

Upper Cambrian trilobites and brachiopods from Severnaya Zemlya, Arctic Russia, and their implications for correlation and biogeography

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Abstract – A new Late Cambrian trilobite–brachiopod fauna from the Kurchavinskaya Formation, Severnaya Zemlya, northern Siberia, allows correlation of the Ketyi Horizon of the NW Siberian succession with the *praecursor* Zone of the Baltic olenid zonation. The presence on Severnaya Zemlya of the typically Siberian trilobite *Kujandaspis ketiensis* indicates that even if Severnaya Zemlya lay on a separate plate, whether Kara or Arctida as postulated by other authors, then it was still probably not far from Siberia. However, the associated brachiopods are partly endemic to Severnaya Zemlya, thus giving some support to the independent palaeomagnetic evidence for their origin on a plate separate from Siberia.

Keywords: Cambrian, Arctic region, Severnaya Zemlya, Trilobita, Brachiopoda.

1. Introduction

Two of the most substantial terranes in Early Palaeozoic times were Baltica and Siberia. Baltica consisted of the northern part of Europe, eastwards to the Ural Mountains and from approximately the Trans-European Suture Zone in the south to the Barents Sea in the north (Cocks & Fortey, 1998). Siberia, although not occupying all of the political area of Siberia today, was nevertheless also very large, extending from the Arctic Ocean southwards into the northern part of China (Smethurst, Khramov & Torsvik, 1998). However, although substantial Upper Cambrian sedimentary sequences occur on both continents, and have yielded a considerable number of fossils, correlation between the two has been difficult, with different zonal schemes, mainly of trilobites, established in both Baltica and Siberia.

The islands of Severnaya Zemlya lie in the Arctic Ocean some 300 km to the north of the Taimyr Peninsula of the northern Siberian Platform. The Early Palaeozoic continental affinity and placement of Severnaya Zemlya (Fig. 1) has been, and remains, controversial. Some workers, for example, Tesakov *et al.* (1998), have simply regarded it as part of the margin of Siberia. Others, for example, Zonenshain, Kuzmin & Natapov (1990), have postulated a separate continental plate termed Arctida, which included the Chukot Peninsula and the Novosibirsk, De Longa and Wrangel islands, as well as Severnaya Zemlya and northern Taimyr (Fig. 2). Yet other geologists have regarded Severnaya Zemlya and the northern Taimyr

Peninsula alone as forming an independent Kara Plate, for which Metelkin *et al.* (2000) have collected palaeomagnetic data suggesting a separate polar wander path from Siberia until their merger in about the late Devonian (340 Ma). Torsvik & Rehnström (2001) have termed the ocean between the Baltica and Kara terranes the Aegir Sea, and documented that Baltica underwent a major rotation of 55 degrees relatively quickly during late Cambrian and early Ordovician time (500–478 Ma).

Fossil faunal data that might be relevant to elucidating the true palaeogeographical position of Severnaya Zemlya has so far been mostly exploratory, for example, the list of species annotated by Lazarenko (1982), but which has no descriptions or illustrations. However, new collections were made in 1999, and some of these provide the subject of this paper, in which we assess their stratigraphical age and also their biogeographical significance to the question of how closely Severnaya Zemlya may have been related to Siberia.

The Cambrian sections in NW Siberia are comparatively well known. They have yielded excellent Upper Cambrian faunal successions of typical platform type, especially those of the River Kulyumbe and other tributaries of the River Yenisei (Enisei). The trilobites and their biostratigraphy were described by Rozova (1968) and Lazarenko & Nikiforov (1968). However, correlation of these faunal successions with standard zonal schemes elsewhere in the world has proved difficult because so many of the species from northern Siberia are endemic (Shergold *in* Whittington *et al.* 1997). The new faunas from Severnaya Zemlya are important because they include a few distinctive trilobites that provide a novel tie-line between northern Siberian

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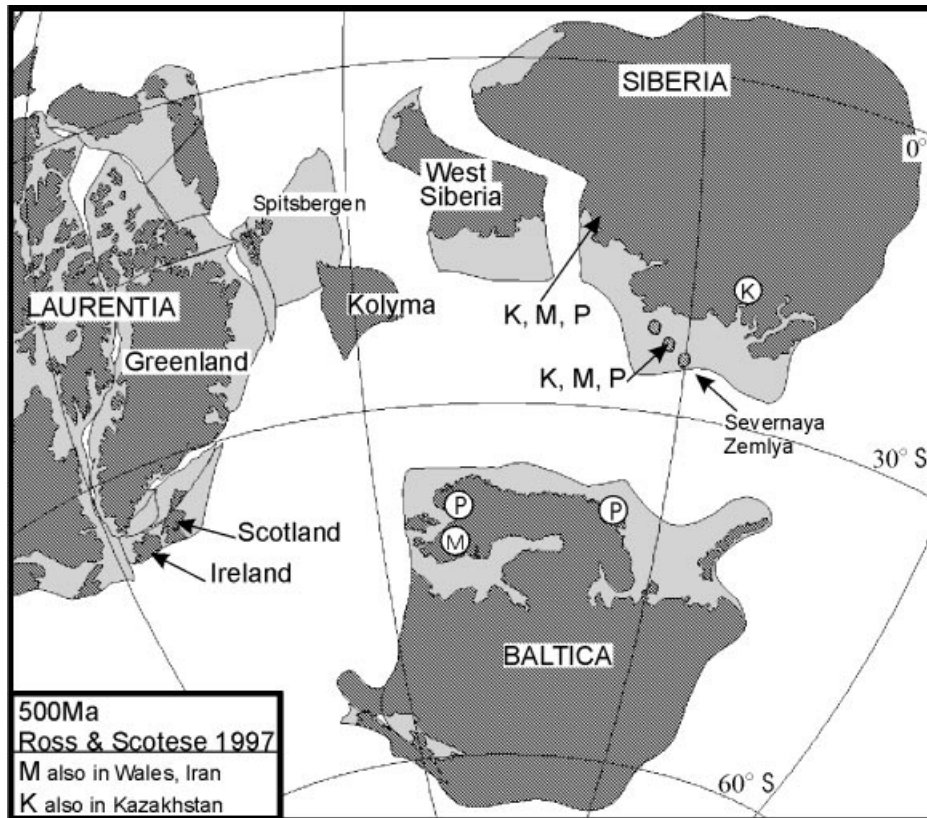


Figure 1. Late Cambrian palaeogeography (base map after Ross & Scotese, 1997), showing inferred proximity of Severnaya Zemlya and Siberia. K represents occurrences of *Kujandaspis* (= *Ketyna*), M = those of *Maladioidella*, and P = *Protoptelura holtedahli*. Deeper stipple is modern land; lighter stipple is modern sea.

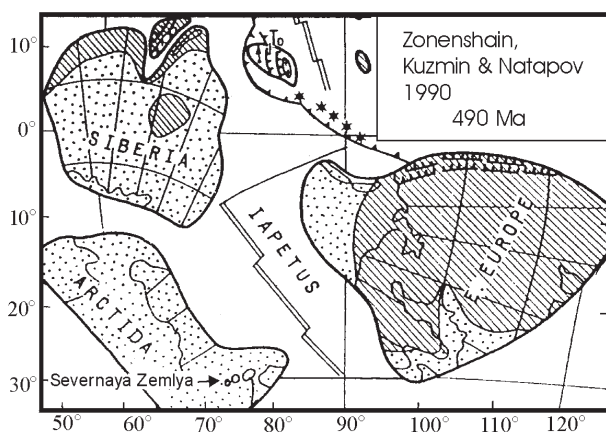


Figure 2. Basal Ordovician palaeogeography according to Zonenshain, Kuzmin & Natapov (1990, fig. 189), showing Severnaya Zemlya as part of the separate plate Arctida. Oblique shading – dry land; stipple – shallow sea; stars – calc-alkaline volcanics. To – Tom.

faunas and those of the well-known Baltic and Chinese sequences.

2. Stratigraphy and localities

The material considered here was collected by members of the Swedarcic International Expedition of

1999, led by D. G. Gee and V. L. Pease, to NW Siberia, in particular northern Taimyr and Severnaya Zemlya. All the specimens discussed in this paper were collected by O. K. Bogolepova and A. P. Gubanov from the Kurchavinskaya Formation in the Kruzhilikha River area of October Revolution Island, Severnaya Zemlya (latitude 79°10'42" N and longitude 97°17'56" E). There the Cambrian Kurchavinskaya Formation is overlain unconformably by the Kruzhilikha Formation. Elsewhere on October Revolution Island the Kruzhilikha Formation, which varies from about 100 m to 250 m in thickness, is overlain by the Ushakov, Ozernin and Strojnin formations of probable Ordovician age, and the Vodopad Formation of early Silurian (Llandovery) age. The detailed stratigraphy is described and discussed in Makarev, Lazarenko & Rogozov (1981) and by Bogolepova, Gubanov & Raevskaya (2001). The collection described here is from a number of individual scree blocks collected from within the Kurchavinskaya Formation, and the material consists of natural moulds of brachiopods, trilobites and eocrinoids preserved in indurated dark-coloured argillaceous sandstones. They occur mostly as scattered fragments strewn on bedding-planes (Samples 99/44 etc.), but are more rarely enclosed within beds of sandstone, as at Sample 99/47.

Table 1. Suggested approximate correlation of selected Upper Cambrian stratigraphical schemes

Olenid zones (Henningsmoen, 1957)	Rozova's (1968) horizons	Datsenko <i>et al.</i> (1968) zones in NW Siberian Platform	Australian stages (Shergold, in Whittington <i>et al.</i> 1997)
<i>Acerocare</i>	Lopari		Datsonian
<i>Peltura scarabaeoides</i> <i>Peltura minor</i> } <i>Protopeltura praecursor</i> <i>Leptoplastus</i> <i>Parabolina spinulosa</i>	Mansi		Payntonian
<i>Olenus</i> (upper part)	Ketyi Yuraki Entsi Madui	<i>Dolgeuloma–Kaninia</i> <i>Kujandaspis</i> <i>Amorphella</i> <i>Irvingella norilica</i> }	Iverian Idamean (part)

3. Faunas and biostratigraphical age

The following fossils were identified:

Sample 99/42: Trace fossil: *Rusophycus* sp.

Sample 99/43: Brachiopods: indet. orthoid A, Eoorthid or Euorthisinid gen. et sp. nov., *Finkelnbergia* sp.

Sample 99/44: Trilobites: *Kujandaspis ketiensis* (Rozova), *Protopeltura holtedahli* Henningsmoen; Brachiopods: lingulides indet., Eoorthid or Euorthisinid gen. et sp. nov., *Finkelnbergia?* sp., *Orusia?* sp., indet. orthoid B; Echinoderm: eocrinoid columnals.

Sample 99/45: Brachiopod: *Billingsella* sp.

Sample 99/46: Brachiopod: huenellid gen. et sp. indet.

Sample 99/47: Trilobites: *Maladioidella* aff. *abdita* (Salter), olenid indet.

Lazarenko (1982) gave a general correlation of the succession in Severnaya Zemlya with those of Novaya Zemlya and the Kharaulakh Hills in the lower reaches of the Lena catchment. The upper part of the Kurchavinskaya Formation was correlated with the upper half of the Upper Cambrian, equivalent to most of the Iverian and the Payntonian stages of the Australian succession (Shergold in Whittington *et al.* 1997, p. 309). Here we infer that the presence of *Kujandaspis ketiensis* indicates correlation with the Ketyi 'horizon' (approximately a substage) in northern Siberia, as discussed below, whereas the presence of *Protopeltura holtedahli* allows approximate correlation with the *praecursor* Zone of the olenid zones of the Baltic Plate (see Table 1).

In northern Siberia, species of *Kujandaspis* (also recorded as *Ketyna*) are abundant and widespread in many sections, such as those along the rivers Kulyumbe and Chopko (Rozova, 1968, fig. 7, table 3; Datsenko *et al.* 1968, atlas, pp. 38–9), and the stratigraphical range of *K. ketiensis* is restricted to correlatives of the Ketyi horizon. Rozova (1968, p. 26) recorded '*K. aff. glabra*' from the overlying beds of the Mansi horizon, though this occurrence is not recorded in her figure 7. In Kazakhstan the type species of *Kujandaspis* occur in strata that Ivshin

(1956) correlated with equivalents of the Idamean Stage of Australia. In the Maly Karatau, Kazakhstan, Apollonov & Chugaeva (1983) recorded species of *Ketyna*, including *K. ketiensis*, from strata ranging up to the latest Iverian.

The type material of *Protopeltura holtedahli* is from strata in Norway inferred to lie between the *Leptoplastus* and *Protopeltura praecursor* zones of the Scandinavian olenid succession (Henningsmoen, 1957, p. 38). Nikolaisen & Henningsmoen (1985) recorded the same species from the *praecursor* Zone in the Digermul Peninsula, northern Norway. These levels, especially the *Leptoplastus* Zone, are difficult to correlate beyond areas where the olenid biofacies is developed, but they are homotaxially equivalent to part of the late Iverian Stage of Australia; they overlie the *Parabolina spinulosa* Zone, which is correlated with the earlier part of the Iverian by means of genera such as *Irvingella*, and the overlying *Peltura scarabaeoides* Zone is correlated approximately with the succeeding Payntonian Stage (Shergold in Whittington *et al.* 1997, pp. 308–9). Lazarenko identified *P. holtedahli* in collections from the River Lena and the Khoiguolakh-Yurage tributary of the Olenek River, north-central Siberia, in strata overlying beds with *Cedarellus felix* (= *Maladioidella abdita* according to Rushton & Hughes, 1996), *Parabolina spinulosa* and *Irvingella major* (Lazarenko, 1966, table facing p. 34). Its horizon therefore overlies the *spinulosa* Zone and is presumably about equivalent to the *Leptoplastus* or *praecursor* zones. Rozova (1968, table 4) correlated Lazarenko's fauna with her Ketyi horizon.

Maladioidella species occur throughout the Iverian, especially in its earlier part (Rushton & Hughes, 1996, fig. 8), and the genus is almost restricted to that stage. *M. abdita* occurs in the *spinulosa* Zone in Wales and Sweden, and is therefore early Iverian. The form from the Kurchavinskaya Formation in Severnaya Zemlya turns out not to be identical with *M. abdita* and may therefore be of a somewhat different age. The brachiopods found in the Kurchavinskaya Formation support the late Cambrian age in a general way, as do the eocrinoid columnals, which are similar to those from the late Cambrian of Utah.

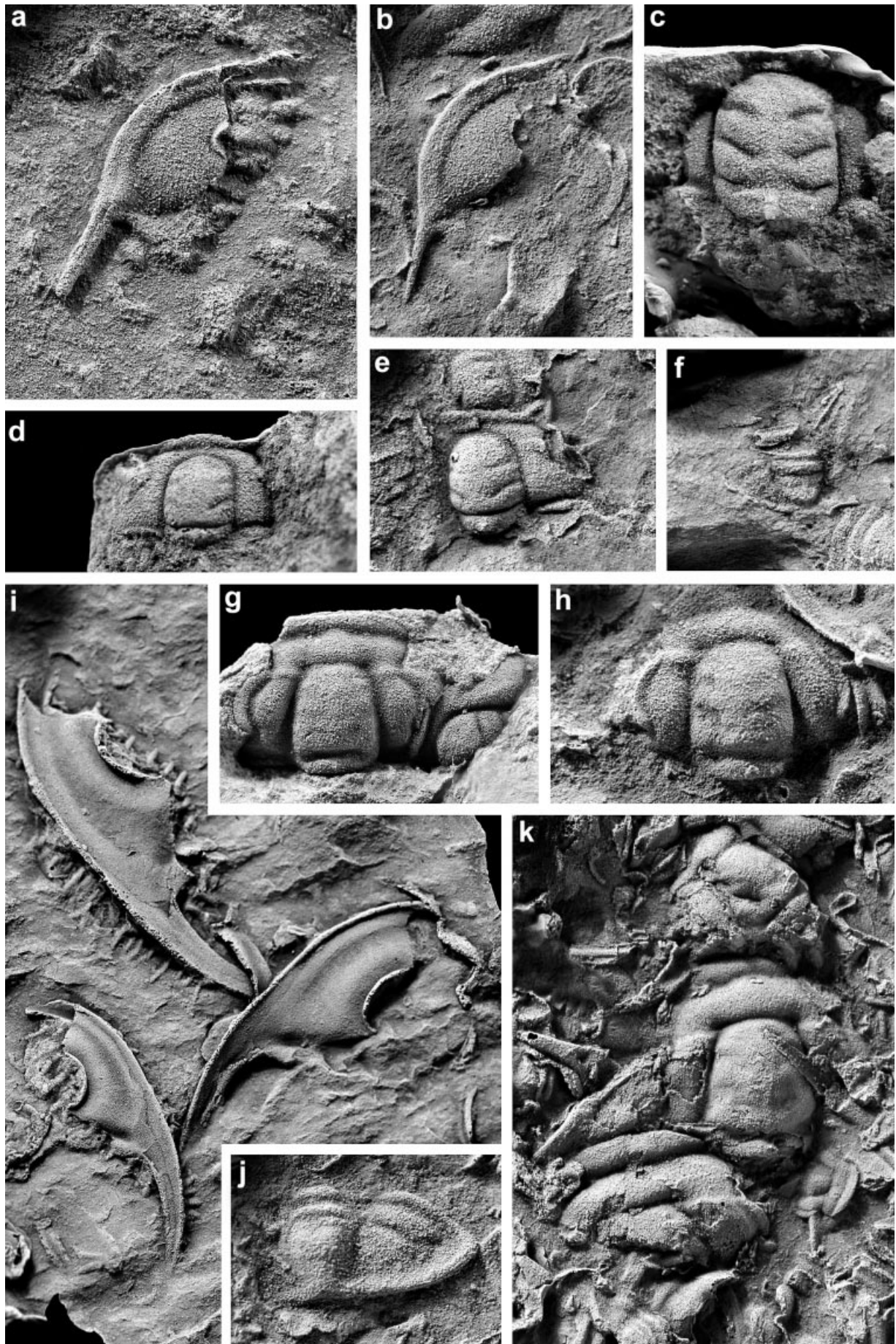


Figure 3. For legend see facing page.

4. Biogeographical assessment

Many of the trilobites that Makarev, Lazarenko & Rogozov (1981) recorded from the Middle and Upper Cambrian of Severnaya Zemlya are widely distributed and cannot readily be used to distinguish between Siberian and Baltic faunas, for example, *Anomocarina* and *Proceratopyge*. Likewise, *Irvingella* and species of the agnostid genera listed by Makarev, Lazarenko & Rogozov (1981) are found around several plates, and olenids are widely distributed where the appropriate facies is developed. *Maladioidella* (= *Cedarellus*) occurs along the northern margins of Gondwana (Rushton & Hughes, 1996, fig. 7) and has now also been found in Sweden: John Ahlgren of Hällekis, Västergötland, has shown one of us (Rushton) specimens collected from the *spinulosa* Zone of Västergötland. The brachiopods are either cosmopolitan or endemic and probably new genera; they are therefore biogeographically equivocal. However, one trilobite in the present collections can be regarded as diagnostic biogeographically: *Kujandaspis ketiensis* is known only from NW Siberia, where it is widely distributed, and from Maly Karatau, Kazakhstan. The occurrence of this distinctive platform species in Severnaya Zemlya provides an indication that there was an intimate connection between this area and eastern Asia, rather than, for example, Baltica. The same affiliation is suggested by a few of the taxa recorded but not illustrated by Makarev, Lazarenko & Rogozov (1981), such as *Palaeodotes florens*, originally described by Lazarenko (1966, p. 49) from the River Olenek in northern Siberia. With its associated widespread forms, the new fauna is consistent with a deeper-water setting than that typical of the Siberian Platform, and would be explicable as coming from a site marginal to Siberia. The same conclusion is suggested also by many of the trilobites, especially the agnostids, recorded by Makarev, Lazarenko & Rogozov (1981). Limited though the trilobite evidence is, it does not suggest that it is necessary to invoke a placement of the Arctida or Kara terrane widely separate from Siberia in the late Cambrian.

However, the brachiopods, although difficult to determine in detail from the available material, do appear to include two genera not described from either Baltica or Siberia and which may prove to be endemic to Severnaya Zemlya, and thus, contrary to the trilobites, provide some evidence that the terrane upon which Severnaya Zemlya lay was separate from

Siberia, giving support to the palaeomagnetic data (Metelkin *et al.* 2000), which also indicate separation.

5. Palaeontological notes

The specimens are preserved in the Museum of Evolution, Uppsala University, Sweden (abbreviated PMU).

5.a. Trilobites

Kujandaspis ketiensis (Rozova, 1963) (Fig. 3g–k)

Ivshin (1956) proposed the genus *Kujandaspis* for plesiomorphic *Aphelaspis*-like ptychoparioids characterized by an inflated preglabellar field that deflects the frontal border forwards. The type species, *K. kujandensis* Ivshin, 1956, was described from the upper Cambrian of Kazakhstan from strata that he correlated with the *spinulosa* Zone. Lazarenko & Nikiforov (1968, p. 53), having studied part of Ivshin's material of *Kujandaspis* and compared it with collections from NW Siberia, concluded that *Ketyna* Rozova, 1963 (type species *K. ketiensis* Rozova, 1963, from the Upper Cambrian Ketyi horizon of the Kulyumbe River, NW Siberia) is a junior synonym of *Kujandaspis*, a view we accept because there are no significant features to separate the two genera.

Lisogor (*in* Zhuravleva & Rozova, 1977, p. 226) discussed these genera and favoured maintaining *Ketyna* on the basis of the following: pits or fossulae at the anterolateral corners of the glabella; the comparative length of the preglabellar field and anterior border; the form of the preglabellar swelling; the narrower anterior border furrow; the wider interocular fixigenae; and the longer papebral lobes. Other workers (Rozova, *in* Zhuravleva & Rozova, 1977; Apollonov & Chugaeva, 1983; Peng, 1992, p. 37) have followed Lisogor. We do not accept Lisogor's conclusions because considerable variation is reported in the fossulae (Lazarenko & Nikiforov, 1968, p. 54) and in features of the preglabellar field (Apollonov & Chugaeva, 1983, p. 69), and the proportions of the fixigenae and palpebral lobes are of no more than specific value. Possibly those authors were influenced by the presence of pits in the frontal border furrow of certain species that they assign to *Ketyna*, but which are not recorded in the type species, nor in *Kujandaspis*.

Our material consists of a dozen cranidia, all either fragmentary or small, two hypostomes, three imperfect pygidia and about twenty librigenae, some from

Figure 3. Trilobites from the Kurchavinskaya Formation (samples 44/7, 44/10, 44/11). (a–f) *Protopeltura holtedahli* Henningsmoen, all latex casts $\times 10$. (a, b) Librigenae, showing broad border, Sample 44/7, PMU Ru6 and Sample 44/10, PMU Ru7. (c) Cranidium showing elongate occipital node, Sample 44/10, PMU Ru8; (d, e) small cranidia, Sample 44/10, PMU Ru9, Ru10; (f) pygidium, Sample 44/7, PMU Ru11. (g–k) *Kujandaspis ketiensis* (Rozova). (g) Small cranidium, Sample 44/10, PMU Ru12, $\times 10$; (h) cranidium, Sample 44/10, PMU Ru13, $\times 10$, (latex); (i) three librigenae, Sample 44/7, latex cast of PMU Ru15, $\times 4$; (j) pygidium, Sample 44/10, latex cast of PMU Ru16, $\times 10$; (k) cranidia, Sample 44/11, latex cast of PMU Ru14, $\times 5$; the central example shows minute pits in the anterior border furrow which is deflected forward around the preglabellar boss.

relatively large individuals (Fig. 3i). The cranidia have a slightly tapered glabella, truncate in front, with a gentle preglabellar swelling that deflects the anterior border furrow and makes it shallower medially (Fig. 3k). Small cranidia have a nearly square glabella and a faint occipital node (Fig. 3g). Palpebral lobes are recurved and nearly half as long as the cephalic axis; in small cranidia they are proportionately longer, extending from opposite the front of the glabella to the middle of L1.

The cranidia resemble those of *K. ketiensis* of similar size (Rozova, 1968, pl. 9, fig. 7; Rozova in Zhuravleva & Rozova, 1977, pl. 10) in having the palpebral lobes about half the length of the glabella (including occipital ring) and interocular genae slightly less than half as wide as the glabella at the eye-line. In the otherwise similar form *K. kujandensis* (Ivshin, 1956, pl. 3, figs 14–22, 25) the palpebral lobes are a little shorter and the interocular genae are about one-third of the glabellar width. *K. rara* Ivshin (1956, pl. 8, figs 12, 24) has even narrower fixigenae. Rozova distinguished *K. glabra* (Rozova, 1968, pl. 9, figs 1–5) by its obsolescent glabellar furrows and deeper pits at the anterolateral corners of the glabella, but both Lazarenko & Nikiforov (1968) and Apollonov & Chugaeva (1983) consider *K. glabra* to fall within the infraspecific variation of *K. ketiensis*. Some comparable species assigned to *Ketyna*, namely *K. magniocolata*, *K. venusta* and *K. costifera* (Apollonov & Chugaeva, 1983, pp. 68, 71) and *K. striata* Peng (1992) differ especially in having definite pits in the frontal border furrow. In our material one specimen shows a suggestion of such pits (Fig. 3k), but, if present, they are very small and sparse.

The hypostome has morphology typical of natant ptychoparoids (Fortey, 1990, fig. 11). The librigena of *Kujandaspis* has not been described; in the larger examples that we refer to the species (Fig. 3i), the length of the preocular suture and the ocular incisure are each approximately equal to the minimum width of the librigena from the ocular incisure to the outer margin, whilst the postocular suture is a little longer. The genal spine is long and stout. The pygidia we refer to the species are short and transverse with 2–3 axial rings and 2–3 pleural furrows (Fig. 3j), as in the example figured as *K. kujandensis* by Lazarenko & Nikiforov (1968, pl. 14, fig. 5) but referred to *K. ketiensis* by Rozova (in Zhuravleva & Rozova, 1977, p. 77).

Protopeltura holtedahli Henningsmoen, 1957 (Fig. 3a–f)

Species of the genus *Protopeltura* differ from those of *Peltura* in having a more truncate front to the glabella, better marked glabellar furrows, generally a definite preglabellar field (albeit narrow), and a genal spine that is continuous with, or almost continuous with, the margin of the librigena. Species of *Protopeltura* are known from the mid-parts of the Upper Cambrian on the Baltic plate (Norway, Sweden, Denmark and the

Holy Cross Mountains of Poland), and in Avalonia, northern Siberia and Kazakhstan. Harrington & Leanza assigned a species from the Tremadoc of Argentina to the genus.

The specimens from Severnaya Zemlya include nine small cranidia (about 2–3 mm long, some fragmentary), nine librigenae (including specimens from larger individuals) and two poorly preserved pygidia. The glabella is very slightly tapered, with two pairs of well-marked furrows. The frontal area is about one-sixth of the cranidial length and is divided subequally into a frontal border and preglabellar field. The occipital ring has a well-marked elongate node (Fig. 3c). The librigenal border is relatively broad, the genal spine long; the pygidium is small, with two axial rings + terminal piece, and appears to have an entire, unspined border.

This form is most similar to *Protopeltura holtedahli* which Henningsmoen (1957, p. 227, pl. 23, figs 16–22) described from a level near the base of the *Protopeltura praecursor* Zone at Slemmestad, Oslo Fjord, Norway. The length–width ratio of the cephalic axis is comparable with the types of that species and the proportional lengths of the frontal area and palpebral lobe are similar, as are the widths of the interocular and postocular fixigenae. *P. holtedahli* is distinguished from other species of *Protopeltura* by the broad border of the librigena and the long genal spine, features seen in the present specimens. *P. aciculata pusilla* Westergård (1922, pl. 14, figs 14–17) has a cranidium quite similar to the form from Severnaya Zemlya, but the librigena has a narrower border and a shorter spine. *P. broeggeri* (Henningsmoen, 1957, pl. 23, figs 7–15) has wider genae and a longer pygidium. Other Scandinavian species have a shorter preglabellar field (or none), and some have a spinose pygidium. *Protopeltura kasakhstanica* Ivshin (1956, pl. 2, figs 4, 5), from the Selety Horizon in Kazakhstan, is illustrated by larger specimens that differ from *P. holtedahli* in having obsolescent glabellar furrows, a shorter frontal area and a more curved frontal margin. *P. olenusorum* Orłowski (1968, p. 275, pl. 7, figs 12–15, pl. 8, figs 1–3), from the Holy Cross Mountains of Poland, has weaker glabellar furrows, a feebler occipital node and narrower fixigenae.

The original material of *Protopeltura holtedahli* was from strata between the *Leptoplastus* Zone and the *Protopeltura praecursor* Zone, but the exact horizon is not certain (Henningsmoen, 1957, p. 38). *P. cf. holtedahli* occurs in 'Assemblage A' in the black shale member of the Kistedal Formation, Digermul Peninsula, northern Norway, which Nikolaisen & Henningsmoen (1985) correlated with the *praecursor* Zone. *P. holtedahli* is also recorded in NE Siberia, from sections in the lower reaches of the rivers Lena and Olenek (Lazarenko, 1966); in both sections it occurs in olenid–agnostid faunas which overlie strata suggestive of an early Iverian age (see Section 3, above).

Maladioidella aff. *abdita* (Salter, 1866) (Fig. 4a–c, e)

Rushton & Hughes (1996) discussed *Maladioidella* and its synonyms *Cedarellus* and *Iranella*, and re-described the widespread species *M. abdita* (Salter). The material from Severnaya Zemlya is comparable to *M. abdita*, and includes a cranidium, an articulated thorax with pygidium, and two pygidia, one associated with some thoracic segments. The cranidium (Fig. 4a) is fragmentary, but is 14 mm wide across the palpebral lobes and is estimated to be about 16 mm long axially. Its glabellar proportions are uncertain, but it agrees with *M. abdita* in that the frontal area is of about the same length as the distance from the front of the glabella to the inner ends of the S1 furrows. It differs from *M. abdita*, however, because in specimens of similar size the palpebral lobe is smaller, being only about half the length of the frontal area; plotted on Rushton

& Hughes' (1996) figure 6c it falls below the abscissa at 0.6. There are at least 12 thoracic segments (Fig. 4b), some of the posterior spines being long and falcate. In outline the pygidia resemble those of *M. abdita* (Rushton & Hughes, 1996, fig. 3g) and *Cedarellus felix* (Lazarenko, 1966, pl. 3, figs 6, 8), but the specimens from Severnaya Zemlya appear to differ in having narrower pleural regions.

Olenid indet. (Fig. 4d)

The single cranidium collected is not well preserved, but the nearly square glabella and slightly divergent preocular sutures are suggestive of a species of *Parabolinites* or *Parabolinella* such as *P. tumifrons* Robison & Pantoja-Alor (1968). It is too incomplete to be identified.

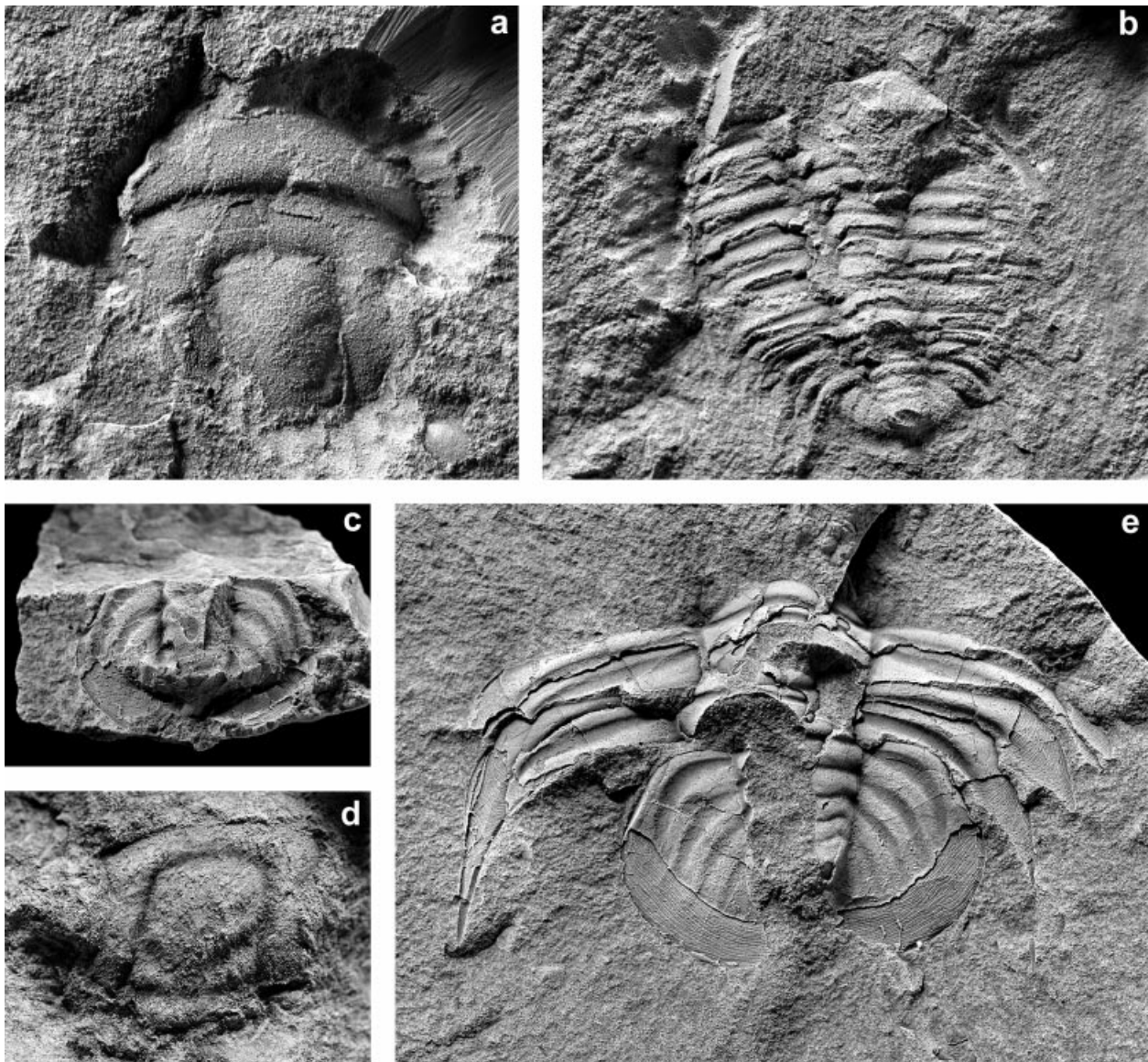


Figure 4. Trilobites from the Kurchavinskaya Formation (Sample 47). (a–c, e) *Maladioidella* aff. *abdita* (Salter). (a) Cranidium, PMU Ru1, $\times 3$; (b) thorax and pygidium, PMU Ru2, $\times 3$; (c) pygidium, PMU Ru3, $\times 2$; (e) posterior segments and pygidium, PMU Ru4, $\times 2$. (d) Olenid indet., cranidium, PMU Ru5, $\times 5$.

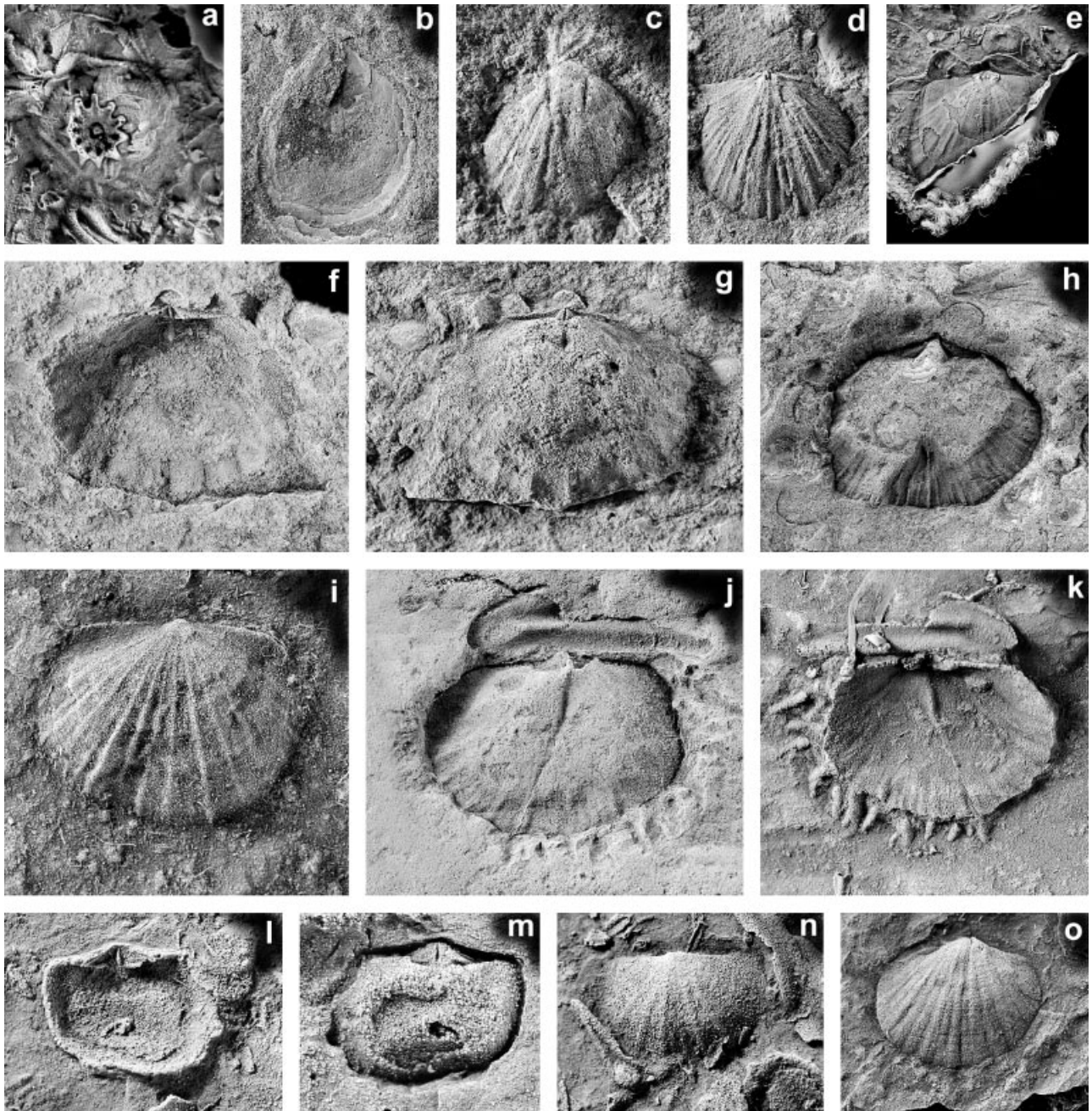


Figure 5. Brachiopods and echinoderm from the Kurchavinskaya Formation. (a) Latex cast of eocrinoid? columnal, Sample 44/10, PMU Ru28, $\times 3$. (b) Linguloid indet., dorsal valve interior, Sample 44/7, PMU Ru17, $\times 3.5$. (c) Indet. orthoid A, ventral valve internal mould, Sample 43/1, PMU Ru18, $\times 3$. (d–h) Euorthisid? gen. et sp. nov. (d) Dorsal valve internal mould, Sample 44/5, PMU Ru19, $\times 3$; (e) latex cast of ventral exterior, Sample 44/10, PMU Ru20, $\times 2$; (f, g) latex cast and internal mould of dorsal valve, Sample 44/5, PMU Ru21, $\times 2.5$; (h) internal mould of ventral valve, Sample 44/1, PMU Ru22, $\times 1.5$. (i–k) *Orusia?* sp. (i) Latex cast of ventral valve exterior, Sample 44/7, PMU Ru23, $\times 4$; (j, k) internal mould and latex cast of dorsal valve, Sample 44/7, PMU Ru24, $\times 3.5$. (l–o) *Finkelbergia?* sp. (l, m) Latex cast and internal mould of dorsal valve, Sample 44/10, PMU Ru25, $\times 6$; (n) latex cast of ventral valve exterior, Sample 44/7, PMU R26, $\times 5$; (o) latex cast of ventral valve exterior, Sample 44/7, PMU Ru27, $\times 4$.

5.b. Brachiopods

Makarev, Lazarenko & Rogozov (1981) listed *Eoorthis wichitaensis* Walcott, *Apheoorthis khantaiskiensis* Yadrenkina and *Billingsella* sp., from the upper part of the Kurchavinskaya Formation, but we have not been able to trace their material, which was not figured; all

three genera are cosmopolitan and range from the Upper Cambrian to the Tremadoc.

The Kurchavinskaya Formation appears to be relatively rich in brachiopods at several horizons, although, since the majority of the recovered specimens are from loose and weathered blocks, in most cases they are relatively poorly preserved. Indeterminate linguloids are

sporadically present, for example, in Samples 44/7 (Fig. 5b) and 44/9. The two specimens of *Billingsella* sp. (Sample 99/45) and the single specimen of huenelid gen. et sp. indet. (Sample 99/46) represent cosmopolitan genera. In addition, at least four different rhynchonelliform (previously termed articulate) genera occur, only two of which can be questionably attributed to a named genus. This partly reflects the fact that late Cambrian brachiopod faunas are relatively poorly known on a world-wide basis, apart from those occurring in North America (Laurentia). However, there are several papers that describe late Cambrian brachiopods from Siberia (e.g. Andreeva, 1968, 1987, 1989; Yadrenkina, 1974). In many cases, good interiors are not figured in those papers, which makes certain identification impossible, but even so, none of the forms from Severnaya Zemlya appears to be identical to taxa described by those authors. From Sample 43/1 an orthoid ventral internal mould (Fig. 5c) shows a pair of strong subparallel dental plates and a rhomboidal outline, and is termed here 'indet. orthoid A'. A relatively large biconvex ribbed orthoid (Fig. 5d–h) is identified from Samples 44/1, 44/5, 44/7 and 44/10. Despite its large size (maximum width 24 mm), it has very much reduced cardinalia, and appears to represent a new, perhaps endemic, genus within the Eoorthidae or perhaps even the closely related Euorthisinidae, although the latter family has not previously been reported from below the Tremadoc (Williams & Harper, 2000). Also in Samples 44/7 and 44/10, there are both ventral exteriors and dorsal interiors of a much smaller form with a maximum width of 3.5 mm (Fig. 5l–o); this is certainly within the Finkelbergiidae and closely comparable to *Finkelbergia buttsi* (Ulrich & Cooper, 1938), originally described from the late Cambrian Chepultepec Formation of Virginia (Ulrich & Cooper, 1938), although that species is slightly more alate and has wider socket plates than the Severnaya Zemlya form. *Finkelbergia* is widespread in Laurentia and Siberia in the late Cambrian and early Ordovician, but is not recorded from Gondwana or Baltica; the form from Severnaya Zemlya can only be identified as *Finkelbergia?* sp. until the interior of the ventral valve is known. From Sample 44/7 is another orthoid, known only from ventral externals (maximum width 10.6 mm) with widely separated small ribs (Fig. 5i), and from a single dorsal internal in which the cardinalia are poorly preserved (Fig. 5j, k; the apparent median septum is an accident of breakage at the time of deposition). This is reminiscent in some respects of *Orusia*, which is widely distributed in North America, Baltica, Wales, Argentina and North China (Williams & Harper, 2000), but can only be identified as *Orusia?* sp. There is yet a further indeterminate orthoid in the same sample, an incomplete ventral internal, which may be another eoorthid, but is listed here only as 'indet. orthoid B'. Thus the total brachiopod fauna

from the Kurchavinskaya Formation is not very similar to those from either Baltica or Siberia.

5. c. Echinoderms

The distinctive columnals (e.g. Fig. 5a) seen in the Kurchavinskaya Formation from Sample 44/7 have been identified by Dr A. B. Smith as very similar to those termed 'Eocrinoid? umbrella columnals' by Sumrall, Sprinkle & Guensburg (1997) from a limestone above the lower Franconian Dunderberg Shale of Utah, USA; the genus from which they came has yet to be described.

6. Conclusions

(1) A new Late Cambrian fossil fauna from Severnaya Zemlya provides evidence of the correlation of the Ketyi 'horizon' (substage) of the NW Siberian Platform with the *Protopeltura praecursor* Biozone of the standard Baltic sequence. Previously, direct evidence of correlation between Baltica and the NW Siberian platform has been elusive at this level.

(2) The evidence from the endemic trilobite species *Kujandaspis ketiensis* (Rozova, 1963) indicates a biogeographical connection between Severnaya Zemlya and the adjacent Siberian Platform. In contrast, the brachiopod fauna appears distinct from that of Siberia. Thus the brachiopods support the concept of Severnaya Zemlya as forming part of a Arctida or Kara terrane separate from Siberia, which has been postulated from independent palaeomagnetic evidence. However, the trilobites indicate that, whatever separation there was, it must have been small enough to maintain faunal contact with Siberia during the late Cambrian.

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