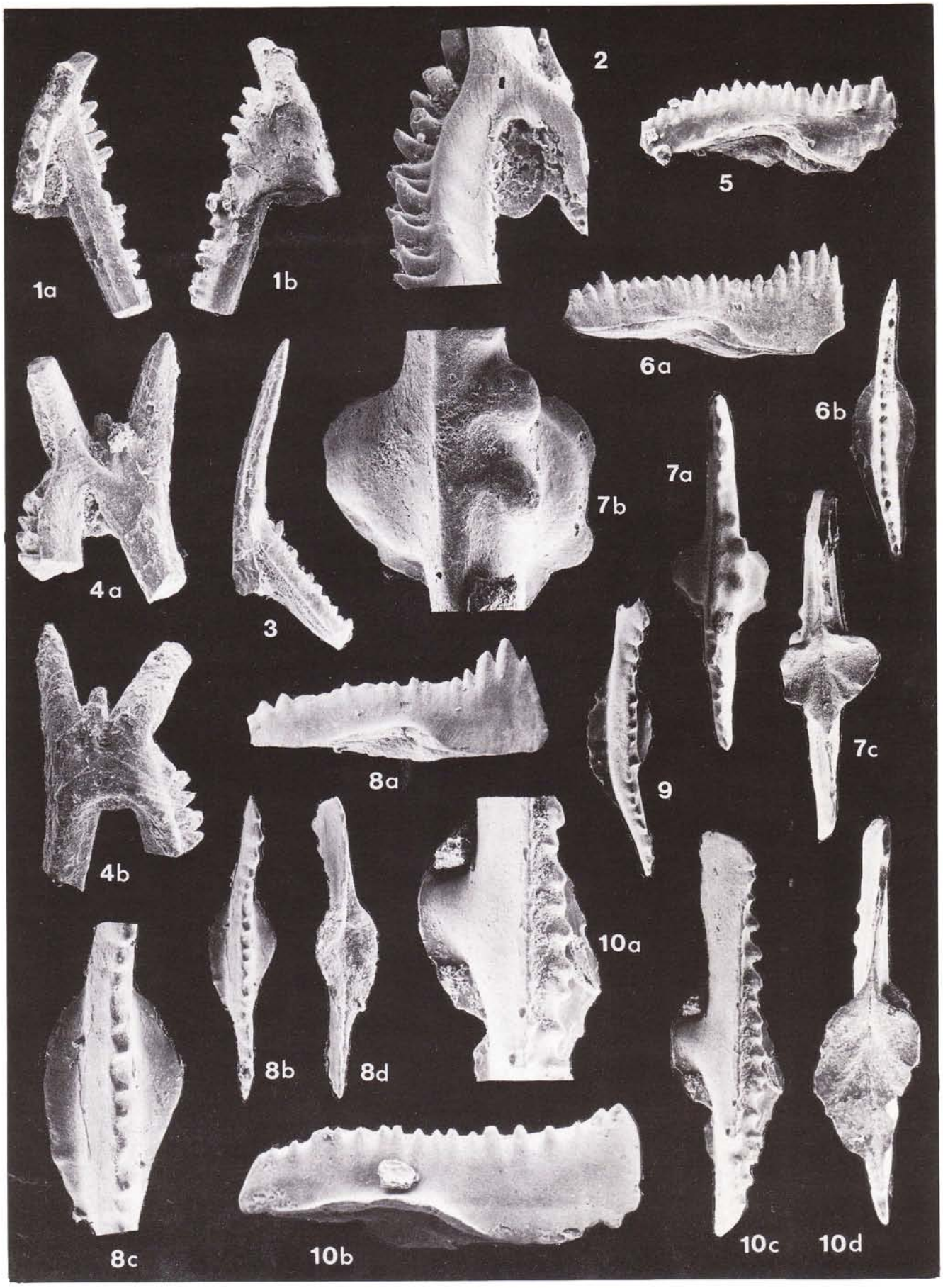
Fig. 6 a,b - *Bispathodus stabilis* Branson and Mehl. SM19. MU 15065. Showing single row of denticles. Respectively inner lateral view and upper view; x 45.

Fig. 7 a,b,c - *Bispathodus aculeatus aculeatus* Branson and Mehl. SM46. MU 15049. Large specimen with small flared basal cavity located radially. Respectively upper view, enlargement of basal cavity area in upper view and lower view; x 30, x c.90, x 30.

Fig. 8 a,b,c,d - *Bispathodus bispathodus* Ziegler, Sandberg and Austin.Transitional specimen. SM28. MU 15058. Showing early development of lateral denticles. Respectively lateral view, upper view, enlargement of upper surface above basal cavity showing development of lateral denticles confined to this part of the upper surface and lower view; x 45, x 45, x c.120, x 45.

Fig. 9 - *Bispathodus bispathodus* Ziegler, Sandberg and Austin. SB41. MU 15059. With development of denticles on right side above basal cavity, upper view; x 45.

Fig. 10 a,b,c,d - *Bispathodus costatus* Branson. SM41A. MU 15060. Respectively enlargement of basal cavity showing ridge-like development of denticles in main row, upper view, lateral view, upper view showing denticles on right side extending to posterior extremity and lower view showing large *B. bispathodus*-type cavity; x 90, x 30, x 30, x 30.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works of significance, both without maps, reporting on traverses in connection with major military expeditions of punitive nature: Griesbach (1892) and Hayden (1900). For reasons of personal safety, Stauffer had been refused permission by the relevant authorities, including the Political Agent Khyber, resident in Peshawar, to venture more than one chain (about 20 m) from either side of the Khyber Road; this is a condition which has long applied to all travellers passing along the highway from Jamrud west to the Afghan border. Exposures along the highway were thus the only basis for Stauffer's commendable interpretation of the stratigraphy and structure of the region away from the road. We anticipate that ground checking additional to the reconnaissance traverses by Griesbach (1892), Hayden (1900), Shah & Siddiqui (in Shah et al., 1980), and by Tahirkheli et al. (1975), the last mainly west of the area shown in Fig. 1, may result in appreciable changes to mapped boundaries in many areas.

Devonian limestones are well exposed in the vicinity of Gundhai Sar, 4-6 km north of Jamrud but, because of a homicidal inter-communal feud over rights to quarry limestone, it was not possible to visit and sample this occurrence during field work in Pakistan in the early 1970s. However, with an armed escort provided by the Political Agent Khyber, the area was mapped and a substantial stratigraphic sequence (>1000 m) was demonstrated (Khan, 1969, 1970; Khan et al., 1970). Six stratigraphic units have been proposed, all included within the Ali Masjid Group (Khan, 1970). At least some of the Gundhai Sar sequence has lithologic and apparently macrofaunal similarities to the Early Devonian (Lochkovian-?Pragian) Nowshera Limestone, outcropping about 50 km east of Peshawar (Ali & Anwar, 1969; Stauffer, 1967, 1968b; Talent & Mawson, 1979, p. 85; Molloy, 1979; Pogue et al., 1992) and, like some horizons in the latter, has an abundance of the twig-like tabulate coral *Cladopora* as well as *Thamnopora*, *Favosites* and *Heliolites*. However, a spot sample of crinoidal limestone overlying the main limestone development in the vicinity of Gundhai Sar, perhaps from the Warran Ghundai Formation of Khan (1970), has now been reported (Pogue et al., 1992, tab. 1, no. 22) to have produced conodonts indicative of the late Famennian *expansa* Zone; that horizon at least is therefore coeval with part of the Misri Khel sequence on which our report is focussed. The tabulate corals cited from Gundhai Sar are not compelling as to age within the Devonian; it is therefore conceivable that the entire sequence at Gundhai Sar is in fact Ali Masjid Formation (or Group). Bed-by-bed sampling for conodonts in that area is clearly desirable.

Samples for this study were collected between 1969 and 1973. In 1970, S.M.I. Shah and J.A. Talent searched for macrofossils and collected samples from typical exposures of the Landi Kotal Formation, Shagai Limestone, Ali Masjid Formation and Khyber Limestone along the Khyber Road and, accompanied by a trio of tribal gunmen, collected samples from north and south of the road in the Ali Masjid-Shagai Fort-Lala China area. In 1972, Shah and R.A. Siddiqui, who had already undertaken reconnaissance traverses in the Khyber area (Shah et al., 1980), collected samples from 4 stratigraphic sections (Fig. 2) in the outcrop-tract of Devonian-Early Carboniferous rocks west of Misri Khel. An unpublished dissertation by Molloy (1979) focussed mainly on conodont data from samples from the Khyber area, including those from west of Misri Khel; the present report is an up-date of Molloy's study.

Stratigraphic context.

Four pre-Mesozoic stratigraphic units are currently recognised in the Khyber region (Fig. 1; Shah et al., 1980); all of these were sampled for the present report.

1. *Landi Kotal Formation* (Stauffer, 1968a; Shah, 1977; Shah et al., 1980; ?= Lala China Slatey Shales of Tahirkheli et al., 1975). This, the oldest unit in the region, consists predominantly of greenish grey slates and phyllites with subordinate quartzites and lenticular limestones and dolomites; basic dykes are frequent. Neither conodonts nor macrofossils were obtained from many spot samples (location of 2 of these specified in Fig. 3) from the Landi Kotal Formation collected along and in the vicinity of the Khyber Road, though Shah (in Shah et al., 1980) reported "poorly preserved crinoid stems, and trace fossils" from an unspecified locality in the Khyber region. The structure and stratigraphic sequence are not sufficiently well known in the Khyber area to usefully hypothesize alignments between the Landi Kotal Formation and the Late Proterozoic to Silurian stratigraphic units in the Attock-Cherat Range (Hussain et al., 1990; Pogue et al., 1992), 30-70 km south-east and east of Khyber area, or with the nearest comparable stratigraphic sequence from which fossils have been reported to the west, the Logar Formation in Afghanistan, about 220 km east of Fig. 1. Fossils from the Logar Formation indicate an age-span of Ordovician-Silurian age; conodonts from one horizon are indicative of a Late Silurian (Ludlow but not latest Ludlow) age (Fesefeldt, 1964; Dürkoop, 1970). A convenient summary of fossils known to date from central and southern Afghanistan has been given by Weippert et al. (1970).

2. *Shagai Limestone* (Stauffer, 1968a; Shah, 1977; Shah et al., 1980). The stratigraphic position of this apparently persistent unit of up to 33 m of limestones and

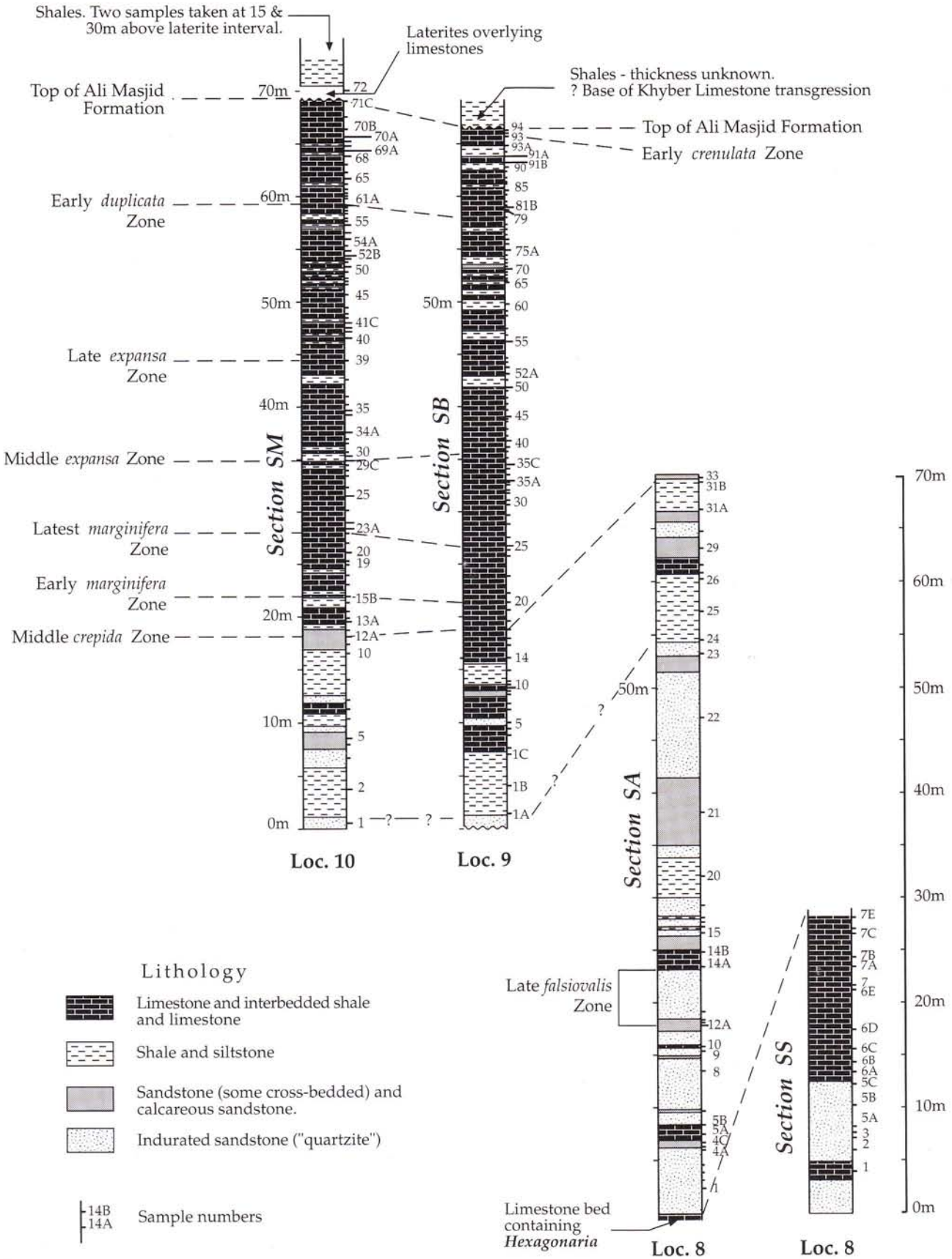


Fig. 2 - Sampled sections through the limestone-shale-sandstone sequence west of Misri Khel, Khyber region. Horizons producing conodonts are indicated by a number; horizons which failed to produce conodonts are without numbers.

	LOCALITY (Refer to Fig. 1)	SAMPLES	AGE DETERMINATION
Ali Masjid Fm (Misri Khel area)	Loc. 8: SS section	12	At SS7D: Fragments of *Icriodus* and *Polygnathus*
	Loc. 8: SA section	22	At 12A, 12B, 14A: Late *falsiovalis* Zone At 31B: Middle *crepida* Zone
	Loc. 9: SB section	101	At 17: Middle *crepida* Zone At 20: Early *marginifera* Zone At 25: Latest *marginifera* Zone At 35A: Early *expansa* Zone At 38: Middle *expansa* Zone At 79: Early *duplicata* Zone At 93: Early *crenulata* Zone
	Loc. 10: SM section	91	At 12A: Middle *crepida* Zone At 15B: Early *marginifera* Zone At 19: Late *marginifera* Zone At 23A: Latest *marginifera* Zone At 29C: Middle *expansa* Zone At 39: Late *expansa* Zone At 61A: Early *duplicata* Zone At 71C: Early *crenulata* Zone
Landi Kotal Fm.	Loc. 4: 5 km west of Jamrud	1	Barren
	Loc. 7: Misri Khel Nala	1	Barren
Shagai Ls. and Ali Masjid Fm. (type areas)	Loc. 5: Type loc. for Shagai Ls. 1 km N.W. of Shagai Fort	14	Barren
	Loc. 6: 1.5 km N.W. of Shagai Fort	2	Barren

Fig. 3 - Summary of results obtained from sampling for conodonts in the south-eastern part of the Khyber region.

dolomites is problematic. We are inclined to the opinion that most of it may be regarded as an unusually persistent unfossiliferous carbonate lens within the Landi Kotal Formation. Neither conodonts nor macrofossils were obtained from the many samples from the Landi Kotal Formation collected along and in the vicinity of the Khyber Road, though Shah (in Shah et al., 1980) reported "recrystallised brachiopod shells" from limestones referred to the Shagai Limestone west of Tauda Mela. Stauffer (1967) suggested a Devonian age for the Shagai Limestone and a ?Carboniferous age for the Ali Masjid Formation; Jan and Kempe (1970) suggested an Early to Middle Silurian age for the Shagai Limestone, regarding it as older than the Early Devonian (Lochkovian and ?Pragian) Nowshera Limestone (Stauffer, 1968b; Ali & Anwar, 1969), whereas Shah et al., (1980) suggested stratigraphic alignment of the Shagai Limestone with the Nowshera Limestone. The age of the Shagai Limestone remains problematic.

3. *Ali Masjid Formation* (Stauffer, 1967, 1968a; Khan, 1970; Shah, 1977; Shah et al., 1980). This unit

PLATE 2

Fig. 1 a,b,c - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM49. MU 15051. With ridge developed on left side above basal cavity margin. Respectively lateral view, upper view and lower view showing widened basal cavity margin on one side; x 45.

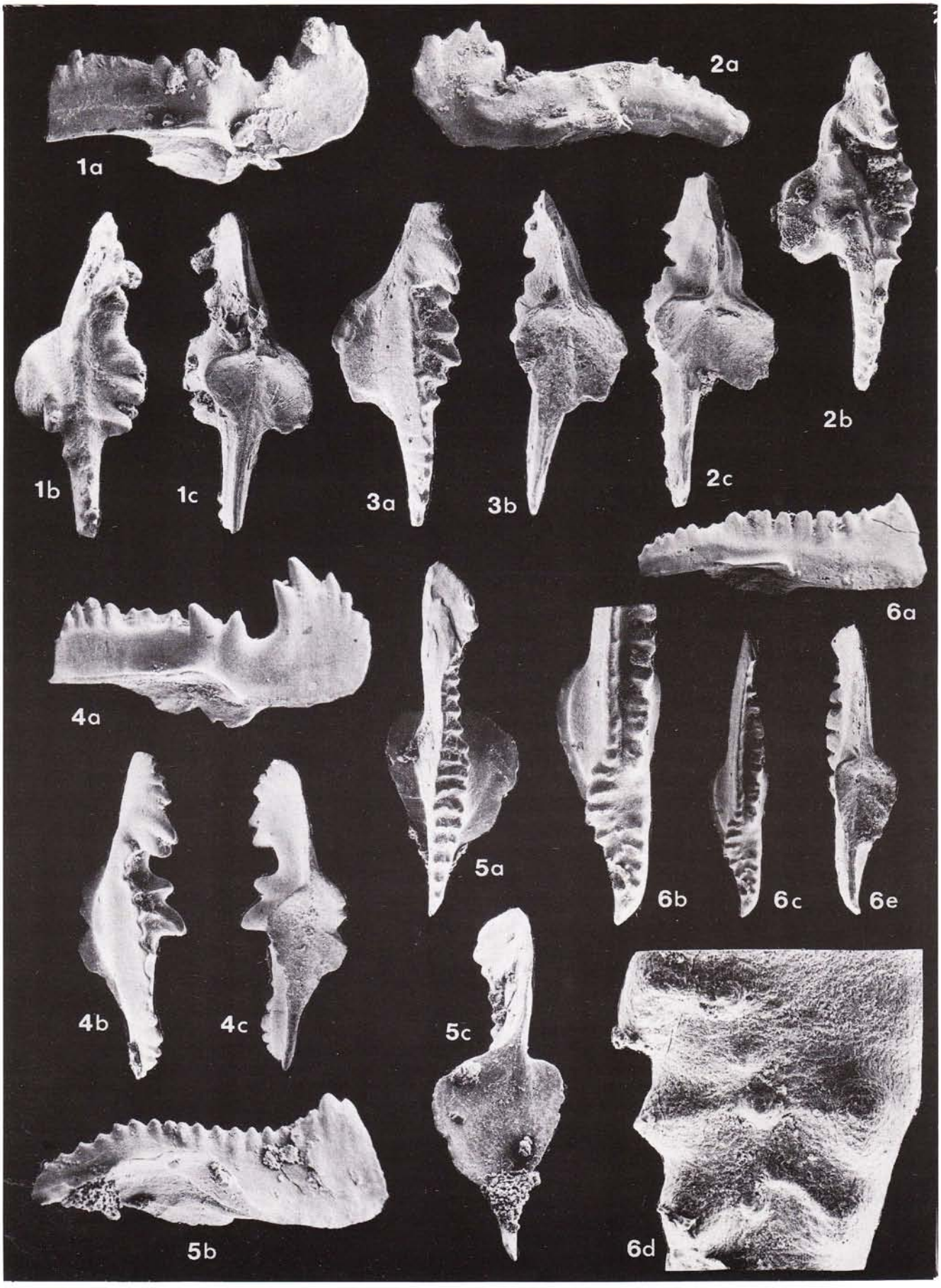
Fig. 2 a,b,c - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SB57A. MU 15053. Form transitional to *Clydagnathus*. Respectively lateral view showing typical clydagnathid-type anterior blade, upper view showing offset of anterior crest toward right-hand margin but lacking denticulation of main blade near crest and lower view; x 30.

Fig. 3 a,b - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM41A. MU 15052. Typical specimen (see Pl. 3, Fig. 1). Respectively upper view, lower view showing widened cavity margin on one side, x 45.

Fig. 4 a,b,c - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM41A. MU 15054. Broken specimen with two denticles on the right side. Respectively lateral view with typical plume-like denticulation of anterior blade, upper view and lower view; x 45.

Fig. 5 a,b,c - *Bispathodus* cf. *jugosus* Branson and Mehl. SM39. MU 15063. Specimen with extremely wide basal cavity extending to posterior tip. Respectively upper view showing right side denticles extending to posterior extremity, lateral view and lower view; x 45.

Fig. 6 a,b,c,d,e - *Bispathodus jugosus* Branson and Mehl. SM41A. MU 15062. With middle row of denticles in posterior third. Respectively lateral view, enlargement of posterior upper half, upper view, enlargement of posterior upper surface showing median row of nodes and lower view; x 30, x c. 60, x 30, x 150, x 30.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consists of a maximum thickness in excess of 200 m of conspicuously red with subordinate brown, grey and white shale, siltstone and limestones. Lateritic horizons, apparently representing diastems are present, notably in the sampled sections west of Misri Khel and near Shagai Fort. Correlation from area to area of outcrop-tracts has been by lithologic similarities and by photo-interpretation occurrences. The designated type locality for the Ali Masjid Formation is a few hundred metres north of Shagai Fort (Loc. 5, Fig. 1), but the formation is well exposed in cuttings on the Khyber Road in the vicinity of Ali Masjid mosque (Loc. 6). Samples from those localities failed to produce conodonts. There is thus some reservation about applying the name Ali Masjid Formation to all outcrop-tracts so designated in previous work. As noted earlier, a spot sample from the limestone-shale-quartzite sequence in the vicinity of Gundhai Sar, 5 km north of Jamrud, outside the area shown in Fig. 1, has produced conodonts indicative of the late Famennian *expansa* Zone (Pogue et al., 1992). At least some of the Gundhai Sar sequence therefore is coeval with the Misri Khel sequence considered here. This provides support for use of the same name, Ali Masjid Formation, for intervening outcrop-tracts previously referred to as Ali Masjid Formation, including the palaeontologically disappointing stratotype section (Stauffer, 1968a; Shah et al., 1980).

4. *Khyber Limestone* (Stauffer, 1968a; Shah, 1977; Shah et al., 1980). This scenically striking unit of 900-1200 m or more of predominantly pale grey, fine- to coarse-grained, sometimes oolitic limestones with subordinate thick-bedded (3-9 m) white dolomites with minor lenses of shale and red quartzite rests unconformably over the Landi Kotal Formation but in some areas appears to pass gradationally upwards from the Ali Masjid Formation, or to rest on it with very low unconformity, for example on the Khyber Road just west of Ali Masjid mosque. A lateritic zone (0.9-2.4 m) at the base of the Khyber Limestone near Misri Khel and near Shagai village suggests a diastem between the Ali Masjid Formation and Khyber Limestone in those areas (Shah et al., 1980, p. 22); limonitic horizons within the Khyber Limestone may include diastems reflecting onlap and offlap during accumulation of the Khyber Limestone. No macrofaunas have been documented from either the Khyber region or the adjacent Tirah area to the west. However, Late Permian foraminifers have been reported from "near Shagai village" (G. Tunger in Shah et al., 1980), and brachiopods, indicating correlation with the Wargal Formation (formerly Middle *Productus* Limestone) of the Salt Range have been reported (Hayden, 1900) from Khyber Limestone in the normally politically inaccessible Bazar valley\Chora valley area 11-14 km west of Tauda Mela (Fig. 1). The Wargal Formation is now regarded (Kapoor, 1992; N.W. Archbold pers. comm.) as being late Kazanian-Midian (Late Permian). Thus the Khyber Limestone can be construed as embracing some if not most of Permian time and conceivably much of Carboniferous time, at least post-*duplicata* Zone, but there is no compelling evidence for this.

PLATE 3

Fig. 1 a,b,c - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM41A. MU 15052. Typical specimen with plume-like denticulation of blade and five denticles on right side, not extending to posterior. Respectively lateral view, upper view and lower view; x 45.

Fig. 2 a,b,c - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM52C. MU 15055. Specimen with three denticles on right side. Respectively lower view showing basal cavity not extending to posterior end, oblique upper view showing incipient denticle or ridge development on left side of blade and enlargement of basal cavity area in upper view; x 45, x 45, x c. 80.

Fig. 3 a,b - *Bispathodus aculeatus plumulus* Rhodes, Austin and Druce. SM39. MU 15056. Broken specimen with single denticle on each side of blade. Respectively lateral view of left side, enlargement of basal cavity area showing peg-like denticle on right side; x 45, x c.80.

Fig. 4 - *Icriodus* cf. *subterminus* Youngquist. SA14A. MU 15081. Upper view showing weak development of middle row denticles; x 80.

Fig. 5 - *Icriodus* cf. *subterminus* Youngquist. SA14A. MU 15082. Upper view showing weak development of middle row denticles in posterior portion; x 80

Fig. 6 - *Icriodus* cf. *alternatus alternatus* Branson and Mehl. SB14. MU 15086. Juvenile specimen upper view; x 120.

Fig. 7 a,b - *Icriodus* cf. *subterminus* Youngquist. SA14A. MU 15083. Respectively upper view showing laterally compressed middle row of denticles in posterior portion, lower view; x 80.

Fig. 8 a,b - *Icriodus* cf. *subterminus* Youngquist. SA14A. MU 15084. Respectively lateral view and lower view; x 80.

Fig. 9 - *Icriodus* cf. *subterminus* Youngquist. SA14A. MU 15085. Lateral view showing reduced size of two posteriormost denticles of median row; x 120.

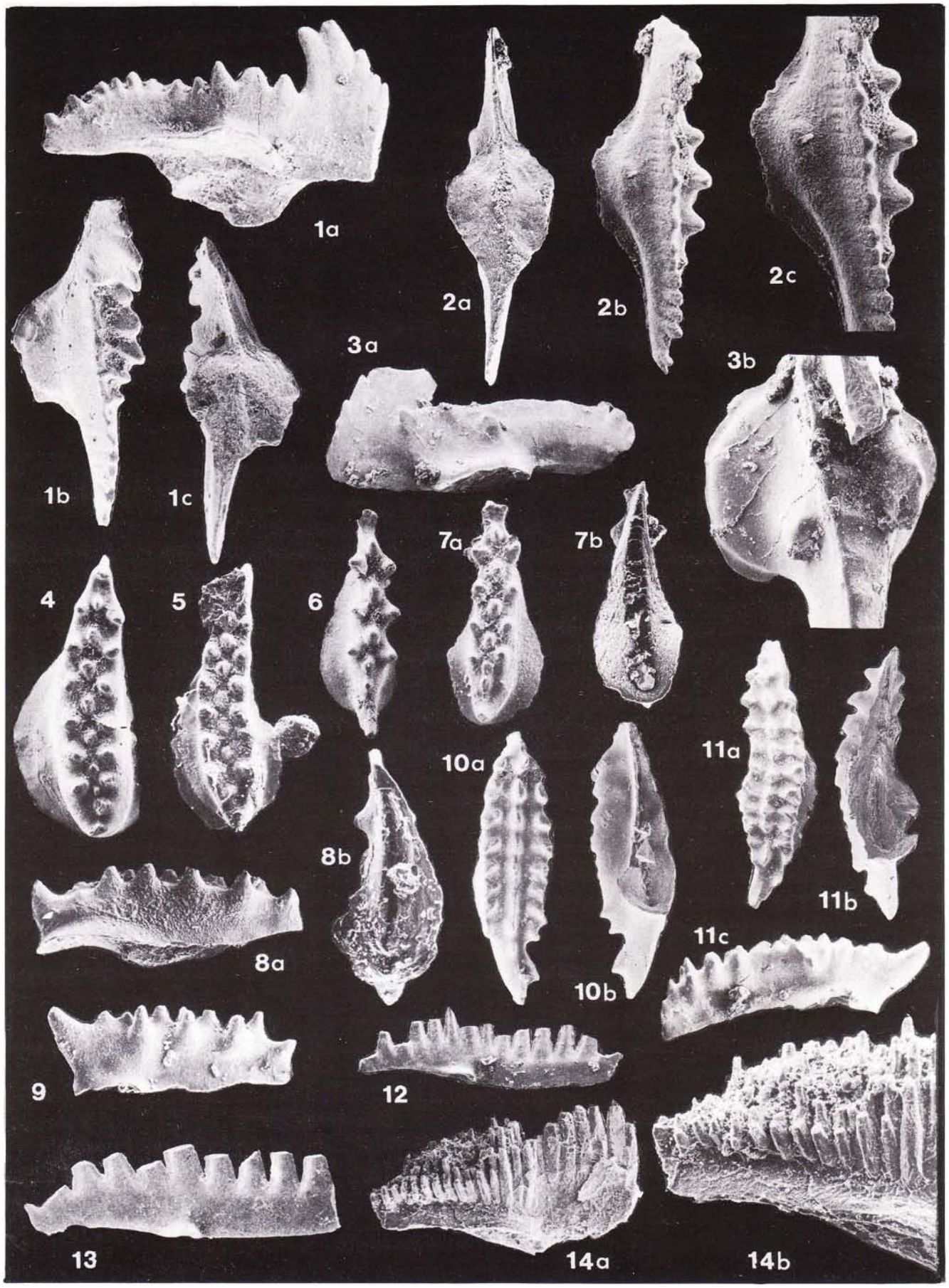
Fig. 10 a,b - *Icriodus* cf. *raymondi* Sandberg and Ziegler. SM41A. MU 15087.Specimen with broken basal cavity margin. Respectively upper view showing horn-like main cusp and ridge-like development of median row denticles and lower view; x 45.

Fig. 11 a,b,c- *Icriodus* cf. *raymondi* Sandberg and Ziegler. SB57A. MU 15088. Upper view showing horn-like main cusp and lateral denticles aligned with, and connected to, median row denticles, lower view and lateral view showing arched lower margin; x 45.

Fig. 12 - *Mehlina* sp. A. SM23A. MU 15175. Lateral view showing basal cavity in posterior third; x 45.

Fig. 13 - *Mehlina* sp. A. SM41A. MU 15176. Lateral view showing sharp anterior and posterior edges on all denticles; x 80.

Fig. 14 a, b - *Polygnathus diversus* Helms. SB32. MU 15180. Respectively lateral view showing high anterior blade and brush formation on right side of unit, enlargement of brush-like denticles, x 120, x 250.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Conodont data and age-inferences.

The four stratigraphic sections sampled in vicinity of Misri Khel bear the field rubrics SS, SA, SB and SM sections (Figs 1-3). Acid-leaching 226 samples from these sections produced over 1100 conodonts representing 62 species and subspecies. Because no new species were encountered during this investigation, and because recent synonymies are available for the species encountered (e.g. Ji & Ziegler, 1993; Mawson & Talent, 1997), the faunas are illustrated but no taxonomic treatment is presented. Conodont genera mentioned in the text and on Tables 1-3 are abbreviated as follows: *Alt. = Alternognathus; Ap. = Apatognathus; Bi. = Bispathodus; Br. = Branmehlia; I. = Icriodus; M. = Mehlina; P. = Polygnathus; Pal. = Palmatolepis; Pel. = Pelekysgnathus; Ps. = Pseudopolygnathus; S. = Scaphignathus; Si. = Siphonodella.*

In recent years the conodont-based zonal scheme for the Late Devonian and the philosophies giving rise to differing opinions concerning the species concept and chronostratigraphy have been energetically debated (e.g. Johnson, 1992; Klapper, 1988; 1989; 1991, 1992; Klapper & Foster, 1993; Sandberg et al., 1988; Ziegler & Sandberg, 1988, 1990, 1992, 1994, 1996). For simplicity, the Late Devonian zonal scheme of Ziegler & Sandberg (1984, 1990) and Weddige (1996) and the Early Carboniferous zonal scheme of Sandberg et al. (1978) are used herein (Fig. 4). In some instances, a former zonal equivalent or approximate equivalent for the Late Devonian (*sensu* Ziegler, 1962, 1971) is quoted in square brackets after the zonal allocation, e.g. Early *rhenana* Zone [= Lower *gigas* Zone].

SS Section.

This section (Loc. 8, Fig. 1) began at the base of a quartzite unit and extended for 28.2 m to the top of a limestone horizon containing species of *Hexagonaria* (Fig. 3). All but one of the 12 samples collected proved barren. Sample SS7D, the uppermost sample, yielded fragments of *Icriodus* and *Polygnathus* indicating only a broad Emsian to Famennian age. The coral fauna from the *Hexagonaria* bed has been investigated by J.W. Pickett (pers. comm.); he considers the fauna to be late Givetian in age.

SA Section.

This section commenced at the *Hexagonaria* bed delineating the top of the SS section; it extended to a fault 112 m above the base of the section (Fig. 2). Of the 22 samples from the SA section, 5 yielded conodonts but only three (SA12A, SA12B and SA14A) produced forms that were sufficiently well preserved to be identified. Conodonts recovered from these horizons (Table 1) include *Icriodus* cf. *subterminus* Youngquist, *Polygnathus angustidiscus* Youngquist; *P.* cf. *alatus* Huddle, *P. unicornis* Müller & Müller, *P. webbi* Stauffer, *P. xylus xylus* Stauffer. Considered together, these indicate a very early Frasnian age (Late *falsiovalis* Zone [= late Lowermost *asymmetricus* and the earliest Lower *asymmetricus* zones]. Sample SA31B produced a specimen of *P. ?semicostatus* Branson & Mehl suggesting that horizon is no older than Middle *crepida* Zone.

PLATE 4

Fig. 1 a,b - *Palmatolepis minuta minuta* Branson and Mehl. SB14. MU15103. Respectively upper view showing shagreen-like surface ornament and lower view; x 80.

Fig. 2 a,b - *Palmatolepis rhomboidea* Sannemann. SB14. MU 15104. Specimen with broken posterior tip. Respectively lower view and upper view showing shagreen-like surface ornament; x 80.

Fig. 3 a,b - *Palmatolepis gracilis gracilis* Branson and Mehl. SM29C. MU 15102. Specimen with broken posterior extremity. Respectively oblique upper view and lower view; x 80.

Fig. 4 - *Pelekysgnathus inclinatus* Thomas. SB57B. MU 15105. Broken specimen with basal cavity infilled, lateral view; x 45.

Fig. 5 - *Pelekysgnathus inclinatus* Thomas. SM41A. MU 15106. Broken specimen in lateral view showing tall inclined apical denticle with striations; x 45.

Fig. 6 - *Pelekysgnathus inclinatus* Thomas. SB53. MU 15107. Lateral view with three denticles posterior of broken apical denticle; x 45.

Fig. 7 a,b - *Pelekysgnathus inclinatus* Thomas. SB38. MU 15108. Respectively lateral view and enlargement of posterior portion of basal cavity showing pit beneath apical denticle; x 45, x c. 120.

Fig. 8 - *Pelekysgnathus* sp. A. SB68. MU 15109. Lateral view showing short, inclined apical denticle with eight posterior denticles; x 45.

Fig. 9 - *Pelekysgnathus* sp. A. SM52A. MU 15110. Lateral view; x 45.

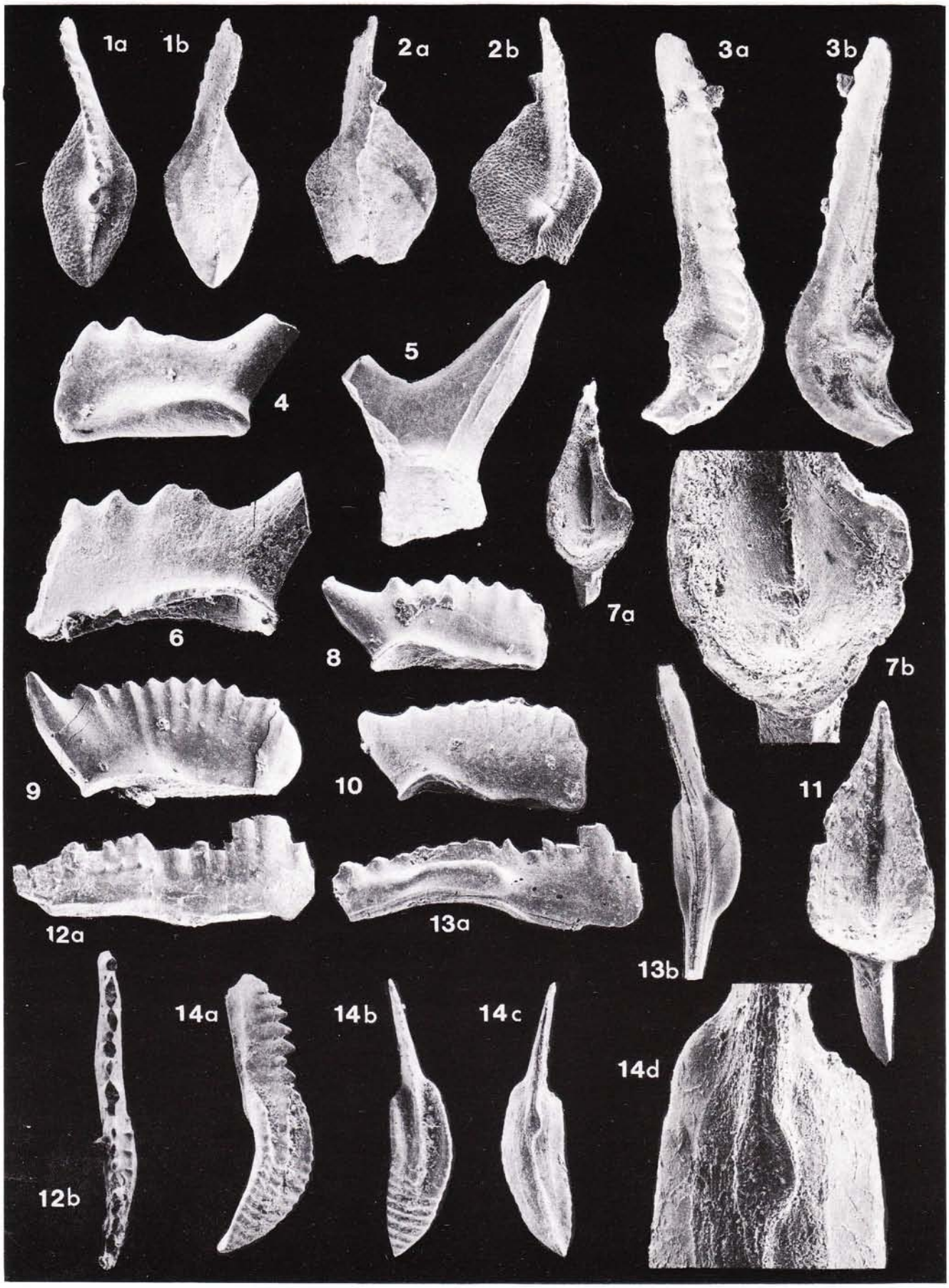
Fig. 10 - *Pelekysgnathus* sp. A. SB64. MU 15111. Lateral view; x 45.

Fig. 11 - *Pelekysgnathus* sp. A. SB57B. MU 15112. Lower view; x 80.

Fig. 12 a,b - *Alternognathus pseudostrigosus* (Dreesen and Dusar). SB14. MU 15153. Showing clear development of platform on right side of posterior margin. Respectively lateral view and upper view; x 45.

Fig. 13 a,b - *Polygnathus angustidiscus* Youngquist. SA12A. MU 15113. Respectively lateral view showing largest denticles near anterior tip and enlargement of denticles posterior of small platform and lower view with basal cavity near anterior margin of platform; x 45.

Fig. 14 a,b,c,d - *Polygnathus semicostatus* Branson and Mehl. SM12A. MU 15136. Respectively lateral view with anterior bar bearing eight denticles, upper view showing oblique transverse ridges across width of posterior third of platform and smooth anterior platform except for crenulated margins and lower view, enlargement of basal cavity showing flared inner margin; x 45, x 45, x 45, x c.120.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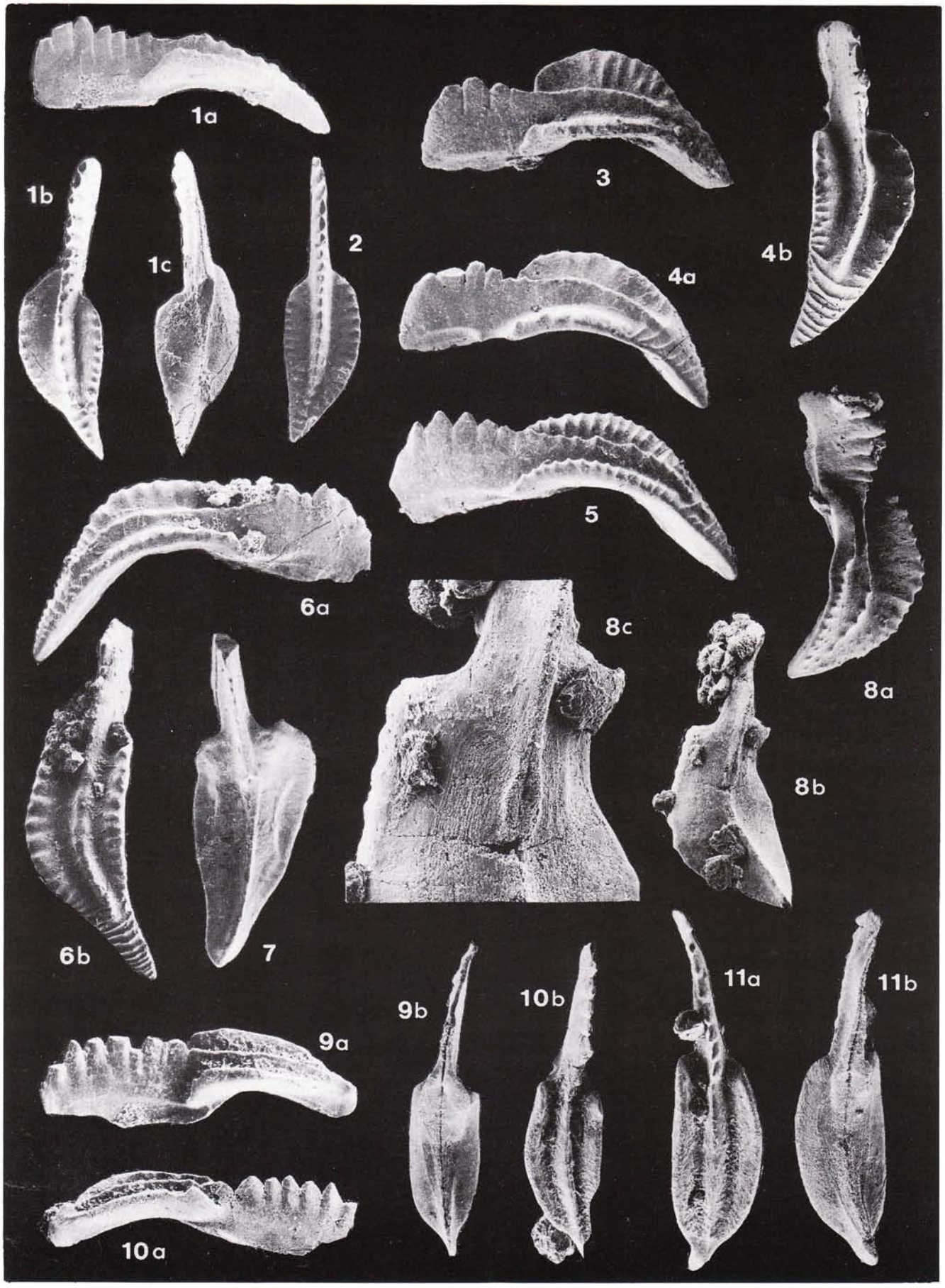
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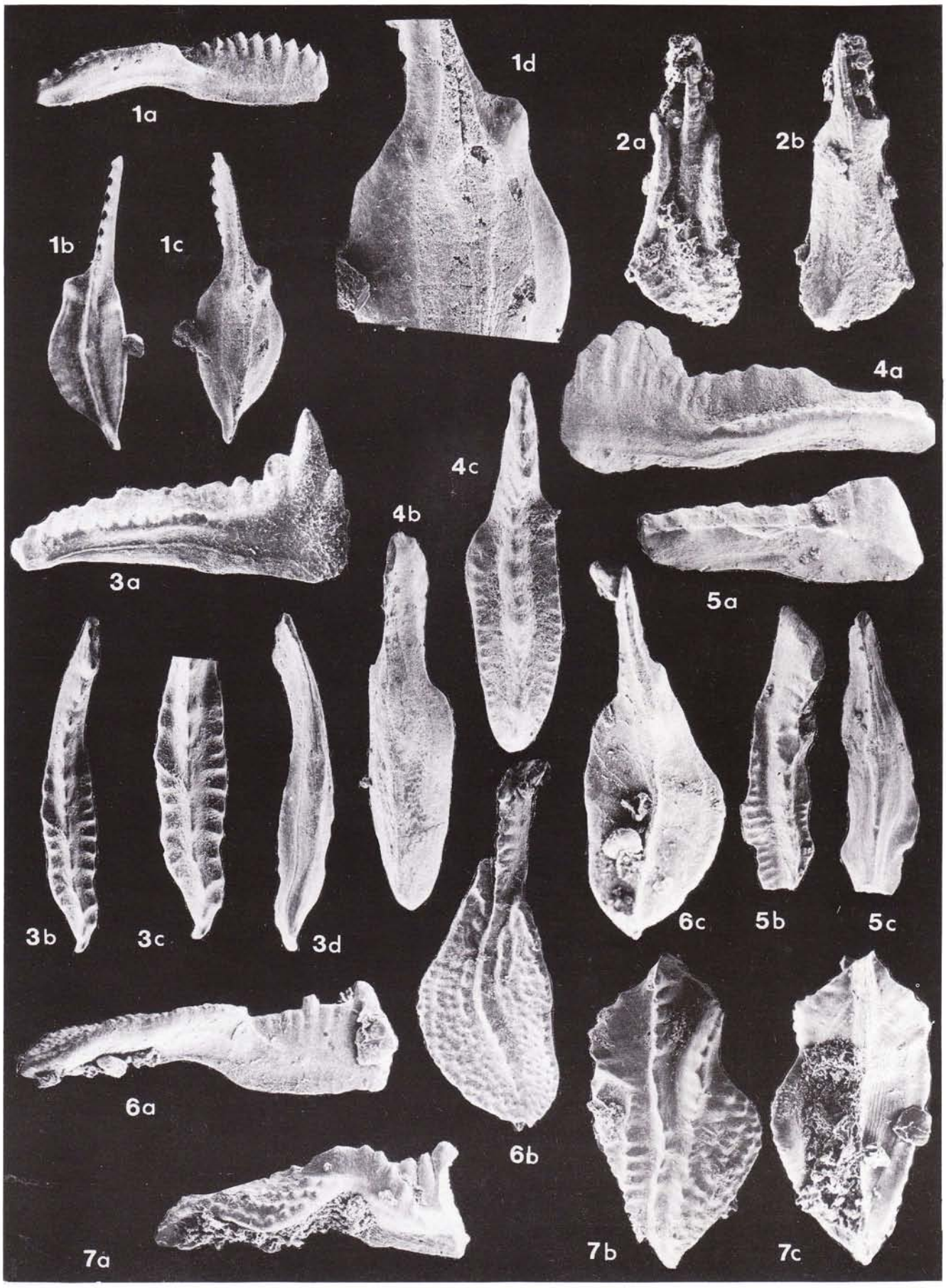
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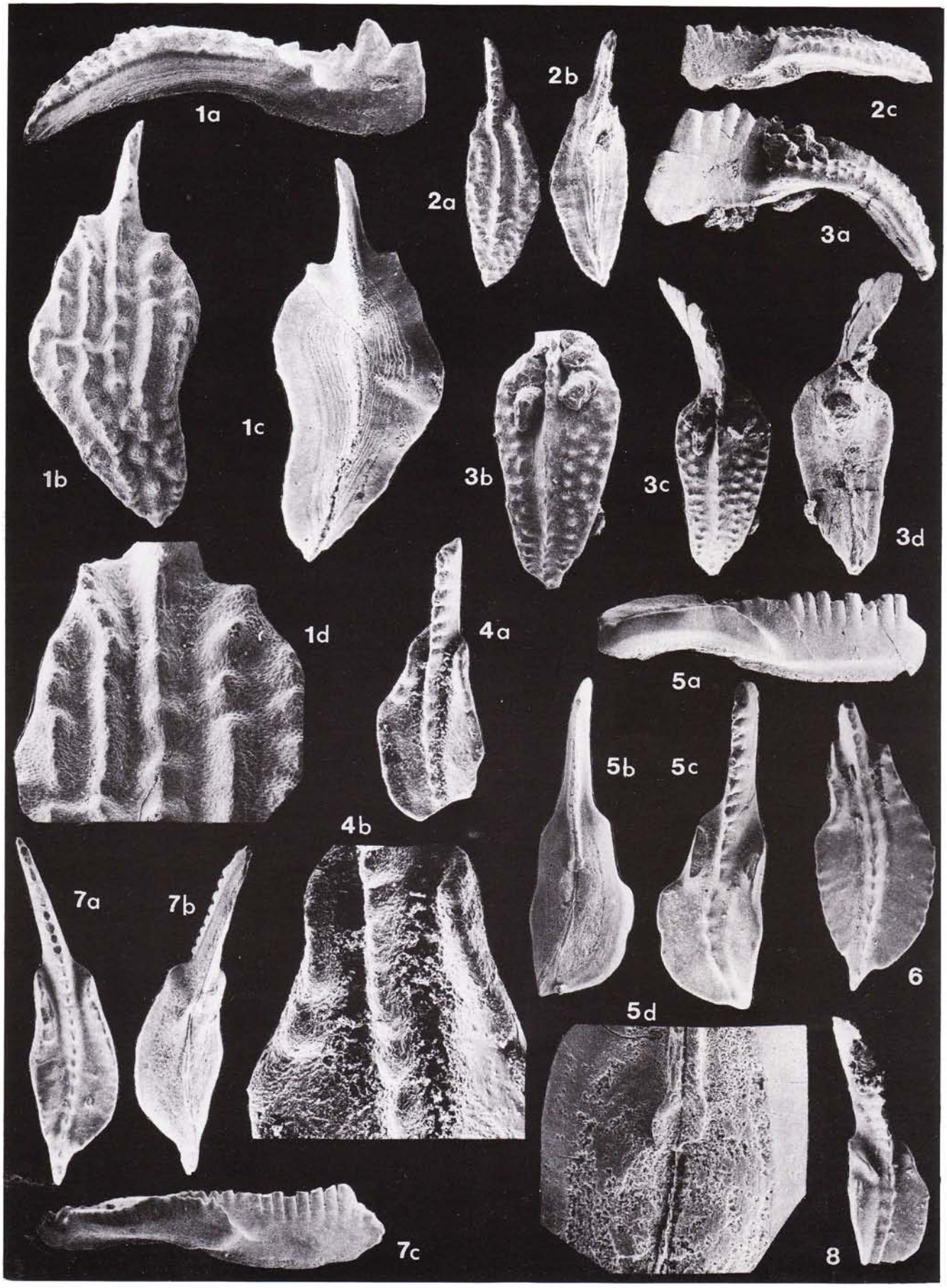
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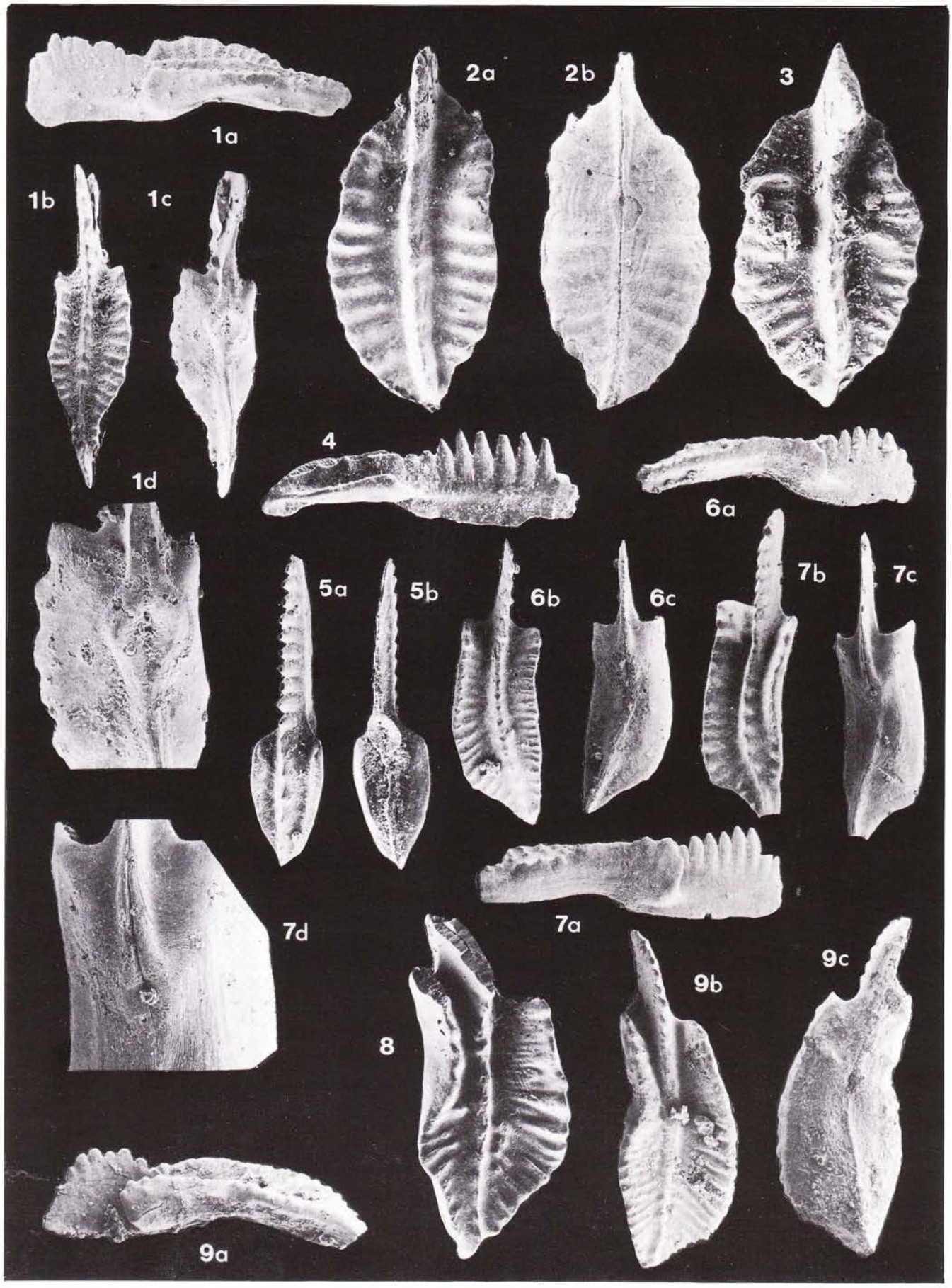
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7d
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9a
9b
9c

Conodont taxa \ SA section Sample No.		SA12A	SA12B	SA14A	SA21	SA31A	SA31B
Icriodus cf. *subterminus*		2	4	15			
Icriodus sp. indet.		X	X	X		X	X
Polygnathus angustidiscus		1					
Polygnathus komi		1					
Polygnathus unicornis				1			
Polygnathus webbi			1	1			
Polygnathus cf. *alatus*			1	3			1
Polygnathus xylus xylus		1	2	14			
Polygnathus sp. indet.				X	X	X	X
Unassigned elements	Pb					X	
	M	X		2			
	Sc		X	X			

Tab. 1 - Distribution of conodont taxa from productive horizons of section SA, Ali Masjid Formation.

occurrence of *Bispathodus aculeatus aculeatus* (Branson & Mehl) in SB38 gives a Middle *expansa* [= Lower *costatus*] age at this level. From SB38 there is a dearth of age-restrictive conodonts to SB79 where *P. inornatus* Branson & Mehl in the fauna indicates an age of at least Early *duplicata* Zone. The co-occurrence of *P. flabellus* Branson & Mehl and *Hindeodus crassidentatus* (Branson & Mehl) in SB93B gives an age of Early *crenulata* Zone for the top of the section.

SM Section.

The SM section (Figs 1, 2) parallels the SB section and is very similar to it both lithologically and biostratigraphically (cf. Tabs 2 and 3). SM12A yielded *I. alternatus alternatus* Branson & Mehl and *P. semicostatus* Branson & Mehl indicating a Middle *crepida* age. *P. pennatuloideus* Holmes in SM15B gives a maximum age of Early *marginifera* age for this horizon. Late *marginifera* Zone can be identified by the incoming of *Bispathodus stabilis* (Branson & Mehl) in SM19 while SM23A can be dated as Latest *marginifera* Zone because of the presence of *Scaphignathus velifer* Helms. Horizon SM29C must be at least Middle *expansa* Zone in age because of the occurrence of *Bi. costatus* E.R. Branson in the fauna and with the incoming of *Bi. aculeatus plumulus* Rhodes et al. in SM39, Late *expansa* Zone is represented. *Bi. jugosus* (Branson & Mehl) occurs in the fauna from SM41A and *Bi. spinulicostatus* (E.R. Branson) appears in SM41C, typical forms for Late *expansa* Zone. From SM41C to SM61A no conodonts diagnostic of age were recovered but in the latter *P. longiposticus* Branson & Mehl indicates an Early *duplicata* age. With *Siphonodella cooperi* Hass and *P. flabellus* represented in SM71C, this horizon must be no older than Late *duplicata* Zone and could conceivably range into the Early *crenulata* Zone.

Summary.

The four sections, considered in combination (Fig. 3), thus span the interval from Late *falsiovalis* Zone (early Frasnian) to Early *crenulata* Zone (mid-Tournaisian). However, there is no data indicative of zones in the interval between Late *falsiovalis* Zone and Middle *crepida* Zone; this interval is represented by about 47 m of sandstones or quartzites with subordinate shale and minor limestone for which no conodont data was obtained. We suggest a major hiatus is located somewhere in this interval. The dearth of conodonts between the Late *expansa* Zone and the Early *duplicata* Zone, an interval represented by about 15 m of limestones and shales, accords with another significant hiatus representing some or all of Early, Middle and Late *praesulcata* zones, as well as the *sulcata* Zone. Yazdi (1996) reports a similar

PLATE 9

Fig. 1 a,b,c - *Polygnathus rostratus* Rhodes, Austin and Druce. SM71B. MU 15131. Specimen transitional to *Siphonodella*. Respectively lateral view showing high anterolateral margin on right side, upper view showing development of lobe on left side margin and lower view showing indistinct keel and slight fold on lower surface at position of lobe; x 30.

Fig. 2 a,b - *Polygnathus rostratus* Rhodes, Austin and Druce. SM62. MU 15129. Pathogenic form. Respectively upper view with lobe-like development on right posterolateral margin and lower view showing interruption in growth lines on lower surface at point of lobe development and also at keel near posterior tip; x 30.

Fig. 3 - *Polygnathus corrugatus* Branson. SM71C. MU 15152. Encrusted specimen in upper view; x 30.

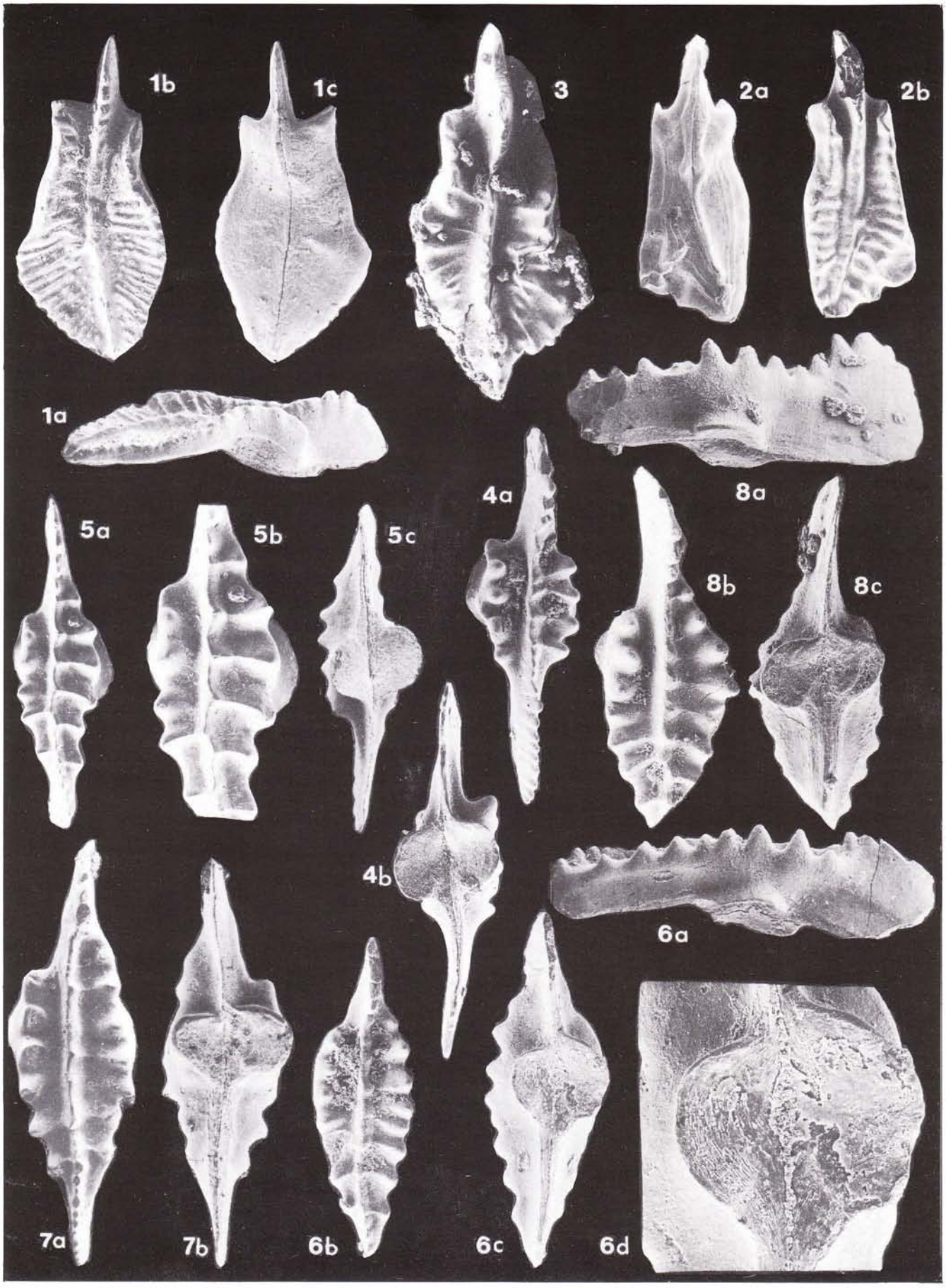
Fig. 4 a,b - *Pseudopolygnathus primus* Branson and Mehl. SM52C. MU 15157. With platform extending approximately two thirds of length of unit on right side. Respectively upper view and lower view; x 45.

Fig. 5 a,b,c - *Pseudopolygnathus primus* Branson and Mehl. SM52A. MU 15155. With asymmetrical platform restricted to central part of unit. Respectively upper view, enlargement of platform in upper view showing groove between marginal nodes and carina on the left side of platform and lower view; x 45, x c.100, x 45.

Fig. 6 a,b,c,d- *Pseudopolygnathus primus* Branson and Mehl. SM52C. MU 15154. Fragmentary specimen with anterior crest broken. Respectively lateral view showing right side platform margin extending to posterior tip, upper view, oblique lower view showing asymmetrical lobes of basal cavity and enlargement of basal cavity showing growth lines; x 45, x 45 x 45, x c.80.

Fig. 7 a,b - *Pseudopolygnathus primus* Branson and Mehl. SM52A. MU 15158 With right side of platform not extending to posterior end. Respectively upper view and lower view; x 45.

Fig. 8 a,b,c - *Pseudopolygnathus primus* Branson and Mehl. SM52C. MU 15156, Fragmentary specimen with posterior part of platform obliquely broken. Respectively lateral view, upper view and lower view; x 45.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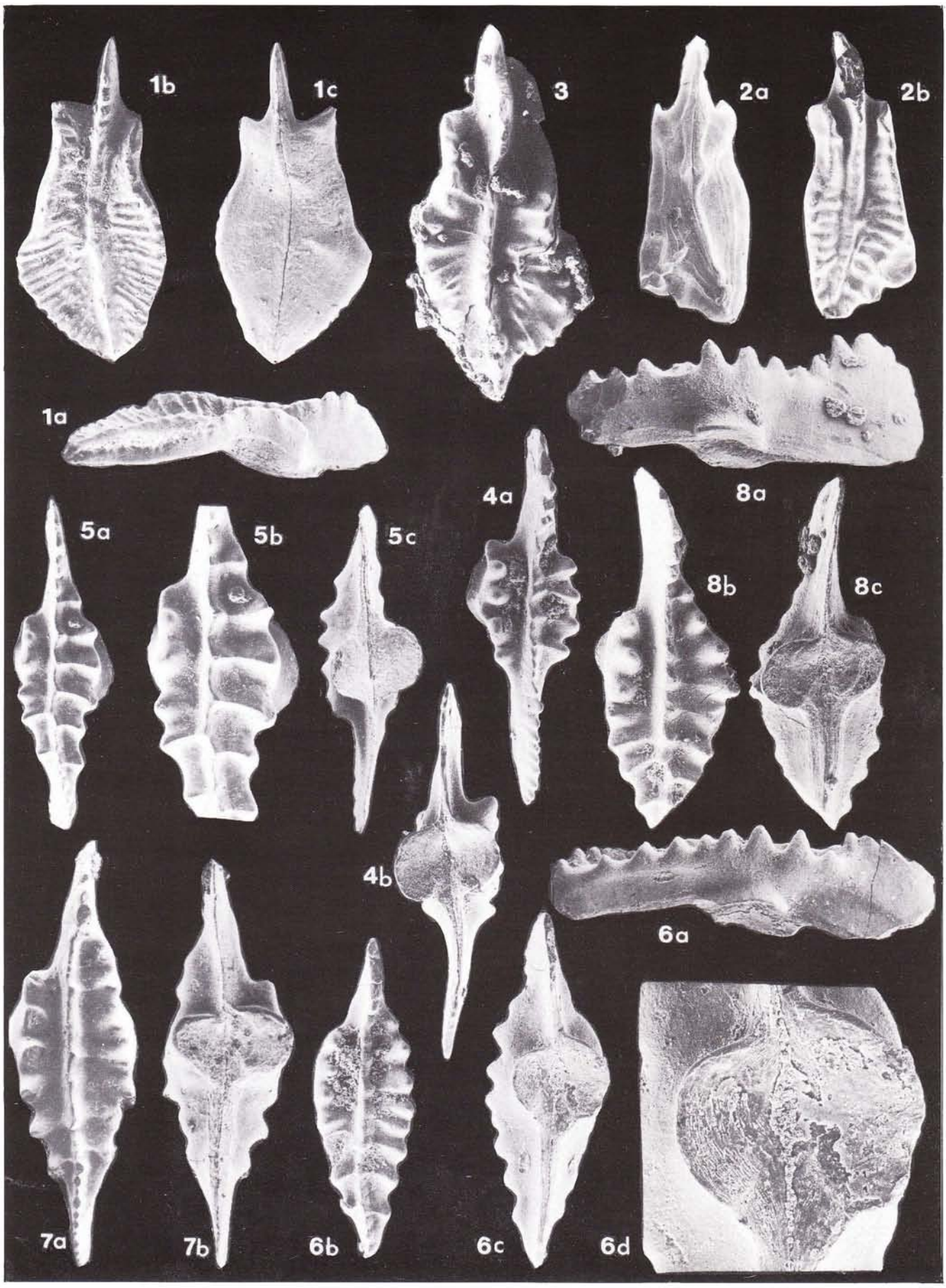
7b
6b
6c
6d

Conodont taxa \ Sample No. / SB Section	14	17	20	25	26	27	29	30	32	33	35A	35B	35C	36	38	41	43	47	50	51	52A	53	54	55	57A	57B	59	61A	64	68	79	81A	89	91A	93	93B	Total
Siphonodella sp. indet.																																				1	1
Pseudopolygnathus sp. indet.																																				1	1
Mehlina sp. D.																																				2	2
Hindeodus crassidentatus																																				2	2
Polygnathus flabellus																																				1	1
Polygnathus communis communis																																	11		1	59	71
Pseudopolygnathus dentilineatus																																	2				2
Polygnathus rostratus																																1				2	3
Polygnathus longiposticus																																1					1
Polygnathus inornatus																															1		2			1	4
Pelekysgnathus sp. A																										1			1	1							3
Bispathodus jugosus																						2															2
Mehlina sp. C																						1															1
Pelekysgnathus sp. Pb																			3			2					1										6
Bispathodus aculeatus plumulus																		1	4			12		7	9	15	5	4					3				60
Bispathodus costatus																2		2		1		4		1		1											11
Icriodus cf. *raymondi*																2									1												3
Bispathodus aculeatus aculeatus															1			1				1		1	1		5	1									11
Pelekysgnathus inclinatus															1	1						2		1		2	1										8
Branmehla inornata												2	1	2				1	5		2	2		1		3	1	1									21
Polygnathus collinsoni												1			2	15	2					1			1	1	1										24
Polygnathus perplexus												1				1																					2
Polygnathus delicatulus											1	19		1	3	11						6		3		3	1										48
Bispathodus bispathodus											1				1	13			2																		17
Polygnathus diversus									1																												1
Apatognathus varians klapperi						1																															1
Apatognathus varians varians						3																															3
Bispathodus stabilis				1		3				3		12		3		7	1		2																	2	34
Branmehla bohlenana				2		3						26		1																							32
Scaphignathus velifer				1	6	2																															9
Branmehla ampla				1	1																																2
Mehlina sp. B				1																																	1
Polygnathus pennatuloideus			1																																		1
Polygnathus buzmakovi			3																																		3
Polygnathus semicostatus		2	2	13	11	12	1	1		1						?1				7																	50
Alternognathodus pseudostrigosus	1																																				1
Icriodus alternatus alternatus	20	20	1																																		41
Palmatolepis rhomboidea	1																																				1
Palmatolepis minuta minuta	1																																				1
Unassigned elements Pb				5		1					1	1				4										1					1					1	15
M	4	1		5	3	4				2		5				7			1					2		1	2	2						1		5	45
Sa	3	1		3								1				2					1															1	12
Sc	2	2		8	2	4					1	3		2	1	5				2		1	1															34
Total	32	26	7	40	23	33	1	1	1	6	4	71	1	9	9	70	3	5	17	10	3	34	1	16	12	28	17	8	1	1	2	2	18	1	1	78	592

Tab. 2 - Distribution of conodont taxa from productive horizons of section SB, Ali Masjid Formation.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Tab. 2 - Distribution of conodont taxa from productive horizons of section SB, Ali Masjid Formation.

Conodont taxa \ Sample No. SB Section	14	17	20	25	26	27	29	30	32	33	35A	35B	35C	36	38	41	43	47	50	51	52A	53	54	55	57A	57B	59	61A	64	68	79	81A	89	91A	93	93B	Total
Siphonodella sp. indet.																																				1	1
Pseudopolygnathus sp. indet.																																				1	1
Mehlina sp. D.																																				2	2
Hindeodus crassidentatus																																				2	2
Polygnathus flabellus																																				1	1
Polygnathus communis communis																																	11		1	59	71
Pseudopolygnathus dentilineatus																																	2				2
Polygnathus rostratus																																1				2	3
Polygnathus longiposticus																																1					1
Polygnathus inornatus																															1		2			1	4
Pelekysgnathus sp. A																										1			1	1							3
Bispathodus jugosus																						2															2
Mehlina sp. C																						1															1
Pelekysgnathus sp. Pb																			3			2					1										6
Bispathodus aculeatus plumulus																		1	4			12		7	9	15	5	4					3				60
Bispathodus costatus																2		2		1		4		1		1											11
Icriodus cf. *raymondi*																2									1												3
Bispathodus aculeatus aculeatus															1			1				1		1	1		5	1									11
Pelekysgnathus inclinatus															1	1						2		1		2	1										8
Branmehla inornata												2	1	2				1	5		2	2		1		3	1	1									21
Polygnathus collinsoni												1			2	15	2					1			1	1	1										24
Polygnathus perplexus												1				1																					2
Polygnathus delicatulus											1	19		1	3	11						6		3		3	1										48
Bispathodus bispathodus											1				1	13			2																		17
Polygnathus diversus									1																												1
Apatognathus varians klapperi						1																															1
Apatognathus varians varians						3																															3
Bispathodus stabilis				1		3				3		12		3		7	1		2																	2	34
Branmehla bohlenana				2		3						26		1																							32
Scaphignathus velifer				1	6	2																															9
Branmehla ampla				1	1																																2
Mehlina sp. B				1																																	1
Polygnathus pennatuloideus			1																																		1
Polygnathus buzmakovi			3																																		3
Polygnathus semicostatus		2	2	13	11	12	1	1		1						?1				7																	50
Alternognathodus pseudostrigosus	1																																				1
Icriodus alternatus alternatus	20	20	1																																		41
Palmatolepis rhomboidea	1																																				1
Palmatolepis minuta minuta	1																																				1
Unassigned elements Pb				5		1					1	1				4										1					1					1	15
M	4	1		5	3	4				2		5				7			1					2		1	2	2					1		5	45
Sa	3	1		3								1				2					1														1	12
Sc	2	2		8	2	4					1	3		2	1	5				2		1	1														34
Total	32	26	7	40	23	33	1	1	1	6	4	71	1	9	9	70	3	5	17	10	3	34	1	16	12	28	17	8	1	1	2	2	18	1	1	78	592

Tab. 3 - Distribution of conodont taxa from productive horizons of section SM, Ali Masjid Formation.

Conodont taxa \ Sample No. SM Section	10	11A	12A	12B	13B	15B	16	18	19	23A	24	25	26	28	29A	29B	29C	33	34A	34B	39	41A	41C	43	46	47	49	50	52A	52C	53	54A	55	61A	62	64	65	66	67B	70A	71B	71C	Total
Siphonodella cooperi																																										1	1
Polygnathus corrugatus																																										1	1
Polygnathus flabellus																																									1	1
Polygnathus communis communis																																									2	2
Polygnathus inornatus																																								1	6	7
Bispathodus aculeatus ssp. indet.																																				1						1
Polygnathus rostratus																																			1						1		2
Polygnathus longiposticus																																		1			1	1	1				4
Pseudopolygnathus primus																											5		8	7													20
Pelekysgnathus sp. A Pa																											3		1	3													7
Pb																											3																3
Branmehla inornata																							3				1			1													5
Bispathodus spinulicostatus																						1																					1
Bispathodus aculeatus aculeatus																						1			2		4	1	1	1	1												11
Pelekysgnathus inclinatus																						1	1			1																	3
Bispathodus jugosus																						10																					10
Bispathodus cf. *jugosus*																					1																							1
Bispathodus aculeatus plumulus																					20	14	9				4			1												48
Apatognathus varians klapperi																			1																								1
Bispathodus costatus																	?1		3	1	9	6		1						?1												22
Palmatolepis gracilis gracilis																	1																										1
Icriodus cf. *raymondi*																2						2																					4
Bispathodus bispathodus														1		4	1		5																								11
Polygnathus collinsoni													6			2		1	1		2	4	1																			17
Scaphignathus subserratus													5																														5
Polygnathus delicatulus										7		1				3	6		1		2	9	3																			32
Mehlina sp. A										1												1																					2
Branmehla bohlenana										1			3			2	3	1	1																								11
Scaphignathus velifer										1	1																																2
Bispathodus stabilis									2	3			6	1			1	2				1																					16
Branmehla ampla									1	1																																	2
Polygnathus cf. *nodoundatus*									2																																		2
Mehlina sp. B								3	4																																		7
Polygnathus pennatuloideus						1	1		2																																		4
Polygnathus buzmakovi			1			6	1																																				8
Icriodus alternatus alternatus	1	1	4	2		4	5		5																																		22
Polygnathus semicostatus	1		9	1		1	4	8	16				5		1	1	2																										49
Unassigned elements Pb			1					1		9			2									2					2													1		1	19
M			1	1			2		1	5			5		1		2			1			1								1		1							1	1	24
Sa			1						1	2													1																				5
Sc			2		2		3	1	3	9	1		4			2	2	2			1									1	1	1									1	1	394
Total	2	1	19	4	2	12	16	13	37	39	2	1	36	2	2	16	18	6	12	2	35	52	19	1	2	1	22	1	10	14	3	1	1	1	1	1	1	1	1	4	14	429

hiatus in the Shishtu Formation, sampled for conodonts at Howz-e-Dorah in the Shotori Range near Tabas, eastern Iran. The latter has produced a considerably greater abundance of pelagic fauna, especially cephalopods, and is therefore inferred to represent generally deeper water than represented by the Ali Masjid Formation of the southern Khyber region or similar shallow water successions in central and southern Afghanistan (Brice, 1970; Dürkoop, 1970; Plodowski, 1970). The conodont biostratigraphy inferred from the faunas of the Ali Masjid Formation is coherent, consistent with lack of major repetition of strata in the area where the sampled sections are located. These results provide some basis for believing that a sustained program of systematic sampling of limestones for conodonts, mounted under appropriate auspices and carried out throughout the Khyber region, could well result in a major breakthrough in understanding of the structure and tectonic evolution of the region.

Acknowledgements.

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PLATE 10

Fig. 1 a,b - *Scaphignathus subserratus* Branson and Mehl. SM26. MU 15159. With posterior extremity broken. Respectively lateral view and upper view showing posterior part of blade offset to left side; x 45.

Fig. 2 a,b - *Siphonodella cooperi* Hass. SM71C. MU 15166. Large specimen. Respectively oblique upper view showing outer rostral ridge extending to lateral margin of platform and lower view; x 30.

Fig. 3 a,b - *Scaphignathus velifer* Helms. SB26. MU 15160. Small specimen. Respectively upper view showing anterior blade offset to right margin and lacking a carina in the posterior part of the platform and lower view; x 45.

Fig. 4 a,b,c - *Scaphignathus velifer* Helms. SM24. MU 15161. Transitional form. Respectively lateral view showing tall posteriormost denticle, enlargement of upper view showing atypical denticle development with carina and lower view showing a similar basal cavity as in specimen MU 15160, (see Fig 3b); x 45, x 80, x 80.

Fig. 5 - *Scaphignathus velifer* Helms. SB27. MU 15162. Upper view with blade offset towards right platform margin and carina developed only in the posterior half of the platform; x 80.

Fig. 6 - *Siphonodella* sp. indet. SB93B. MU 15166. Fragmentary specimen showing four rostral ridges on anterior part of platform; x 45.

Fig. 7 - *Bispathodus stabilis* Branson and Mehl. SB93B. MU 15066. Lateral view; x 45.

Fig. 8 a,b,c - *Bispathodus stabilis* Branson and Mehl. SM19. MU 15067. With widely flared basal cavity extending to posterior extremity. Respectively lateral view, upper view and lower view; x 45.

Fig. 9 - *Bispathodus stabilis* Branson and Mehl. SM26. MU 15069. Juvenile specimen in lateral view showing widely flared cavity extending to posterior tip; x 80.

Fig. 10 - *Bispathodus stabilis* Branson and Mehl. SM26. MU 15068. Lateral view showing widely flared basal cavity and coalescence of denticles above basal cavity; x 45.

Fig. 11 a,b,c- *Mehlina* sp. B. SM18. MU 15177. Respectively lateral view, upper view and lower view showing narrow basal cavity margins; x 45.

Fig. 12 - *Mehlina* sp. C. SB53. MU 15178. Lateral view showing sub-circular basal cavity and uneven size of posterior denticles; x 30.

Fig. 13 - *Hindeodus crassidentatus* Branson and Mehl. SB93B. MU 15170. Lateral view showing enlarged anterior denticles; x 45.

Fig. 14 - *Mehlina* sp. D. SB93B. MU 15179. Oblique lateral view; x 45.

PLATE 11

Fig. 1 a,b,c,d,e - *Branmehla ampla* (Branson and Mehl). SB25. MU 15167. With small, sub-circular basal cavity. Respectively lateral view, upper view, lower view, enlargement of basal cavity area and enlarged lower view; x 45, x 45, x 45, x c.120, x c.120.

Fig. 2 a,b,c,d - *Branmehla bohlenana* (Helms). SM29C. MU 15168. Respectively lateral view, enlargement of basal cavity in lower view showing slightly smaller inner margin, lower view showing slight deflection of the posterior part and upper view; x 45, x c.150 x 45, x 45.

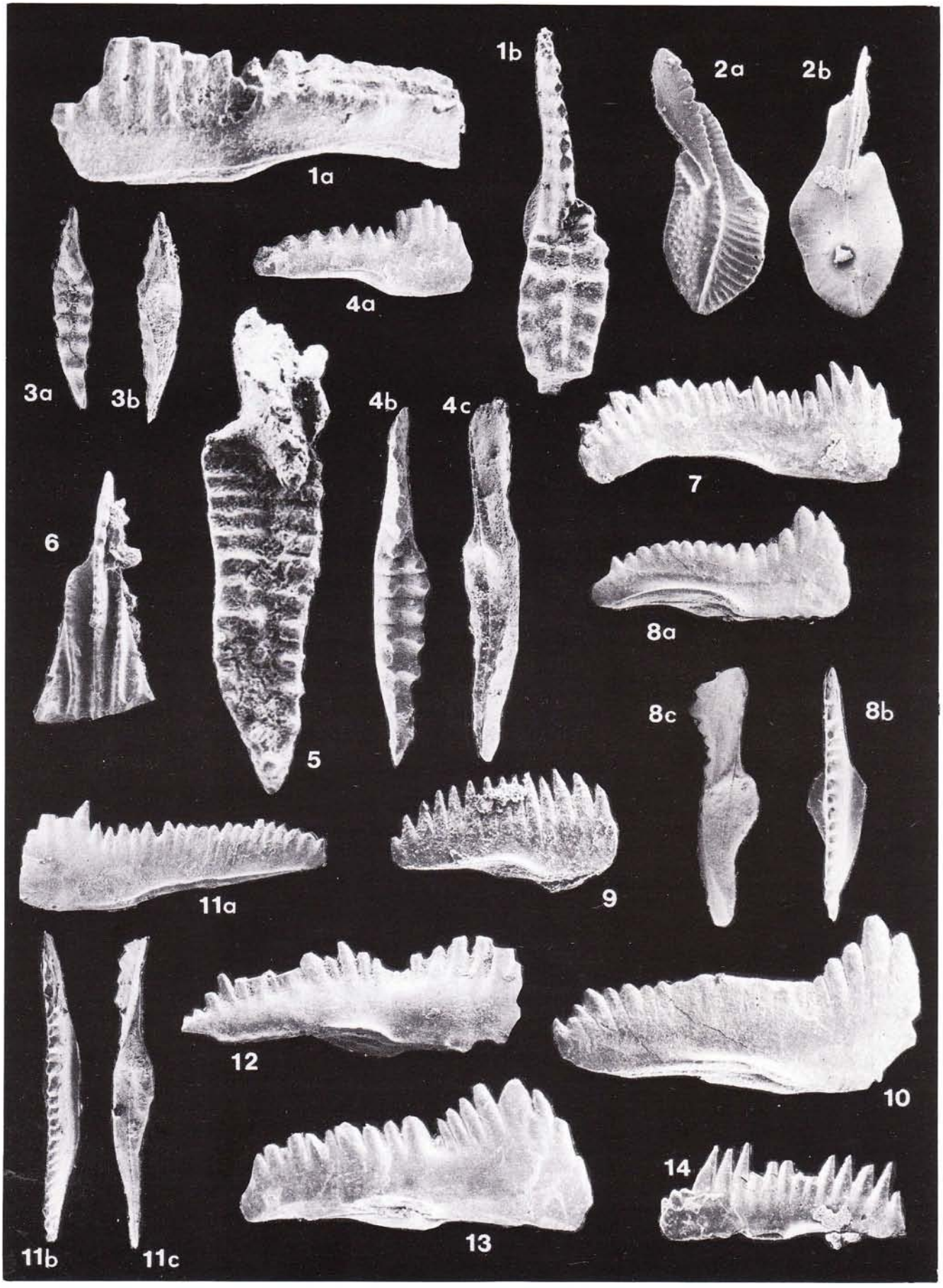
Fig. 3 a,b,c *Branmehla bohlenana* (Helms). SB35B. MU 15169. Cautiously assigned to *B. bohlenana*. Respectively lateral view showing discrete denticles and discrete apical denticle above basal cavity, lower view and enlargement of basal cavity area in upper view; x 45, x 45, x c.150.

Fig. 4 a,b,c,d - *Branmehla inornata* (Branson and Mehl). SM41C. MU 15171. Respectively lateral view showing straight lower margin and increasing height of anterior denticles, enlargement of basal cavity, upper view and lower view; x 45, x c.150, x 45, x 45.

Fig. 5 - *Branmehla inornata* (Branson and Mehl). SB35B. MU 15172. Broken specimen in lateral view; x 45.

Fig. 6 - *Branmehla inornata* (Branson and Mehl). SB35B. MU 15173. Broken specimen in lateral view showing increasing height of denticles towards apical denticle; x 45.

Fig. 7 a,b,c,d,e - *Branmehla inornata* (Branson and Mehl). SB47. MU 15174. Juvenile specimen. Respectively lateral view, upper view showing inward deflection of the posterior bar, lower view, enlargement of basal cavity area in lower view and enlargement of basal cavity area in upper view; x 45, x 45, x 45, x c.150, x c.150.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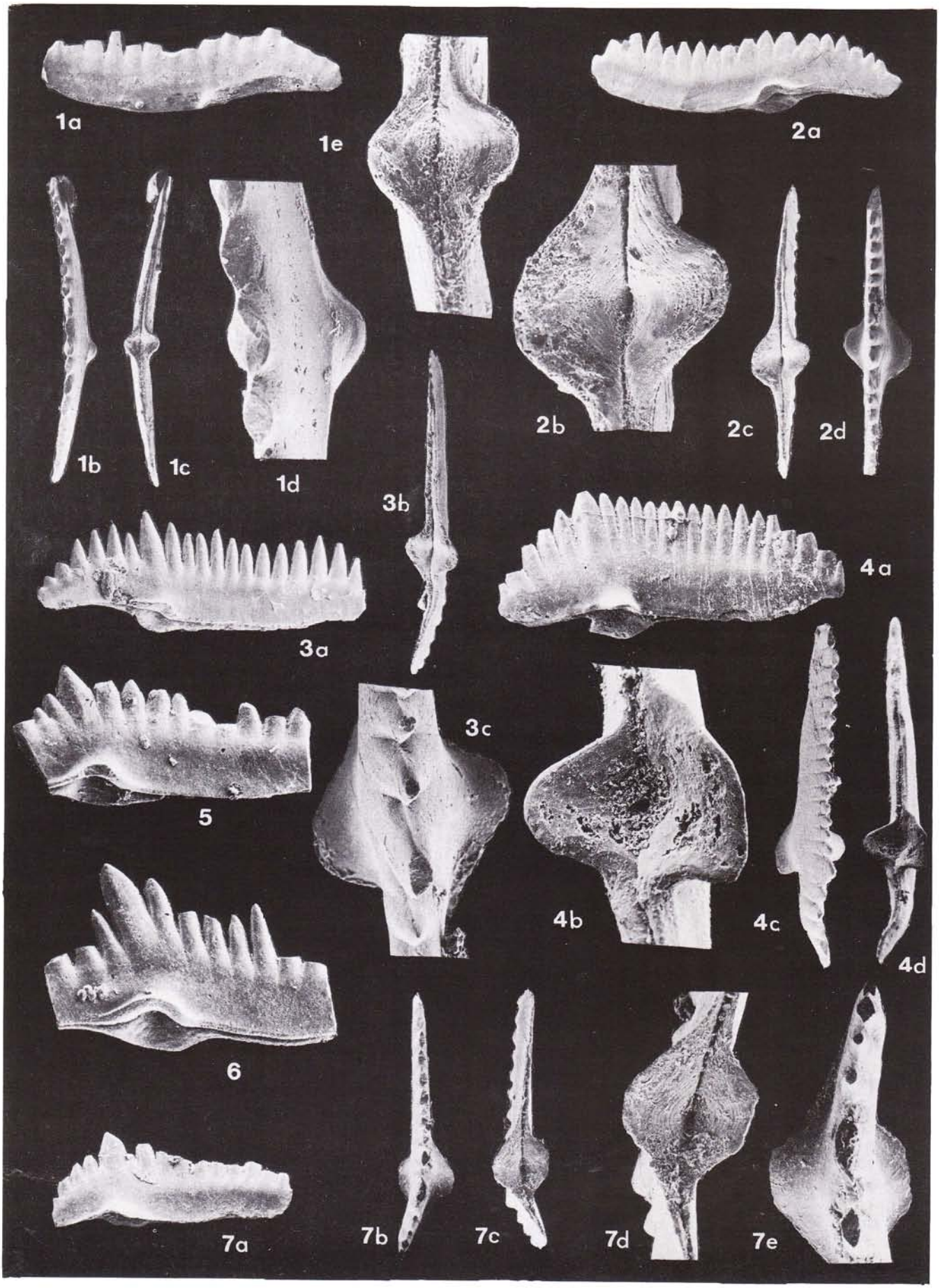
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