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Cambrian rocks and faunas, Hüdai area, Taurus Mountains, southwestern Turkey

by William T. DEAN and Necdet ÖZGÜL

Abstract

Inliers south of Hüdai, in the western Taurids, contain supposed Precambrian low-grade metamorphic and volcanic rocks of the Kocayayla Formation (>1000 m), overlain, probably unconformably, by the Hüdai Quartzite Formation (>500 m). The latter passes into the Çal Tepe Formation, comprising thickly-bedded dolomite (150 m estimated), followed by medium-bedded pink and grey nodular limestone with interbedded red mudstone (16.25 m). Trilobites from the lowest 1.2 m of the nodular limestone unit include: *Acadoparadoxides (Acadoparadoxides) mureroensis* (SDZUY, 1958), *Protolenus (Protolenus) pisidianus* n. sp., *Latoucheia* (s.l.) sp., *Ellipsocephalus* sp. and *Corynexochella? venusta* n. sp. The faunule is of earliest Middle Cambrian age by comparison with northern Spain. A corresponding faunule, with only *Acadoparadoxides (Acadoparadoxides) mureroensis* and *Corynexochella? venusta*, occurs in part of the Light-grey Limestone Member of the Çal Tepe Formation near Seydişehir. At Hüdai, Çal Tepe Formation carbonates are followed, apparently conformably, by unfossiliferous sandstone and shale (250 m) of the Seydişehir Formation (questionably of Cambrian to Ordovician age), succeeded in turn by markedly unconformable Mesozoic conglomerates of the Ilyasli Formation.

Key-words: Cambrian, trilobites, biostratigraphy, Turkey.

Résumé

Des boutonnières au sud de Hüdai, dans les Taurides occidentales, contiennent des roches volcaniques peu métamorphisées de la Formation de Kocayayla (>1000 m), d'âge probablement fin précambrien. Elles sont surmontées par la Formation du Quartzite de Hüdai (>500 m), vraisemblablement discordante et à laquelle succède la Formation de Çal Tepe. Cette dernière comprend d'épais bancs dolomitiques (150 m estimés) suivis par des calcaires nodulaires roses et gris (16.25 m), en bancs d'épaisseur moyenne et avec des intercalations de "mudstone" rouge. Dans le premier 1.20 m de calcaire nodulaire, les trilobites incluent *Acadoparadoxides (Acadoparadoxides) mureroensis* (SDZUY, 1958), *Protolenus (Protolenus) pisidianus* n. sp., *Latoucheia* (s.l.) sp., *Ellipsocephalus* sp. et *Corynexochella? venusta* n. sp. La faunule appartient, par comparaison avec des données d'Espagne septentrionale, à la partie la plus ancienne du Cambrien Moyen. Une faunule équivalente, avec uniquement *Acadoparadoxides (Acadoparadoxides) mureroensis* et *Corynexochella? venusta*, est connue près de Seydişehir dans une partie du Membre du Calcaire gris clair de la Formation de Çal Tepe. A Hüdai, les carbonates de la Formation de Çal Tepe sont suivis par des grès et des "shales" apparemment concordants de la Formation de Seydişehir (250 m), d'âge supposé cambrien à début ordovicien, et sur lesquels reposent les conglomerats mésozoïques nettement discordants de la Formation d'Ilyasli.

Mots-clefs: Cambrien, trilobites, biostratigraphie, Turquie.

Introduction (W.T.D., N.Ö.)

The Taurus Mountains run from east to west, subparallel to the Mediterranean coast in southern Turkey (Fig. 1), and form part of the Taurids, one of the major structural units into which the country was divided by KETİN (1966) and ÖZGÜL (1984). The first description of what are now known to be Lower Palaeozoic rocks in the western Taurus was by BLUMENTHAL (1947), who introduced the term Seydişehir-Schichten (later Seydişehir Formation), named for the town south-east of Lake Beyşehir, where the almost entirely clastic succession is probably incomplete; no section was designated as stratotype. The rocks consist mainly of alternating beds of quartzite and silty

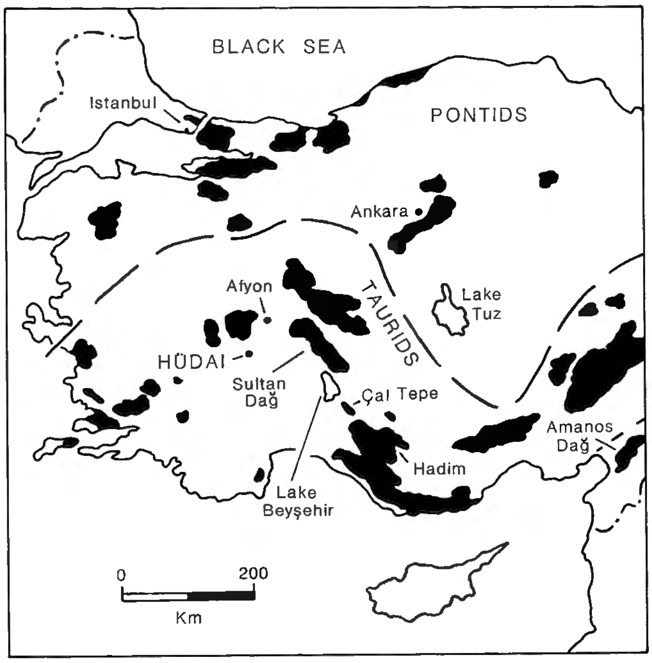


Fig. 1 — Outline map of western Turkey showing outcrops of Palaeozoic (undivided) rocks in black, with tectonic units and principal place names mentioned in text. Adapted from maps in KETİN (1966), GUTNIC *et al.* (1979) and ÖZGÜL (1984).

shale, with subsidiary grey shale, and those in the highest part of the formation were subsequently shown by MONOD (1967) to be of early Ordovician (Arenigian) age. Carbonates conformably underlying the Seydişehir Formation were named Çal Tepe Formation by DEAN & MONOD (1970) and found to contain Early and Middle Cambrian trilobites. The formation was divided into units, subsequently formalised (DEAN, 1980) as members, in ascending order: Dolomite Member (> 50 m), Black Limestone Member (24 m), Light-grey Limestone Member (11 m), and Red Nodular Limestone Member (47 m). ÖZGÜL (*in* ÖZGÜL & GEDİK, 1973) demonstrated the extension of the Çal Tepe Formation into the Hadim — Bağbaşi area, 60 km to the southeast, where the rocks crop out in a tectonic window and include an older Dark Shale Member, of uncertain age, not seen at the Çal Tepe. Middle Cambrian conodonts (ÖZGÜL & GEDİK, 1973) and trilobites (DEAN & ÖZGÜL, 1981) were documented from the same area.

In the Taurids north-west of Lake Beyşehir, outcrops of Çal Tepe Formation and Seydişehir Formation were reported from the highland area of the Sultan Dağ by HAUDE (1972), who found trilobites of Middle and Late Cambrian age, identified by SDZUY (*in* HAUDE, 1972) and later described by SHERGOLD & SDZUY (1984). The Çal Tepe and Seydişehir formations and older rocks in areas west of the Sultan Dağ were recognised in 1988 in the Hüdai-Sandikli area, 35 km southwest of Afyon (Fig. 1), by ÖZGÜL and colleagues from Turkish Petroleum Corporation (TPAO). In particular, unidentified trilobites were found at Çiloğlantarla Tepe, 4 km southwest of Hüdai (Fig. 2), in the Çal Tepe Formation, which there consists mostly of thick-bedded dolomite (150 m), overlain in turn by a thin (16.25 m) unit of pink and pale grey nodular limestone with red mudstone interbeds. Samples from the limestone beds yielded microfossils of uncertain affinities described by GEDİK (1989) as species of *Hadimopanella*. GEDİK's (1989, fig. 2) table of strata showed the Kocayayla Formation (c. 1000 m) and overlying Hüdai Formation (c. 1000 m) as Precambrian; the succeeding Çal Tepe Formation (c. 50-300 m) as Lower Cambrian; and the Seydişehir Formation (> 1000 m) as Lower Cambrian to Ordovician. Details of the succession are not clear and some of the claimed ages are incorrect. A proposed zonation based on Hadimopanellid species is difficult to equate with Çal Tepe stratigraphy, especially as type localities of relevant species are imprecise, based on a composite Çal Tepe — Hüdai carbonate succession that does not take into account differences between the two areas.

Middle Cambrian carbonates crop out at intervals along the western half of southern Turkey, from the Amanos Dağ at least to Hüdai, and in all cases they are referred to the Çal Tepe Formation. Lateral extension of individual members outside the type Seydişehir-Hadim area is, however, limited and the units represent diachronous litho-facies. The red nodular limestone facies is the most persistent and has been shown to become younger overall from west to east along southern Turkey (DEAN *et al.*, 1993); the Çiloğlantarla section is of particular interest as being the oldest occurrence yet known. Present results are based on field-work carried out during 1990 and 1991 by the authors with Olivier MONOD and Francine MARTIN as part of a TPAO project in the western Taurus, and in collaboration with colleagues from that organisation.

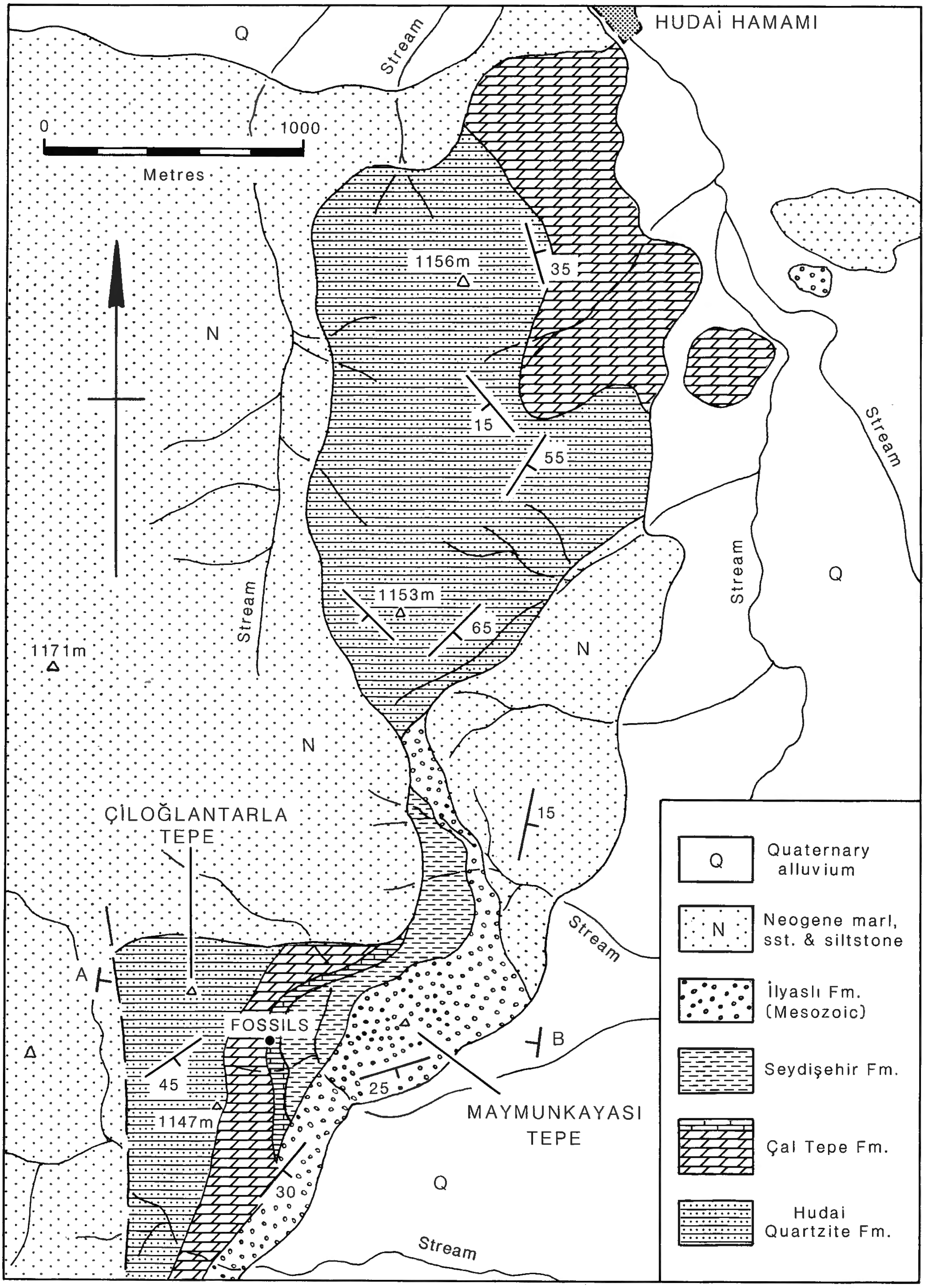
Review of lithostratigraphy (N.Ö.)

In the northern part of the western Taurus, including the Hüdai area, the basement rocks consist of Precambrian, Cambrian and Ordovician units. These are overlain, with marked unconformity, by a transgressive sequence of Mesozoic sediments that begins with a thick (200 m) succession of conglomerate and sandstone, the İlyasli Formation, of Late Triassic (?) to Early Jurassic age. The Precambrian and Lower Palaeozoic rocks, termed Sandikli Group, are divided into four parts, in ascending order: Kocayayla Formation; Hüdai Quartzite Formation; Çal Tepe Formation; and Seydişehir Formation (Fig. 3). The general dip is easterly, so that successively higher units are seen in a traverse from Çiloğlantarla Tepe to Maymunkayasi Tepe (Fig. 4). Palynological samples from the Kocayayla, Çal Tepe and Seydişehir formations in the Hüdai area yielded neither acritarchs nor chitinozoans.

KOCAYAYLA FORMATION

The unit, more than 1000 m thick, consists of low-grade schist (green-schist), quartzite, and metavolcanics to which the name "porphyroïde" has been applied (GUTNIC *in* BRUNN *et al.*, 1971). Opinions vary as to the age of the formation. GUTNIC (1977) considered the rocks to be Precambrian because of their proximity to unmetamorphosed Cambrian-Ordovician units in the Sultan Dağ, but did not exclude an Upper Palaeozoic age as a coral fauna had been found in epimetamorphic schists possibly belonging to the same unit. ÖZGÜL (1984) favoured a Precambrian age for the formation, which is known also as the "Sandikli metaporphyroid". During studies by ÖZGÜL and TPAO colleagues since 1988, the Kocayayla Formation was shown to be overlain with possible unconformity by the Hüdai Quartzite Formation, followed in turn by the Çal Tepe Formation, so that a late Precambrian age is considered likely. Some support for such an age was provided by KRONER & ŞENGÖR (1990), who obtained an isotopic age measurement of 543 ± 7 Ma

Fig. 2 — Geological map (by N. ÖZGÜL) of the area south of Hüdai. Line of the stratigraphic section in Fig. 4 is between points A and B.


HUDAİ HAMAMI
Q
Stream
0
1000
Metres
1156m
35
N
15
55
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65
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N
15
ÇİLOĞLANTARLA
TEPE
Stream
A
FOSSILS
45
1147m
25
30
B
MAYMUNKAYASI
TEPE
Q
Stream
Q
Quaternary alluvium
N
Neogene marl, sst. & siltstone
İlyaslı Fm. (Mesozoic)
Seydişehir Fm.
Çal Tepe Fm.
Hudai Quartzite Fm.

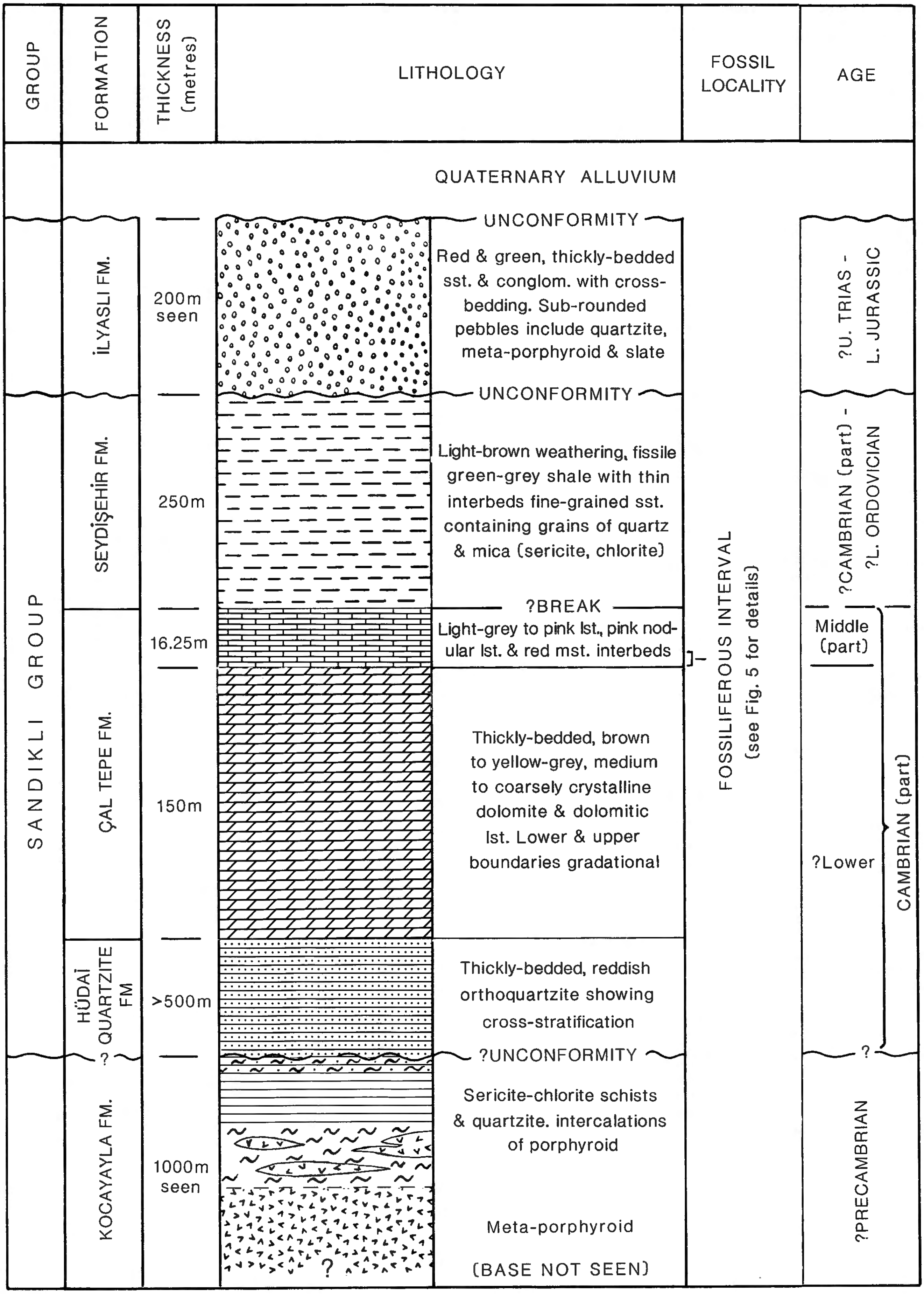
GROUP
FORMATION
THICKNESS (metres)
LITHOLOGY
FOSSIL LOCALITY
AGE
QUATERNARY ALLUVIUM
UNCONFORMITY
İLYASLI FM.
200m seen
Red & green, thickly-bedded sst. & conglom. with cross-bedding. Sub-rounded pebbles include quartzite, meta-porphyroid & slate
?U. TRIAS - L. JURASSIC
UNCONFORMITY
SANDIKLI GROUP
SEYDİŞEHİR FM.
250m
Light-brown weathering, fissile green-grey shale with thin interbeds fine-grained sst. containing grains of quartz & mica (sericite, chlorite)
?CAMBRIAN (part) - ?L. ORDOVICIAN
?BREAK
16.25m
Light-grey to pink lst., pink nodular lst. & red mst. interbeds
Middle (part)
FOSSILIFEROUS INTERVAL (see Fig. 5 for details)
ÇAL TEPE FM.
150m
Thickly-bedded, brown to yellow-grey, medium to coarsely crystalline dolomite & dolomitic lst. Lower & upper boundaries gradational
?Lower
CAMBRIAN (part)
HÜDAİ QUARTZITE FM
>500m
Thickly-bedded, reddish orthoquartzite showing cross-stratification
?UNCONFORMITY
?
KOCAYAYLA FM.
1000m seen
Sericite-chlorite schists & quartzite. intercalations of porphyroid
Meta-porphyroid
(BASE NOT SEEN)
?PRECAMBRIAN

Fig. 3 — Stratigraphic column for the area south of Hüdai. Carbonates of the Çal Tepe Formation above the thickly-bedded dolomites are shown as a single unit on the map in Fig. 2; outcrops of Precambrian rocks lie outside the limits of the map.

from what they termed, erroneously, the "Sandikli Granite".

HÜDAI QUARTZITE FORMATION

Comprises >500 m of thick-bedded, reddish, white and grey, laminated quartz arenite which exhibits cross-bedding and is considered to represent a beach deposit. The unit grades upwards into the Çal Tepe Formation, of latest Lower (?) and earliest Middle Cambrian age, and so is assigned questionably to the Lower Cambrian.

ÇAL TEPE FORMATION

Outcrops form small inliers in two areas, to the south-west and north-east of Sandikli, though only the former is relevant to the present discussion. The succession (Fig. 3) corresponds to others in the Sultan Dağ and may be correlated generally with those in the Çal Tepe and Hadim areas, though it differs in detail. Of the thickness of almost 170 m, the lowest 150 m are composed mainly of thickly-bedded, coarsely crystalline, brown dolomite, which has not yielded macrofossils.

As elsewhere in southern Turkey, the succeeding strata form the most conspicuous part of the Çal Tepe Formation. They comprise 16.25 m of medium-bedded, pink, beige and light-grey nodular limestone, intercalated with often bright red mudstone and containing patches of brown, ferruginous clay overprinted by alteration. Macrofossils were found in the rubbly-weathering lower part of the unit (see later), but proved almost impossible to extract from the micritic limestone nodules, though trilobite fragments were often visible in cross-section.

SEYDIŞEHIR FORMATION

Only the lowest 200 m of the unit are visible, the remainder being overlain by markedly unconformable conglomerates of the Ilyasli Formation, of Mesozoic age (?U. Trias — L. Jurassic) and termed "Verrucano Conglomerates" by GUTNIC (1977), or by Neogene or Quaternary sediments. The rocks comprise light-brown weathering, green-grey, often highly micaceous (sericite and chlorite) shale with thin interbeds of fine-grained quartz sandstone. The unit is apparently conformable upon the Çal Tepe Formation and the lowest beds may therefore be of Cambrian age, but no macrofossils were seen.

Position of fossil localities (WTD)

All the macrofossils are from a 3.25 m unit (Fig. 5) of pink, nodular limestone with red mudstone interbeds and occasional lenses of pink-grey packstone. The unit is divided into informal beds A-H that may be followed in ascending order east-southeast along the lower slope on the south side of Çiloğlantarla Tepe, but macrofossils were found only in Beds A0 to B, an overall thickness of about 1.3 m. Localities at this measured section include: FOB-49, FOB-50, FOB-51 and FOB-52, all sampled in 1991. The unit can be traced northwards up the hill slope, "stepped" by minor faults, and the first collections were obtained in 1990 from localities B.45-1, B.45-2, B.45-3 and B.45-3a. All the last three represent the same fossiliferous level in the upper part of the hill, but there are minor changes in lithology along the strike and the most abundant specimens were found at B.45-3 and B.45-3a in an impersistent bed of calcarenite not seen lower on the hill.

Age and relationships of the fossils (WTD)

Stratigraphically the most significant of the trilobites is *Acadoparadoxides (Acadoparadoxides) mureroensis* (SDZUY, 1958), described from northern Spain (SDZUY, 1958). The species was later used as index for the lowest

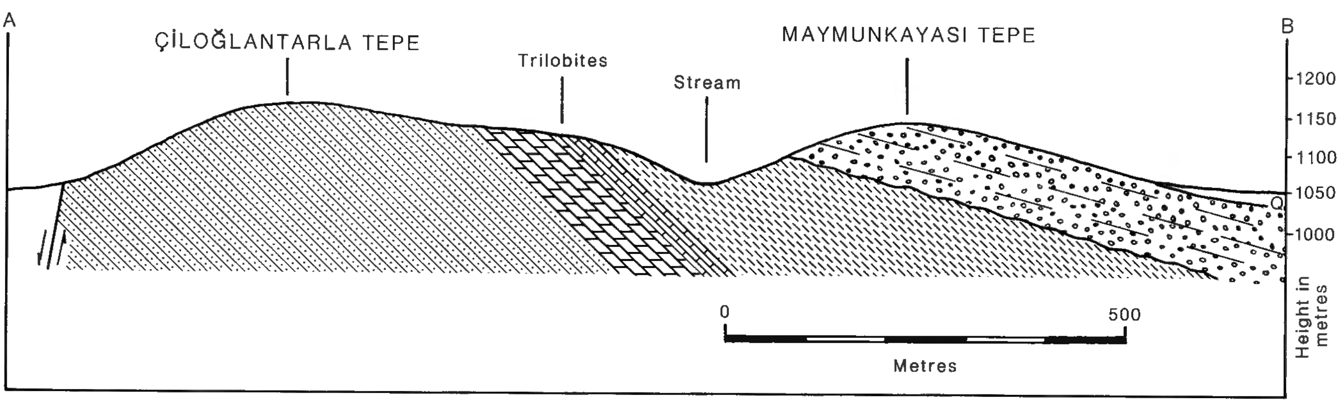

Fig. 4 — Transverse section (A-B in Fig. 2) through Çiloğlantarla Tepe and Maymunkayasi Tepe.

part of the Middle Cambrian there, the "Schichten mit *P. mureroensis*" (SDZUY, 1971; 1972, p. 45), later formalised (PALMER, 1979, p. A133) as basal zone of the Middle Cambrian in the Mediterranean region and North Africa. *Paradoxides* (s.l.) is conventionally accepted as a reliable index for the Middle Cambrian in northern Europe and Scandinavia, particularly Sweden, where a "standard" succession of agnostid and paradoxidid zones was established (WESTERGÅRD, 1946, 1953), with the so-called "*Paradoxides oelandicus* Stage" at the base. However,

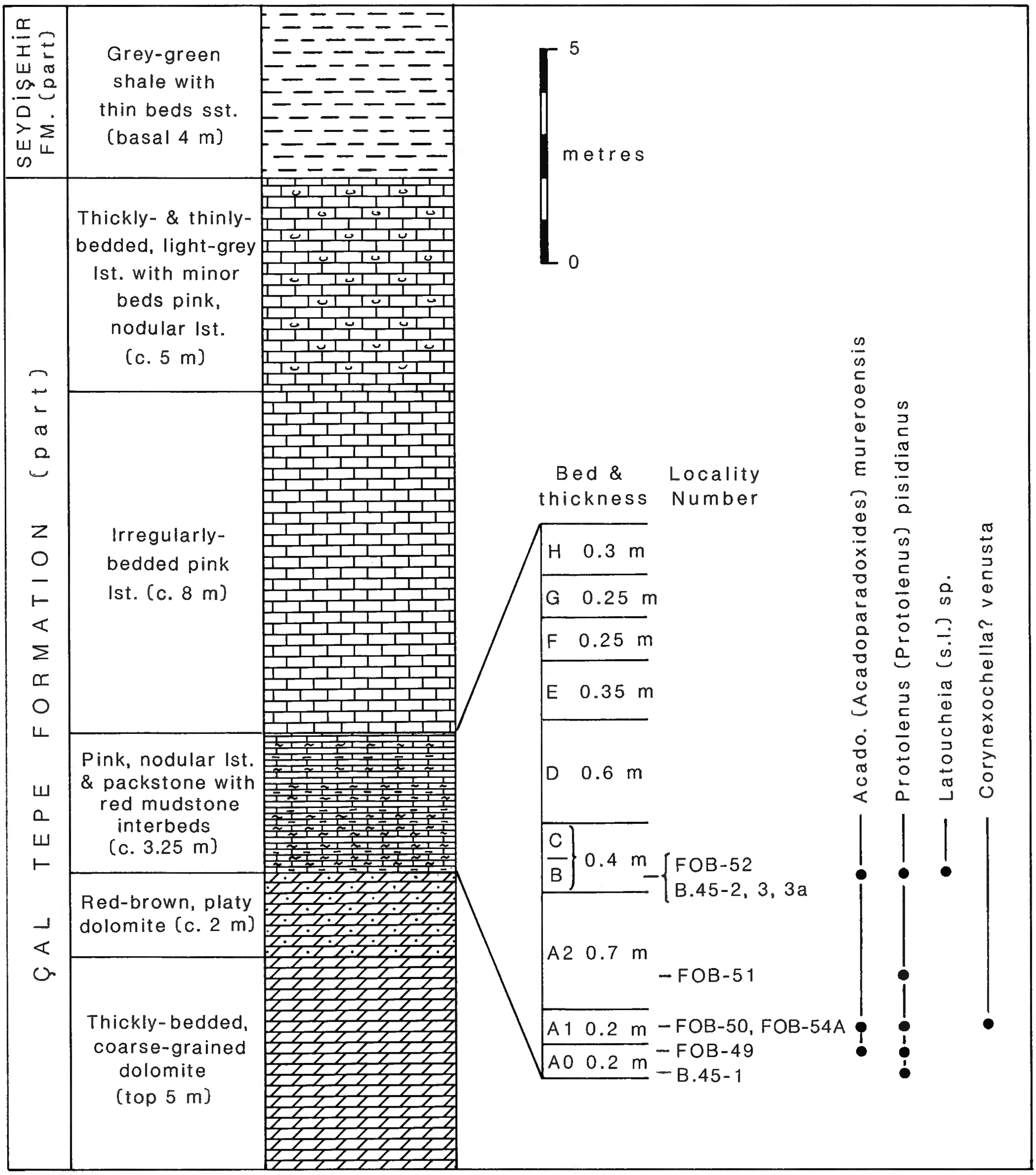

Fig. 5 — Detailed section through the highest part of the Çal Tepe Formation at Çiloğlantarla Tepe, with stratigraphic levels of fossil localities and ranges of macrofossils.

the junction of Lower and Middle Cambrian is marked by a break in sedimentation on a regional scale. BERGSTRÖM (1980) noted that the lowest Middle Cambrian is not represented in Scandinavia, and according to BERGSTRÖM & GEE (1985, p. 254) both highest Lower and lowest Middle Cambrian strata are absent there. The unconformity at the base of the Middle Cambrian in parts of both Gondwanaland and Laurentia was noted by FRITZ (1972), and its possibly world-wide significance has been attributed to a so-called Hawke Bay Event (PALMER & JAMES, 1980) or Hawke Bay Regression (AHLBERG, 1984). In Morocco HUPÉ (1960) showed the base of the Middle Cambrian marked by the appearance of *Acadoparadoxides* and the disappearance of *Protolenus*. This view was modified by GEYER (1990a, b), who recorded *Protolenus (Protolenus)* only from the lower Middle Cambrian (with base defined by the appearance of *Paradoxides* s.l.) and claimed that the *Protolenus* Zone and equivalent strata in eastern Canada and the Welsh Basin were of similar age. *Protolenus* is reported also from the early Middle Cambrian of Poland, in association with *Paradoxides* and *Ellipsocephalus* (ORŁOWSKI, 1964, p. 72).

A recognisable Lower/Middle Cambrian boundary in southern Turkey has proved elusive owing to the lack of sections that are continuous or contain suitable fossiliferous lithologies. Late Lower Cambrian rocks frequently comprise dolomites that are essentially barren of both macro- and microfossils, while those of the Middle Cambrian include both grey micrites, from which fossils are difficult to extract, and a diachronous red nodular facies that is younger overall from west to east, a distance of more than 1200 km (DEAN *et al.*, 1993). The red nodular limestones at the section south of Hüdai are the oldest, dated occurrence of the facies, and the lithological transition from coarse-grained dolomite, by way of a small thickness (2 m) of red-brown dolomite, suggests the possible presence of a deepening, transgressive sequence. The oldest trilobites found at Çiloğlantarla Tepe (Loc. B.45-1) were *Protolenus (Protolenus) pisidianus*, closely followed (only 0.1 m higher) by *Acado. (Acadoparadoxides) mureroensis*, accompanied by *Pr. (Pr.) pisidianus*. The apparent absence of the paradoxidid from B.45-1 may be due to collection failure but could reflect small differences in biofacies. Both these trilobites were found throughout the small thickness of fossiliferous beds, the whole of which is assigned an early Middle Cambrian age corresponding to the *Acado. (Acadoparadoxides) mureroensis* Zone of Spain. *Corynexochella? venusta*, rare at Loc. FOB-54A, provides a link with the Çal Tepe area, near Seydişehir (Fig. 1), where it has so far been found, with *Ac. (Ac.) mureroensis*, at only a single level 1.8 m above the base of the Light-grey Limestone Member.

Evidence of age from other trilobites is meagre. Cranidia determined as *Latoucheia* (s.l.) sp. generally resemble specimens described from only the Middle Cambrian of Morocco by GEYER (1990b). The type species of the genus was based on material from the "*Protolenus* Limestone" (COBBOLD, 1921) of England, assigned to the "Protolenid-Strenuellid Zone" by COWIE *et al.* (1972) and conventionally considered as late Lower Cambrian (for example, THOMAS *et al.*, 1984, p. 9). Lower Cambrian trilobite faunas are notoriously provincial in their distribution, and it is still not known whether the stratigraphic ranges of genera in Morocco are equally applicable elsewhere. Macrofossils are generally uncommon in the Cambrian carbonates of southern Turkey and consist largely of trilobites, almost always as disarticulated fragments. The specimen from Loc. B.45-3 now illustrated as *Scenella?* sp. represents a group found rarely and sporadically in the Taurids. The type species, *S. reticulata* BILLINGS (1872, p. 479), described but not figured from Topsail Head, Conception Bay, eastern Newfoundland, was later illustrated by KNIGHT (1941, pl. 2:5c). According to HUTCHINSON (1962, p. 50) *Scenella* occurs in the *Callavia* Zone of the Lower Cambrian in the type area, but the group, interpreted variously as molluscs or coelenterates (references in PEEL, 1988, p. 156), is known from Lower and Middle Cambrian faunas in Gondwanaland, Baltica and Laurentia.

Systematic descriptions of trilobites (WTD)

Terminology is that used in the first edition of Volume O of the Treatise on Invertebrate Paleontology (HARRINGTON *et al. in* MOORE 1959, p. 0124), with emendations proposed for the second edition (WHITTINGTON & KELLY, in press). Figured material is in the Institut royal des Sciences naturelles de Belgique, Brussels, and specimen numbers have the prefix IRScNB. Numbers of specimens collected at the various localities are as follows: rare (1-4), moderately common (5-10), abundant (11-20), very abundant (>20).

Family PARADOXIDIDAE HAWLE & CORDA, 1847
Genus *Acadoparadoxides* ŠNAJDR, 1957

Type species: *Paradoxides Sacheri* BARRANDE, 1852, from the Middle Cambrian of Jince, Czechoslovakia, by original designation of ŠNAJDR (1957, p. 238).

Subgenus *Acadoparadoxides* ŠNAJDR, 1957

Acadoparadoxides (Acadoparadoxides) mureroensis
(SDZUY, 1958)
Plate 1, Figures 4, 7, 8, 16?;
Plate 2, Figures 4, 7-10, 12-14, 16-18)

1958 — *Paradoxides mureroensis* SDZUY, p. 239, pl. 1, figs. 12, 13.
1961 — *Paradoxides mureroensis* SDZUY — SDZUY, p. 317, pl. 11, fig. 6; pl. 16, figs. 2-17; pl. 17, figs. 1-5; Fig. 24.

1969 — *Paradoxides (Eccaparadoxides) mureroensis* SDZUY — REPINA, p. 17.
1971 — *Paradoxides (Acadoparadoxides) mureroensis* SDZUY — SDZUY, p. 769, 771, Table 1.
1986 — *Paradoxides (Acadoparadoxides) mureroensis* SDZUY — LIÑAN & GOZALO, p. 51, pl. 11, figs. 1-13.
1993 — *Acadoparadoxides* sp. — DEAN *et al.*, pl. 1, fig. 18.

Figured specimens: IRScNB Nos. a 3067, a 8824, a 8825, a 8829 — a 8835.

Horizon, localities and abundance: Çal Tepe Formation; Çiloğlantarla Tepe, Localities B.45-2 (rare), B.45-3 (abundant), B.45-3a (rare), FOB-49 (rare), FOB-50 (rare), FOB-52 (rare) and FOB-54A (rare).

Description and discussion:
The species was founded (SDZUY, 1958) on a large holotype cranidium, length about 33 mm, and a pygidium about 19 mm long. Both specimens are compressed and distorted, as are the numerous examples in SDZUY's (1961, p. 317) later description, so that S1-2 often appear deep medially; but the close resemblance to the Turkish material is evident, even though the latter is preserved in relief. The glabella has almost straight sides, only slightly divergent as far as S4; S3 and S4 are faint or indiscernible and the anterior half of the glabella stands high above, and indents slightly, the anterior border, which is wide (exs.) with flat top. There is a strong resemblance to cranidia of *Acado. (Acadoparadoxides) pinus* (WESTERGÅRD, 1936, p. 38), from the upper part of the *Oelandicus* Beds of Öland, Sweden, and slightly younger than the Spanish and Turkish material. Minor differences shown by the Turkish specimens include: S2 deeper, straighter, and shallower medially; palpebral lobe wider, thicker, more convex in plan, with more conspicuous palpebral furrow; larger occipital ring, bounded by S0 that flexes forwards medially (this character is less obvious in compressed specimens). Some comparison may also be made with *Paradoxides cultus* EGOROVA (see EGOROVA & SAVITSKIY, 1969, p. 142, pl. 21, figs. 1-6) from the *P. cultus — Popigaia popigaica* Zone of the Siberian Platform, particularly in the palpebral and postocular areas and the anterior border; but the glabella in front of S2 is proportionately longer, as is the less rounded frontal glabellar lobe, and S3-4 are better defined.

Of the two left free cheeks illustrated by SDZUY (1961, pl. 16, figs. 12, 13) one shows an apparent inner spine angle that is not seen on the other Spanish specimen or in the Turkish material (Pl. 2, Fig. 18) and is due to mechanical deformation.

An almost complete, small, undistorted hypostome (Pl. 2, Figs. 10, 14) shows clearly the strong convexity and conspicuous Bertillon pattern of ridges. Again, comparison may be made with *Acado. (Acadoparadoxides) pinus* (WESTERGÅRD, 1936, pl. 6, figs. 14, 15), but the posterolateral spines seen in both species (see also SDZUY, 1961, pl. 16, figs. 14-17; LIÑAN & GOZALO, 1986, pl. 11, figs. 7, 9) and located in front of the posterolateral angles are not preserved.

The pygidia illustrated by SDZUY are compressed, but show the single, transversely straight axial ring, the gently curved, posteriorly divergent lateral margins, and the broadly rounded posterior margin. All these are visible on the one available Turkish pygidium, but the uncrushed axial portion is seen to be notably convex and apparently consists of the true axis fused posteriorly with the confluent extensions of the small pleural fields. A similar ''composite'' axis is seen in pygidia of *Acado. (Acadoparadoxides) pinus* figured by WESTERGÅRD (1936, pl. 6, figs. 7-11), but the latter are relatively narrower, subhexagonal in outline, and the posterior margin is straight or slightly concave.

Family ELLIPSOCEPHALIDAE MATTHEW, 1887
Subfamily ELLIPSOCEPHALINAE MATTHEW, 1887

Genus *Ellipsocephalus* ZENKER, 1833

Type species: by monotypy, *Elleipsocephalus* (sic) *ambiguus* ZENKER (1833, p. 51), a junior subjective synonym of *Trilobites Hoffii* SCHLOTHEIM (1823, p. 30).

Ellipsocephalus **sp.**
(Plate 1, Figures 23, 24)

Figured specimen: IRScNB No. a 8823.

Horizon and locality: Çal Tepe Formation, Çiloğlantarla Tepe, locality B.45-2.

Description and discussion:
A single cranidium 8 mm long and 11 mm wide resembles in most respects that of *E. hoffii*, from the Middle Cambrian of Bohemia, redescribed by ŠNAJDR (1958, p. 88, pl. 7, figs. 1, 3-8; pl. 8, figs. 1-7). The Turkish specimen differs in having the glabellar outline very slightly tapered as far as the eye ridges and parabolic frontally. In these features it is better compared with *Ellipsocephalus polytomus* LINNARSSON, 1877, from the *Paradoxides oelandicus* ''Stage'' of ÖLAND, Sweden, and redescribed by WESTERGÅRD (1936, p. 56, pl. 11, figs. 5-17). Of the latter author's illustrations, pl. 11, figs. 9, 11, 12 show the front of the glabella subparabolic, but in pl. 11, fig. 10 the outline widens gently and is subangular anterolaterally. *E. polytomus*, found also in the early Middle Cambrian of Poland (ORŁOWSKI, 1964, pp. 72, 82) has a smooth exoskeleton, as has the present specimen, but the internal mould of the latter shows equisized L1-L3 separated by distinct lateral glabellar furrows not seen on the incomplete external surface. *E.* aff. *polytomus* from the Middle Cambrian of Morocco (GEYER, 1990b, p. 102, pl. 14, figs. 5a, b) has the glabellar outline angular

anterolaterally and there appear to be no glabellar furrows on the internal mould.

Two undetermined meraspid cranidia of ellipsocephalid type from Loc. B.45-3 are illustrated. The larger (IRScNB a 8836; Pl. 2, Fig. 11) has the incomplete anterior border strongly arched in plan, as in *Protolenus (Protolenus) pisidianus* n. sp.; but the anterior border furrow and preglabellar furrow are less well defined, while the glabella, with traces of S1-S2, is relatively narrow and very slightly tapered. The smaller cranidium (IRScNB a 8837; Pl. 2, Fig. 15), slightly more complete but poorly preserved, shows traces of S1-S3, has an almost parallel-sided glabella, and the preglabellar field is long (sag.), bounded by a weakly developed, narrow (sag.) anterior border. Possibly an immature *Protolenus*, the specimen is insufficient for confident determination.

Subfamily PROTOLENINAE R. & E. RICHTER, 1948
Genus *Protolenus* MATTHEW, 1892

Type species: *Protolenus elegans* MATTHEW, 1892, by subsequent designation of VOGDES, 1893.
Objective junior synonym: *Protolenus (Bergeronia)* MATTHEW (1895, p. 146), based on same type species as *Protolenus.*

Subgenus *Protolenus* MATTHEW, 1892

Protolenus (Protolenus) pisidianus n. sp.
(Plate 1, Figures 1-3, 5, 6, 10, 11, 14, 15, 19)

Derivation of name: from the ancient province of Pisidia.

Diagnosis:
Species of *Protolenus (Protolenus)* with parabolic glabellar outline having basal breadth 0.6 of length (sag.); glabella strongly convex longitudinally, with convex frontal lobe that occupies 0.26 of glabellar length and curves down steeply to short (sag.), declined preglabellar field; latter may exhibit radiating caecal venation and is slightly wider (sag.) than anterior border, which is of low convexity and strongly arched forwards in plan, bounded by shallow anterior border furrow that ends in-line with S3; L2, L3 equisized but L1 slightly shorter (exs.) than L2 on holotype; gently curved S1-S3 extend across one-third of glabellar breadth and are well defined on internal mould; S0 deep on internal mould, transversely straight over median half but curves forwards slightly near axial furrows; palpebral lobe long, from S0 to S3, widest (tr.) opposite S1; eye ridge forms node that is thickest near edge of axial furrow, opposite S3, and dies out abaxially, truncated by shallow, frontal portion of palpebral furrow; surface of exoskeleton smooth.

Type material: Holotype, IRScNB No. a 8814 (Pl. 1, Figs. 2, 3, 6); paratypes IRScNB Nos. a 8813, a 8816, a 8818, a 8820.

Horizon, localities and abundance: Çal Tepe Formation, Çiloğlantarla Tepe, localities B.45-1 (abundant, including holotype), B.45-2 (abundant), B.45-3 (abundant), FOB-49 (rare), FOB-50 (rare, poorly preserved), FOB-51 (rare).

Description and discussion:
For many years the name *Protolenus* was used indiscriminately and often inaccurately for trilobites of general protolenid type that are now known to differ significantly from the type species. The latter, and other species from New Brunswick, eastern Canada, were reassessed by GEYER (1990b, p. 179), who assigned Moroccan material to new species of the subgenus *P. (Protolenus).* Of these *P. (P.) interscriptus* GEYER (1990b, p. 179, pl. 45, figs. 1-5, text-fig. 62) may best be compared with the new species and both have similar glabellar outline and lobation. *P. (P.) interscriptus* differs as follows: the anterior border is narrower (sag.), more sharply defined; the eye ridge is well defined and more transverse in direction (in the new species it is node-like, highest just outside the axial furrow and truncated abaxially by the shallow, anterior extension of the palpebral furrow); a parafrontal band is more strongly developed; the eye is slightly shorter (mid-L1 to mid-L3, compared with S0 to mid-L3); S0 is shallow medially and the subtriangular occipital ring has median length c. 0.39 that of the glabella (compared with 0.24, and an almost transversely straight posterior margin). Caecal venation, clearly seen on the preglabellar field in illustrations of Moroccan cranidia, is preserved rarely in the Turkish material (for example Pl. 1, Fig. 15). *P. (P.) interscriptus* is from the *Cephalopyge* Zone, lowest but one of the zones established by GEYER (1990a) for the Middle Cambrian in Morocco, and one of the paratypes (GEYER, 1990b, pl. 45, fig. 4) is associated with a fragment of fixed cheek of *Acadoparadoxides.* GEYER's illustrations show the preglabellar field apparently only gently declined, but this feature depends on preservation and the steep declination as shown by GEYER (1990b, pl. 42, fig. 11b) for *P. (P.) elegans* may prove to be more typical of the subgenus. In *P. (P.) pisidianus* the preglabellar field varies slightly in length (estimated 0.13 to 0.18 that of glabella) but may appear longer in compressed material. Cranidia of *P. (P.)* sp. from the "summit of the Lower Cambrian" in Sardinia illustrated by PILLOLA (1991, pl. 30, figs. 1-3) are too deformed for detailed comparison; but the glabellar outline is broadly similar to that of *P. (P.) pisidianus,* with L1 shorter than L2-3, though the preglabellar field is shorter and less well defined. As far as comparison is possible, *P. (P.) polonicus* ORŁOWSKI (1964, p. 88, pl. 11, figs. 1-6), from the early Middle Cambrian of Poland, is particularly distinguished from the Turkish species by the less arcuate anterior margin, which ends in-line with the centre of the proportionately shorter frontal glabellar lobe rather than almost opposite S3.

A syntype cranidium of *Protolenus (Protolenus) elegans* MATTHEW, 1892, from New Brunswick, eastern Canada, illustrated by GEYER (1990b, pl. 42, figs. 11a, b) has much in common with the new species, including

L1 slightly shorter (exs.) than L2-3 and the node-like adaxial development of the eye ridge. But it differs in the slightly shorter, narrower frontal glabellar lobe and the outline of the narrower (sag.) anterior border, which is notably less convex and ends much farther forwards. In the same specimen and in syntype cranidia of two other Canadian species, *P. (P.) articephalus* (MATTHEW, 1886) and *P. (P.) paradoxides* MATTHEW, 1892 (see GEYER, 1990, pl. 42, figs. 9, 10), the frontal portion of the palpebral furrow is more strongly developed than in *P. (P.) pisidianus* and its truncation of the eye ridge is more clearly visible.

Genus *Latoucheia* HUPÉ, 1953

Type species. *Protolenus latouchei* COBBOLD, 1910, p. 42, by original designation of HUPÉ (1953, p. 218).

Latoucheia (s.l.) sp.
(Plate 1, Figure 20; Plate 2, Figures 1-3, 5, 6)

Figured specimens: IRScNB Nos. a 8822, a 8828.

Horizon and localities: Çal Tepe Formation, Çiloğlantarla Tepe, Localities B.45-3 and B.45-3a.

Description and discussion:
Cranidium No. a 8822 generally resembles specimens assigned by GEYER (1990b, p. 198, pl. 50, figs. 9-12) to *Latoucheia (Pseudolenus)* HUPÉ (1953, p. 230, pl. 10, fig. 18) from the *Cephalopyge* Zone of Morocco. Differences include the relatively wider (sag.) anterior border and narrower (sag.) preglabellar field with median tubercle of the Turkish specimen. The latter may also have a longer frontal glabellar lobe and lateral glabellar furrows that are directed less strongly backwards adaxially; but preservation is insufficient for assessing these features, or the possible presence of a baccula as shown in some of GEYER's illustrations. An additional cranidium (Pl. 2, Fig. 6) has the anterior area broken and the presence of a median tubercle cannot be confirmed, but radiating caecal venation is developed on the preglabellar field. An incomplete latex cast of No. a 8822 (Pl. 1, Fig. 20) shows the strong curvature of the anterior cephalic margin, the low anterior border, and the curved, widely divergent anterior section of the facial suture. The glabellar outline in the Turkish specimens is generally similar to that of *Latoucheia (Latoucheia) pusilla* GEYER (1990b), also from the *Cephalopyge* Zone of Morocco; but the latter has a relatively longer frontal glabellar lobe and the anterior area is narrower (tr.), with the anterior border furrow ending in-line with the front of the glabella instead of well behind it.

The type species of *Latoucheia, Protolenus latouchei* COBBOLD (1910, p. 42, pl. 7, figs. 1-6; see also COBBOLD, 1931, pl. 39, fig. 19 and LAKE, 1934, p. 177, pl. 23, figs. 4-7), was based mainly on cranidia, with two incomplete free cheeks, from the so-called *Protolenus* Limestone of Comley, Shropshire. The species is in need of modern revision but published descriptions, supplemented by topotype material, suggests that it differs from those discussed above in having a more convex preglabellar field, a higher, subcylindrical glabella, a low, weakly defined anterior border that widens (sag.) medially, and coarse, closely-spaced tubercles, particularly on the glabella, that become smaller on the preglabellar field. Whether these differences are of more than specific significance has still to be demonstrated.

Family ? CORYNEXOCHIDAE ANGELIN, 1854

Subfamily ? CORYNEXOCHELLINAE SUVOROVA, 1964
Genus *Corynexochella* SUVOROVA, 1964

Type species: *Corynexochella occulta* SUVOROVA, 1964, by original designation.

Corynexochella? venusta n. sp.
(Plate 1, Figures 9, 12, 13, 17, 18, 22)

Derivation of name: venusta (Latin), elegant.

Diagnosis:
Small trilobites with cranidium semicircular in outline, strongly convex longitudinally and transversely; unfurrowed glabella expands gently forwards from S0 to broadly rounded frontal lobe that overhangs narrow (*sag.*), flat, anterior border; axial furrow straight, deep; large occipital ring has low median tubercle just behind centre, is produced backwards and upwards to form short, stout occipital spine, and curves forwards abaxially to merge with fixigena; small palpebral lobe, abaxially inclined, sited well forwards, in front of line through centre of glabella; librigena not known, but evidently very small, narrow; fixigena plump, quadrant-shaped; posterior border widest (exsag.) distally, narrows adaxially to end behind extremity of occipital ring; surface of exoskeleton apparently smooth, but fixigena shows traces of very fine pitting; anterior branch of facial suture traverses flat anterior border to meet margin at acute angle; posterior branch longer, curves gently to meet posterior margin almost at right-angle.

Type material: Çal Tepe Formation. Holotype cranidium IRScNB No. a 8815 (Pl. 1, Figs. 17, 18, 22); unfigured paratype cranidia IRScNB Nos. a 8817, a 8819; all from the Light-grey Limestone Member, 1.8 m above its base, at the southeast end of the Çal Tepe, near Seydişehir. Paratype cranidium IRScNB No. a 8821 (Pl. 1, Figs. 9, 12, 13), Çiloğlantarla Tepe, Locality FOB-54A.

Dimensions of holotype:
Median length of cranidium, excluding occipital spine = 3.5 mm (estd.); overall breadth of cranidium = 6 mm

(estd.); median length of glabella, excluding occipital ring = 2.8 mm; frontal breadth of glabella = 2.1 mm.

Description and discussion:
Little need be added to the specific diagnosis; an apparent basal glabellar lobe in the holotype is a superficial feature due to compression. *Corynexochella occulta* SUVOROVA (1964, p. 230, pl. 26, figs. 21-23, text-fig. 68) is based on poorly preserved material but differs from the Turkish species in having proportionately larger fixigenae and a lower glabella that projects less far in front of the fixigenae. In *C.? venusta* the occipital ring has the sub-spinose posterior margin strongly inclined posteriorly, in marked contrast to *C. occulta*, in which the occipital ring is apparently uniformly wide (sag.). Particularly distinctive of *C.? venusta* is the end of the occipital ring, which is confluent with the fixigena (Pl. 1, Fig. 18). No comparable structure is shown in SUVOROVA's drawing of the cranidium of *C. occulta* but could possibly be inferred from her photograph of the holotype (SUVOROVA, 1964, pl. 26, fig. 21). Each half of the posterior border in *C.? venusta* is a narrow (exsag.) triangle in outline but widens slightly about one-third its length from the axial furrow to form a small but distinct fulcral socket. A similar feature may be present in *C. occulta* but is not shown in SUVOROVA's reconstruction. The type material of *C. occulta* came from the Mayan Stage, late Lower Cambrian, of Siberia, and is slightly older than the Turkish species.

Comparison may also be made with the corynexochids *Acontheus rusticus* REPINA (*in* REPINA *et al.*, 1975, p. 131, pl. 15, figs. 12-15) and *A. verus* REPINA (*in* REPINA *et al.* 1975, p. 132, pl. 16, figs. 1-3) from the Middle Cambrian of Turkestan. *A. rusticus* has a smaller occipital ring, with more distinct median spine, than *C.? venusta*, and the facial suture cuts the anterior border farther from the axial furrow. In the holotype of the Russian species the glabella projects less far forwards than in *C.? venusta*, but in another specimen (*loc. cit.*, pl. 15, fig. 15) the glabella not only projects farther forwards but is narrower and more convex frontally. The occipital ring of *A. verus* resembles that of *C.? venusta* but the glabella, which carries traces of S1, is less elongated, the fixigena proportionately smaller, and the genal angle less distinct, so that the confluent lateral and posterior border furrows appear almost semicircular.

The type species of *Acontheus, A. acutangulatus* ANGELIN 1851 from the Andrarum Limestone (Middle Cambrian, *Solenopleura? brachymetopa* Zone) of Sweden, was redescribed by WESTERGÅRD (1950, p. 9, pl. 8, figs. 4-6) and exhibits features distinguishing it from both the above Russian species and *Corynexochella? venusta*. The glabellar outline is notably elongate, with concave rather than straight sides, and expands more strongly anteriorly so that the frontal breadth, attained well in front of the fixigenae, is twice the basal breadth; there is a distinct, transglabellar S1, traces of S2 and S3, and the genal angle is produced to form a sharp fixigenal spine. On the basis of their cranidia, *A. rusticus* and *A. verus* may be more appropriately assigned to *Corynexochella.*

Corynexochella may be compared with *Hicksia* DELGADO, 1904, based on *H. elvensis* DELGADO (1904, p. 333), from the Lower Cambrian of Portugal and redescribed by TEIXEIRA (1952, p. 13; includes synonymy). Both have an unfurrowed glabella, a flat anterior border, and swollen, quadrant-shaped fixigena; but in *H. elvensis* the eye is sited farther back, an occipital spine is not developed, and the surface carries a finely reticulate pattern of low ridges. Another genus is which the glabella expands forwards to a rounded frontal lobe, the eye is small, and the fixigena is swollen and quadrant-shaped, is *Trinia* POLETAEVA *in* POLETAEVA & CHERNYSHEVA, 1956, type species *P. bella* POLETAEVA *in* POLETAEVA & CHERNYSHEVA, 1956, from the upper Middle Cambrian of Siberia (see ORLOV, 1960, p. 78, fig. 90). Put originally in the Family Triniidae, the genus was classified as "Order and Family Uncertain" by HENNINGSMOEN (*in* MOORE, 1959, p. 0516), but has much in common with *Corynexochella*. Judging by the incomplete line illustrations, *Trinia bella* differs from the Turkish species in having a wider, more strongly expanded glabella, proportionately smaller fixigena, and the eye set farther back, almost opposite the centre of the glabella. The anterior border and anterior section of the facial suture of *Trinia* are insufficiently clear for comparison.

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Explanation of Plates

Plate 1

All specimens except one are from the Çal Tepe Formation at Çiloğlantarla Tepe; IRScNB No. a 8815 (Figs. 17, 18, 22) is from the Light-grey Limestone Member of the Çal Tepe Formation at its type section, near Seydişehir.

Figs. 1-3, 5, 6, 10, 11, 14, 15, 19 — *Protolenus (Protolenus) pisidianus* n. sp. 1, 5, dorsal and anterior views of small cranidium, paratype, IRScNB No. a 8813 (x 4), Loc. B.45-3; 2, 3, 6, dorsal, left lateral and anterior views of cranidium, holotype, IRScNB No. a 8814 (x 3), Loc. FOB-51; 10, 11, 15, anterior, right lateral and dorsal views of slightly compressed cranidium, paratype, IRScNB No. a 8816 (x 3), Loc. FOB-49; 14, longitudinally compressed cranidium, paratype, IRScNB No. a 8818 (x 3), Loc. B.45-2; 19, slightly sheared, small cranidium, paratype, IRScNB No. a 8820 (x 3.5), Loc. B.45-2.

Figs. 4, 7, 8, 16? — *Acadoparadoxides (Acadoparadoxides) mureroensis* (Sdzuy, 1958). 4, 7, 8, dorsal, right lateral and posterior views of pygidium, IRScNB No. a 8824 (x 4), Loc. FOB-50; 16?, incomplete, left librigena assigned questionably to the species, IRScNB No a 8825 (x 2.5), Loc. FOB-49.

Figs. 9, 12, 13, 17, 18, 22 — *Corynexochella? venusta* n. sp. 9, 12, 13, dorsal, anterior and right lateral views of cranidium, paratype, IRScNB No. a 8821 (x 6), Çiloğlantarla Tepe, Loc. FOB-54A; 17, 18, 22, anterior, dorsal and left lateral views of cranidium, holotype, IRScNB No. a 8815 (x 6), Çal Tepe Formation, 1.8 m above base of Light-grey Limestone Member, section at southeastern end of Çal Tepe, near Seydişehir.

Fig. 20 — *Latoucheia* (s.l.) sp. Latex cast of part of cranidium (see also Pl. 2, Figs. 1-3, 5), IRScNB No. a 8822 (x 3), Loc. B.45-3.

Fig. 21 — *Scenella?* sp. Dorsal view of shell, IRScNB No. a 8826 (x 4), Loc. B.45-3.

Figs. 23, 24 — *Ellipsocephalus* sp. Anterior (x 4) and dorsal (x 3.5) views of cranidium, IRScNB No. a 8823, Loc. B.45-2.

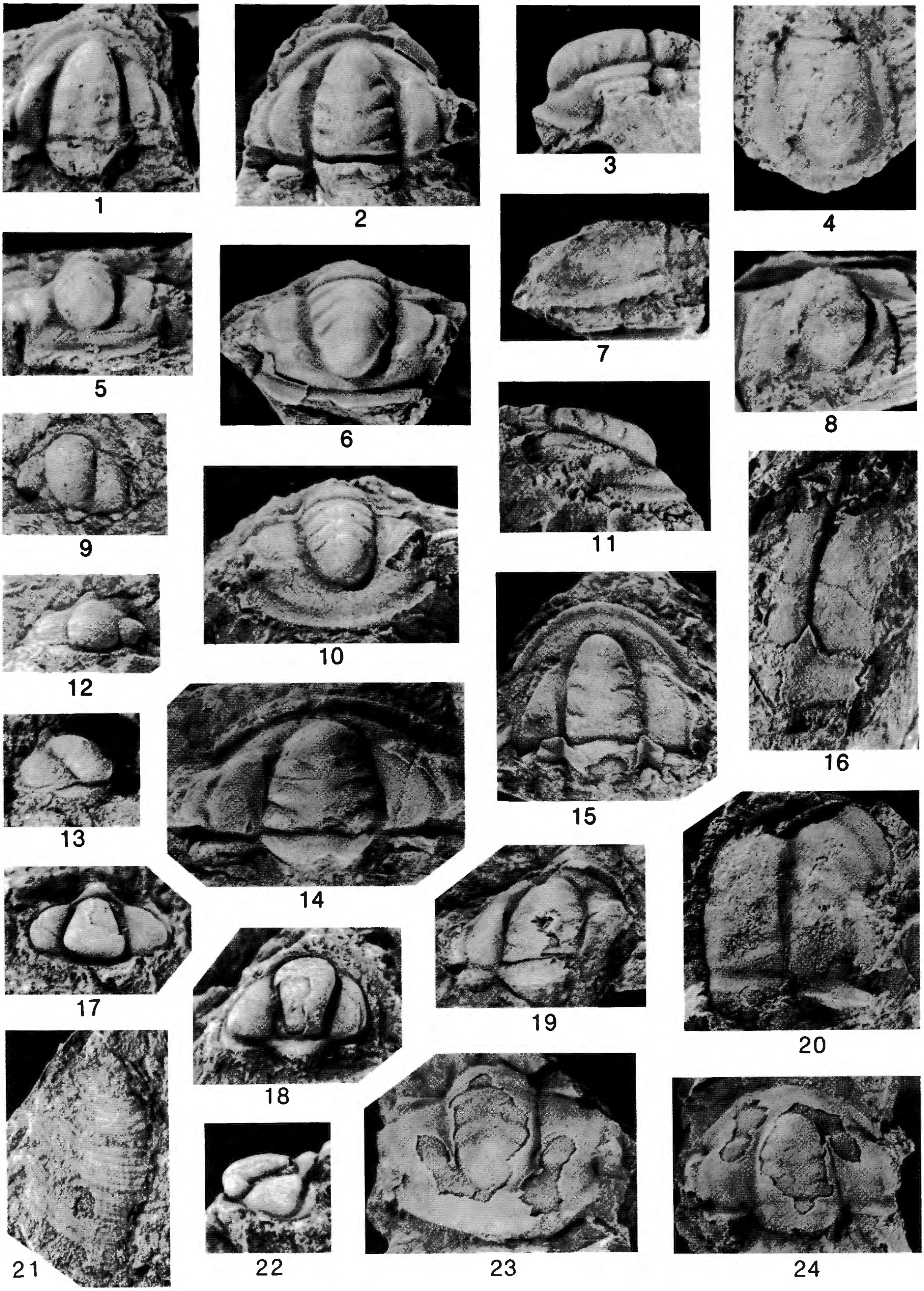
Plate 2

All specimens from the Çal Tepe Formation at Çiloğlantarla Tepe.

Figs. 1-3, 5, 6 — *Latoucheia* (s.l.) sp. 1, 2, 5, dorsal, anterior and right lateral views of cranidium (x 2), IRScNB No. a 8822 (see also Pl. 1, Fig. 20), Loc. B.45-3a; 3, enlargement of frontal area of same specimen, showing median tubercle immediately in front of preglabellar furrow (x 4); 6, front of damaged cranidium, showing caecal venation, IRScNB No. a 8828 (x 4), Loc. B.45-3a.

Figs. 4, 7-10, 12-14, 16-18 — *Acadoparadoxides (Acadoparadoxides) mureroensis* (SDZUY, 1958). 4, front of cranidium, IRScNB No. a 8829 (x 3), Loc. B.45-3a; 7, latex cast of left side of cranidium, IRScNB No. a 8830 (x 3), Loc. B.45-3; 8, latex cast of rear of cranidium, IRScNB No. a 8831 (x 3), Loc. B.45-3a; 9, anterior half of large glabella, IRScNB No. a 8832 (x 1.5), Loc. B.45-3a; 10, 14, hypostome, IRScNB No. a 8833 (x 4), Loc. B.45-3; 12, latex cast of right palpebral area, IRScNB No. a 8834 (x 2.5), Loc. B.45-3a; 13, 16, 17, dorsal, anterior and right anterolateral views of cranidium, IRScNB No. a 3067 (x 3), figured as *Acadoparadoxides* sp in Dean *et al.* (1993, pl. 1, fig. 18), Loc. B.45-3a; 18, part of left librigena, IRScNB No. a 8835 (x 1.5), Loc. B.45-3.

Figs. 11, 15 — Undetermined ellipsocephalid meraspid cranidia. 11, IRScNB No. a 8836 (x 5); 15, IRScNB No. a 8837 (x 5); both from Loc. B.45-3.



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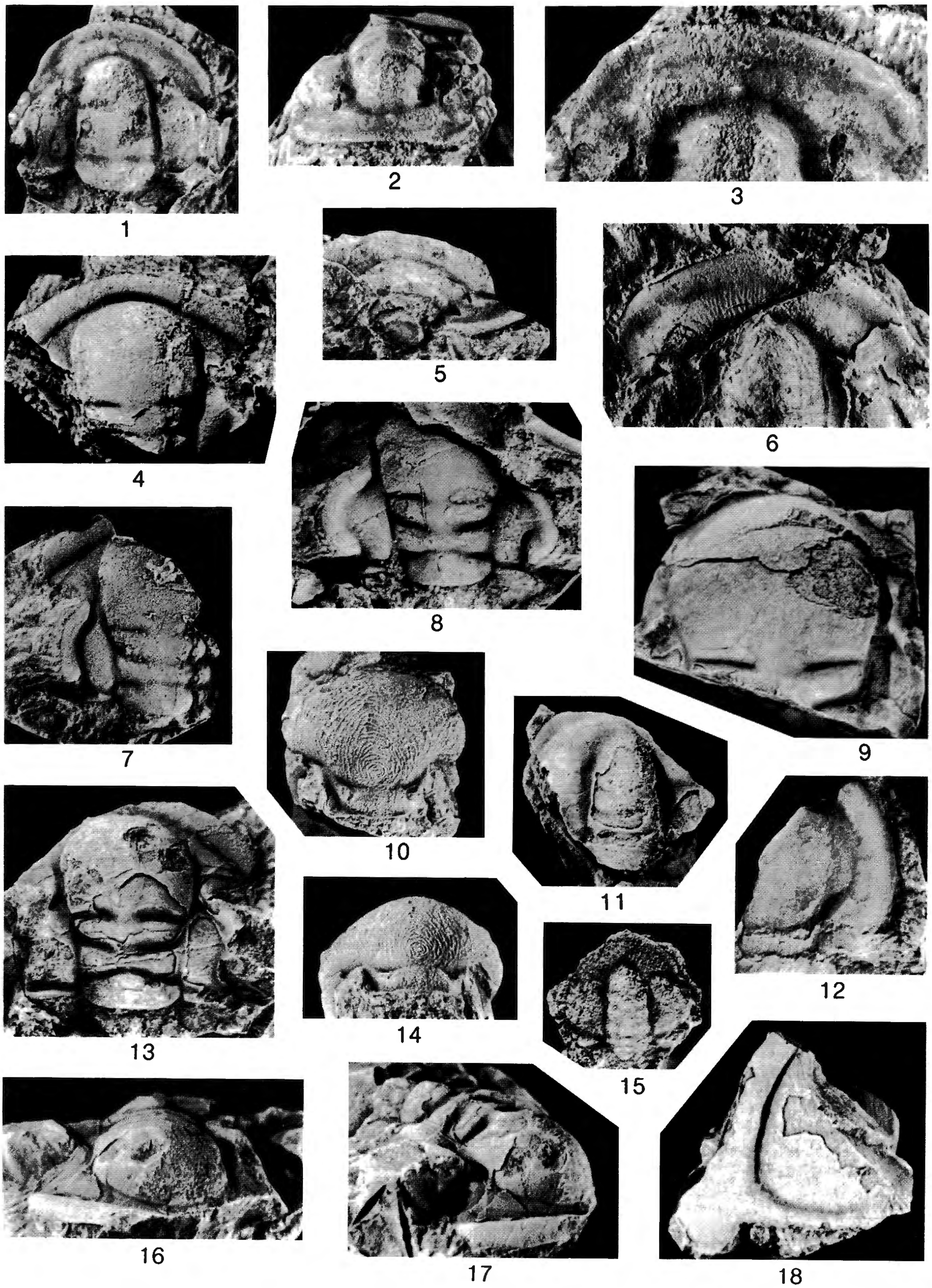

W.T. DEAN and N. ÖZGÜL — Plate 2.