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BULLETIN 469

**MIDDLE CARBONIFEROUS FUSULINACEAN
BIOSTRATIGRAPHY, NORTHERN
ELLESMERE ISLAND (SVERDRUP BASIN,
CANADIAN ARCTIC ARCHIPELAGO)**

J.R. Groves, W.W. Nassichuk,
Rui Lin, and S. Pinard

1994



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Critical readers

C.A. Ross
GeoBiostrat
600 Highland Drive
Bellingham, Washington 98225-6410
U.S.A.

C.H. Stevens,
San José State University
San José, California, 95192, U.S.A.

Authors' addresses

J.R. Groves
Amoco Production Company
P.O. Box 3092
Houston, Texas 77253 U.S.A.

W.W. Nassichuk,
Rui Lin
S. Pinard
Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada
3303-33rd Street N.W.
Calgary, Alberta T2L 2A7

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PREFACE

Carboniferous and Lower Permian fusulinaceans are widely distributed throughout the Sverdrup Basin. They exhibit significant evolutionary changes that make them ideally suited to dating depositional and structural events within the basin. Since their discovery in the basin in 1950, they have been of extraordinary importance in developing stratigraphic and biostratigraphic frameworks for the basin. Furthermore, they provide a means of correlating Carboniferous and Permian strata within the Sverdrup Basin with other regions in the circum-Arctic area and throughout the world.

It is generally considered that Carboniferous and Permian strata in the Sverdrup Basin and elsewhere in the circum-Arctic regions of the world have significant petroleum potential. This report presents information that will assist in better understanding the geology and enabling better evaluation of hydrocarbon and mineral resources in an important part of Canada.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

Les fusulinacés du Carbonifère et du Permien inférieur sont largement répartis dans tout le bassin de Sverdrup. Les changements d'évolution significatifs qu'ils ont subis en font des chronomètres idéaux pour dater les événements sédimentaires et structuraux qui ont marqué le bassin. Depuis leur découverte dans le bassin en 1950, les fusulinacés ont eu une importance extraordinaire dans l'élaboration des cadres stratigraphiques et biostratigraphiques du bassin. De plus, ils constituent un moyen de corréliser les couches carbonifères et permiennees déposées dans le bassin de Sverdrup avec d'autres régions de la zone circum-arctique et dans le monde entier.

Il est généralement considéré que les couches carbonifères et permiennees dans le bassin de Sverdrup et ailleurs, dans les régions circum-arctiques du monde, présentent un potentiel pétrolier élevé. Le présent bulletin contient des informations qui aideront à mieux comprendre la géologie et à mieux évaluer les ressources en hydrocarbures et en minéraux dans une importante région du Canada.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

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MIDDLE CARBONIFEROUS FUSULINACEAN BIOSTRATIGRAPHY, NORTHERN ELLESMERE ISLAND (SVERDRUP BASIN, CANADIAN ARCTIC ARCHIPELAGO)

Abstract

The Sverdrup Basin is an elongate pericratonic depression underlying much of the Canadian Arctic Archipelago. The oldest rocks in the basin, nonmarine marlstones that constitute the Viséan Emma Fiord Formation, occur in isolated structural depressions along the southern margin and in the centre of the basin. The Borup Fiord Formation, consisting mainly of marine and nonmarine siliciclastics, was the first widespread sedimentary unit to be deposited following initial rifting and collapse of the basin. At its type section on northern Ellesmere Island, the Borup Fiord Formation contains a thin marine limestone with biserial ammonite and asteroarchaediscid foraminifers of Serpukhovian (Chesterian) age. This limestone is the only datable unit within the entire Borup Fiord Formation.

Continued rifting and subsidence of the Sverdrup Basin led to predominantly marine conditions, which are recorded at the basin margins by a thick succession of bioclastic limestone belonging to the Nansen Formation. The presence of primitive fusulinaceans from the lower several metres of the Nansen in its type area strongly suggests an early Bashkirian (Morrowan) age. Erosional relief, coupled with biostratigraphic evidence, indicates an unconformable contact between the Borup Fiord and Nansen formations. Successively higher deposits within the lower 350 m of the Nansen are characterized by fusulinacean assemblages that range from Bashkirian through early late Moscovian (early Desmoinesian) time.

Fusulinaceans are particularly useful in correlating Middle Carboniferous strata in the Sverdrup Basin with standard reference sections in subArctic North America, Russia, and elsewhere in the Commonwealth of Independent States. The Nansen contains species of primitive pseudostaffellins previously documented from the Bashkirian stratotype on the western slope of the south Urals. A lineage for the origin of the Fusulininae is tentatively proposed. Evolutionary inferences suggest that both pseudostaffellin and fusulinin clades arose in early Bashkirian time from the splitting of plectostaffelloid stock. One new species, *Plectostaffella reitlingeri* Groves, is described.

Résumé

Le bassin de Sverdrup est une dépression péricratonique allongée qui s'étend sous la grande partie de l'archipel Arctique canadien. Les roches les plus anciennes du bassin, soit des marnes non marines qui comprennent la Formation d'Emma Fiord du Viséen, reposent dans des dépressions structurales isolées situées le long de la marge méridionale et dans le centre du bassin. La Formation de Borup Fiord, surtout composée de roches silico-clastiques marines et non marines, a été la première unité sédimentaire étendue à se déposer après la distension initiale et la subsidence du bassin. À son stratotype situé dans le nord de l'île d'Ellesmere, la Formation de Borup Fiord contient un mince calcaire marin à bisériammininidés et astéroarchaediscidés du Serpukhovien (Chestérien). Ce calcaire est la seule unité datable de toute la Formation de Borup Fiord.

La distension continue et la subsidence du bassin de Sverdrup ont favorisé la mise en place de conditions surtout marines comme en témoignent les marges du bassin qui contiennent une épaisse succession de calcaire bioclastique appartenant à la Formation de Nansen. La présence de fusulinacés primitifs dans les quelques mètres inférieurs de la Formation de Nansen dans sa région type laisse fortement supposer un âge du Bashkirien (Morrowien) précoce. Le relief d'érosion, combiné aux indices biostratigraphiques, indique un contact discordant entre les formations de Borup Fiord et de Nansen. Les dépôts successivement plus hauts au sein des 350 m inférieurs de la Formation de Nansen sont caractérisés par des associations de fusulinacés dont l'âge varie du Bashkirien au début du Moscovien tardif (Desmoinesien précoce).

Les fusulinacés sont particulièrement utiles pour corrélés les strates du Carbonifère moyen dans le bassin de Sverdrup avec les coupes de référence dans les régions subarctiques de l'Amérique du Nord, de la Russie et de la Communauté des États indépendants. La Formation de Nansen contient des espèces de pseudostaffellinés primitifs antérieurement documentés à partir du stratotype bashkirien sur le versant ouest de l'Oural méridional. Une lignée est proposée provisoirement pour l'origine des Fusulininae. Des inférences sur l'évolution indiquent que les clades de pseudostaffellinés et de fusulininés sont apparus au Bashkirien précoce après la division du stock de plectostaffelloïdés. Une nouvelle espèce, *Plectostaffella reitlinger* Groves, est décrite.

Summary

Carboniferous and Permian carbonates and evaporites with associated basal redbeds, marine shale and volcanic rocks form the initial fill of the Sverdrup Basin, a pericratonic depression underlying much of the Canadian Arctic Archipelago. The basic architecture of the basin was caused by rifting in the Carboniferous. The oldest rocks in the basin, nonmarine marlstones of the Viséan Emma Fiord Formation, occur in isolated structural depressions along the southern margin and in the centre of the basin. The Borup Fiord Formation, mainly marine and nonmarine siliciclastics, was the first widespread sedimentary unit to be deposited following initial rifting and collapse of the basin. At its type section on northern Ellesmere Island, the Borup Fiord Formation contains a thin marine limestone with biserialaminid and asteroarchaediscid foraminifers of Serpukhovian (Chesterian) age. This limestone is the only datable unit within the entire Borup Fiord Formation.

Continued rifting and subsidence of the Sverdrup Basin led to predominantly marine conditions, which are recorded at the basin margins by a thick succession of bioclastic limestone belonging to the Nansen Formation. The Nansen contains up to 2500 m of rhythmically bedded or cyclic shelf carbonates in the type area, but the thickness may have been exaggerated, particularly in the lower part, by repetition due to thrust faulting. Many of the cyclic beds in the mid-shelf part of the Nansen Formation are capped by oolitic grainstone. Other grain components in the Nansen rocks include a wide variety of crinoids, brachiopods, bryozoans, fusulinacean and other foraminifers, algae, micritized grains, and a variety of other shell fragments.

Closer to, or at the edge of, the Nansen shelf, lenticular organic mounds (reefs), constructed of phylloid algae and *Palaeoaplysina* and stabilized by syndepositional submarine cement, may be present. Thick beds of oolitic sand and coarse fusulinacean grainstone also are common in the shelf edge setting. In the type area, strata in the lower (Bashkirian, Moscovian) part of the Nansen interfinger with basin centre evaporite, argillaceous limestone and shale beds of the Otto Fiord and overlying Hare Fiord formations.

Foraminifer assemblages from the Nansen Formation show close affinities with those documented from elsewhere in the Eurasian-Arctic faunal realm, particularly Russia, Kazakhstan and the Ukraine. Paleogeographic similarities, including the common development of the primitive pseudostaffellin lineage, facilitate direct correlations between the lower Nansen and equivalents in those countries.

The presence of primitive fusulinaceans from the lower few metres of the Nansen in its type area strongly suggests an early Bashkirian (Morrowan) age. Successively higher deposits within the lower 350 m of the Nansen are characterized by fusulinacean assemblages that range from Bashkirian through early late Moscovian (early Desmoinesian) time. The Nansen contains species of primitive pseudostaffellins previously documented from the Bashkirian stratotype on the western slope of the south Urals. A lineage for the origin of the Fusulininae is tentatively proposed. Evolutionary inferences suggest that both pseudostaffellin and fusulinin clades arose in early Bashkirian time from the splitting of plectostaffelloid stock.

An early Bashkirian (Morrowan) age is suggested for the lower Otto Fiord Formation. *Eoschubertella obscura* and *Ozawainella mosquensis* occur in a thin limestone band near the top of

the Otto Fiord. These establish a probable minimum age of late early Bashkirian (AkavasskyAskynbashsky), but they may be as young as early Moscovian. In sub-Arctic North American terms, this age is most likely Atokan.

Samples from the lower Hare Fiord Formation did not yield biostratigraphically useful fusulinacean taxa apart from those already observed in the underlying Otto Fiord. Nevertheless, the following ammonoids are from the lower 30 m of the Hare Fiord Formation in the type area, and Nassichuk (1975) suggested an Atokan (Bashkirian or early Moscovian) age: *Metapronorites ellesmerensis* Nassichuk, *Phanerocheras lenticulare* Plummer and Scott, *Syngastrioceras smithwickense* (Plummer and Scott), *Diaboloceras involutum* Nassichuk, *Neogastrioceras arcticum* Nassichuk, and *Phanerocheras lenticulare* Plummer and Scott.

Sommaire

Les roches carbonatées et les évaporites carbonifères et permienes ainsi que les couches rouges basales, les shales marins et les roches volcaniques associés ont été les premiers sédiments à remplir le bassin de Sverdrup, dépression péricratonique qui s'étend sous la grande partie de l'archipel Arctique canadien. L'architecture de base du bassin est due à une distension au Carbonifère. Les roches les plus anciennes dans le bassin, soit des marnes non marines de la Formation d'Emma Fiord du Viséen, occupent des dépressions structurales isolées le long de la marge méridionale et dans le centre du bassin. La Formation de Borup Fiord, principalement composée de roches silico-clastiques marines et non marines, a été la première unité sédimentaire étendue à se déposer après la distension initiale et l'effondrement du bassin. À son stratotype situé dans le nord de l'île d'Ellesmere, la Formation de Borup Fiord comporte un mince calcaire marin contenant des bisériamminidés et des astéroarchaediscidés du Serpukhovien (Chestérien). Ce calcaire est la seule unité datable de toute la Formation de Borup Fiord.

La distension continue et la subsidence du bassin de Sverdrup ont favorisé la mise en place de conditions surtout marines, comme en témoignent les marges du bassin qui contiennent une épaisse succession de calcaire bioclastique appartenant à la Formation de Nansen. Celle-ci contient jusqu'à 2 500 m de roches carbonatées de plate-forme cycliques ou à stratification rythmique dans la région type, mais l'épaisseur a pu être exagérée, en particulier dans la partie inférieure, par une répétition due à un chevauchement. De nombreuses couches cycliques de la partie de la Formation de Nansen sise au milieu de la plate-forme continentale sont recouvertes de grainstone oolitique. D'autres composantes granulaires dans les roches de la Formation de Nansen contiennent une grande variété de crinoïdes, de brachiopodes, de bryozoaires, de fusulinacés et d'autres foraminifères, d'algues, de grains micritisés et de divers autres fragments de coquilles.

À proximité ou en bordure de la plate-forme de Nansen pourraient être présents des monticules organiques lenticulaires (récifs), construits par des algues phylloïdées et *Palaeoaplysina* et stabilisés par un ciment sous-marin synsédimentaire. Les épaisses couches de sable oolitique et de grainstone grossier à fusulinacés sont fréquentes dans la marge de la plate-forme. Dans la région type, les couches de la partie inférieure (Bashkirien, Moscovien) de la Formation de Nansen s'interstratifient avec les couches d'évaporites, de calcaire argileux et de shale des formations d'Otto Fiord et de Hare Fiord sus-jacente du centre du bassin.

Les associations de foraminifères de la Formation de Nansen présentent des affinités étroites avec celles qui ont été documentées dans le passé dans le domaine faunistique eurasién-arctique, en particulier en Russie, au Kazakhstan et en Ukraine. Les similarités paléogéographiques, y compris l'apparition généralisée de la lignée ancestrale des pseudostaffellinés, facilitent l'établissement de corrélations directes entre la partie inférieure de la Formation de Nansen et ses équivalents dans ces pays.

La présence de fusulinacés primitifs dans les quelques mètres inférieurs de la Formation de Nansen dans sa région type laisse fortement supposer un âge du Bashkirien précoce (Morrowien).

Les dépôts successivement plus hauts au sein des 350 m inférieurs de la Formation de Nansen sont caractérisés par des associations de fusulinacés dont l'âge varie du Bashkirien jusqu'au début du Moscovien tardif (Desmoinésien précoce). La Formation de Nansen contient des espèces de pseudostaffellinés primitifs antérieurement documentés dans le stratotype bashkirien sur le versant ouest de l'Oural méridional. Une lignée est provisoirement proposée pour l'origine des Fusulininae. Des inférences sur l'évolution indiquent que les clades de pseudostaffellinés et de fusulinés sont apparus au Bashkirien précoce après la division du stock de plectostaffelloïdés.

Un âge du Bashkirien précoce (Morrowien) est proposé pour la partie inférieure de la Formation d'Otto Fiord. Les espèces *Eoschubertella obscura* et *Ozawainella mosquensis* se rencontrent dans une mince bande de calcaire près du sommet de la Formation d'Otto Fiord. Elles indiquent un âge minimal probable de la fin du Bashkirien précoce (Akavassky-Askynbashsky), mais elles pourraient aussi ne remonter qu'au Moscovien précoce. Dans la chronologie subarctique de l'Amérique du Nord, cet âge est fort probablement atokanien.

Des échantillons de la partie inférieure de la Formation de Hare Fiord n'ont pas donné des taxons de fusulinacés utiles pour la biostratigraphie, à l'exception de ceux déjà observés dans la Formation d'Otto Fiord sous-jacente. Néanmoins, les ammonoïdés suivants proviennent des 30 m inférieurs de la Formation de Hare Fiord dans la région type, et Nassichuk (1975) a proposé un âge atokanien (Bashkirien ou Moscovien précoce) : *Metapronorites ellesmerensis* Nassichuk, *Phaneroceras lenticulare* Plummer et Scott, *Syngastrioceras smithwickense* (Plummer et Scott), *Diaboloceras involutum* Nassichuk, *Neogastrioceras arcticum* Nassichuk, et *Phaneroceras lenticulare* Plummer et Scott.

INTRODUCTION

Middle Carboniferous (Bashkirian and Moscovian) fusulinaceans are widely distributed throughout the Sverdrup Basin, an elongate pericratonic depression that underlies much of the Canadian Arctic Archipelago (Fig. 1). Numerous species have been listed by Troelsen (1950), Tozer and Thorsteinsson (1964), Thorsteinsson (1974), Nassichuk (1975) and others, but the only ones that have been described previously in the literature are from the upper Moscovian (Podolsky and Myachkovsky) interval.

Thompson (1961) was the first to describe Carboniferous fusulinaceans from the Sverdrup Basin. He compared a number of species from upper Moscovian strata in the Nansen Formation on Ward Hunt Island with species from Desmoinesian strata in the United States and from equivalent strata in Asia and Europe: *Beedeina huntensis* (Thompson), *Fusulinella zelleri* Thompson, *Neostaffella wardensis* (Thompson), *Ozawainella? arctica* Thompson, and *Wedekindellina lata* Thompson.

Rui et al. (1991) described 60 species from upper Moscovian strata in the type area of the Nansen Formation (Fig. 1) and assigned them to two assemblage zones: the *Wedekindellina lata*-*W. uralica longa* Zone, which is equivalent to the Podolsky horizon in the Russian Platform, and the younger *Fusulinella eopulchra* Zone, which is equivalent to the Myachkovsky horizon in the Russian Platform. According to Rui et al. (*ibid.*), species in these zones in the Nansen characterize a specific paleogeographic region, designated the Arctic Province. Fusulinaceans in the Arctic Province appear to lack the diversity shown by those in other paleogeographic provinces in late Moscovian time; that is, in the Midcontinent, Andean, Tethyan, and Ural provinces.

In this report we have also described a number of species of *Neostaffella*, *Pseudostaffella*, *Beedeina*, *Wedekindellina*, and *Fusulinella* from the type area of the Nansen Formation in the same stratigraphic section from which Rui et al. (1991) identified the *Wedekindellina lata*-*W. uralica longa* Zone. Our materials, however, were derived from a fault-bounded

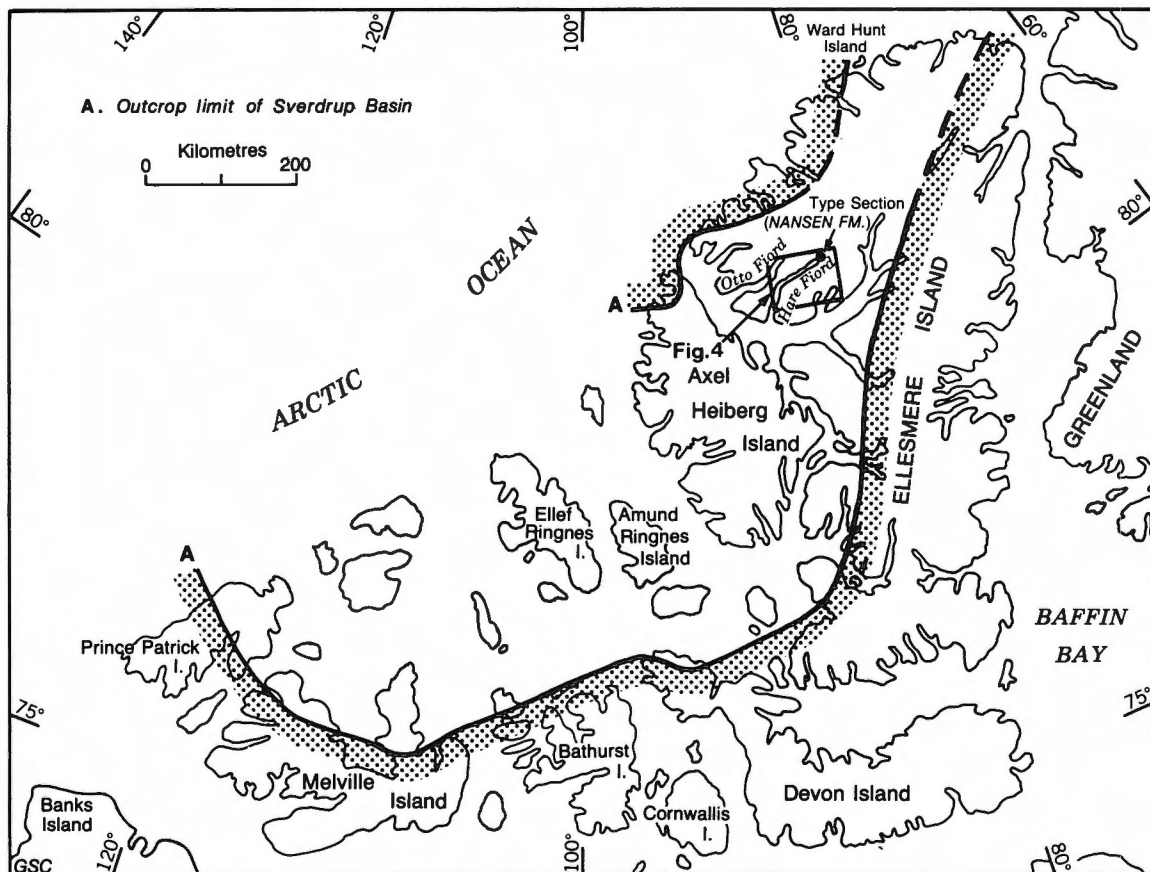


Figure 1. Index map of Canadian Arctic Archipelago and Sverdrup Basin. Detail of Hare Fiord area is shown in Figure 4.

block several hundred metres below the *W. lata*–*W. uralica longa* Zone of Rui et al. (*ibid.*) and we believe at least part of the upper Moscovian (Podolsky) interval in the type area of the Nansen is repeated due to faulting.

Thorsteinsson (1974) identified a number of Bashkirian and lower Moscovian fusulinaceans from strata throughout the Sverdrup Basin, particularly from the Canyon Fiord Formation on Ellesmere Island. The first description of fusulinaceans of that age in the basin, however, are contained in this report. In 1990, collections from the lower part of the type Nansen Formation and from equivalent strata in the nearby type areas of the Otto Fiord and Hare Fiord formations were assembled by two of the authors (JRG and WWN) and other members of the Working Group on Pennsylvanian Stratigraphy in North America.

In the same general area of northern Ellesmere Island, Mamet (*in* Nassichuk, 1975) reported *Eostaffella* sp., *Millerella* sp., *Pseudostaffella* sp., *Profusulinella* sp., and undetermined ozawainellids from Bashkirian strata in the Otto Fiord Formation in the vicinity of Hare Fiord. Moreover, in the same report, Mamet listed *Ozawainella* sp., and *Profusulinella* sp. from Bashkirian or lower Moscovian strata in the Hare Fiord Formation in the Blue Mountains, and *Eostaffella* sp. from Bashkirian strata in the lower part of the type Nansen Formation.

Ross (*in* Nassichuk, 1975) identified *Pseudostaffella gorskyi* (Dutkevich) and *Eostaffella kashira* var. *rhomboides* Rauser from lower Moscovian (Kashirsky) strata at the top of the Otto Fiord Formation in the Krieger Mountains, just south of Hare Fiord. Slightly higher in the same section, Ross (*ibid.*) also reported several fusulinaceans from strata that he considered to be of early Moscovian age (Vereysky or Kashirsky) in the lower part of the Hare Fiord Formation: *Eoschubertella* cf. *E. obscura* var. *mosquensis* Rauser, *Profusulinella* (*Aljutovella*) cf. *P. (A.) cybaea* Lentovich, *Staffella* (*Parastaffella*) sp., and *Pseudostaffella* ex gr. *P. gorskyi* (Dutkevich). Farther north, along the north coast of Ellesmere Island, Ross (pers. comm., 1977) reported several other species from lower Moscovian (Kashirsky) strata: *Profusulinella* cf. *P. paratimanica* Rauser, and *P.* cf. *P. prisca* Deprat from the lower part of a succession of limestones equivalent to the Nansen Formation on Ward Hunt Island, and *Profusulinella* cf. *P. prisca* Deprat, and *Pseudostaffella* sp. from near the base of the same formation at Cape Nares.

Finally, Mamet (*in* Thorsteinsson, 1974) identified several species of *Eostaffella* in an abundant and diverse fauna of foraminifers from the type section of

the Borup Fiord Formation on the north side of Hare Fiord. The Borup Fiord comprises mainly sandstone and conglomerate and underlies the Nansen or its lateral equivalent, the Otto Fiord Formation in central parts of the Sverdrup Basin. Mamet (*ibid.*) indicated that the Borup Fiord fauna is of Namurian age. New collections available to us from the type section of the Borup Fiord lack the diversity of those studied by Mamet, but are quite clearly of pre-Bashkirian (Serpukhovian) age. Although the base of the Namurian in Europe is virtually equivalent to the base of the Serpukhovian in the province of Bashkiria in the western Urals, the middle and upper Namurian (Namurian B, C) interval overlaps with the lower Bashkirian. Accordingly, in this report, the interval between Viséan and Bashkirian is referred to the Serpukhovian stage rather than to the Namurian.

In July, 1990, members of the Middle Pennsylvanian Working Group of the International Subcommission on Carboniferous Stratigraphy visited northern Ellesmere Island to collect fusulinaceans and other foraminifers, as well as conodonts, from Middle Carboniferous strata. The main objective was to compare Arctic taxa with coeval assemblages from standard reference sections elsewhere in North America and the European part of the Commonwealth of Independent States (C.I.S.) (Russian Platform, Donetz Basin, western Urals). Middle Carboniferous fossils from the Sverdrup Basin are strategic for phylogenetic reconstructions and biostratigraphy because of their paleogeographic position linking upper Paleozoic Old and New World faunal realms (Ross and Ross, 1985).

In this paper, we document the distribution of fusulinaceans from the type area of the Nansen Formation beyond the head of Hare Fiord (Fig. 1). We also discuss biostratigraphic relationships between the Nansen and the underlying Borup Fiord Formation as well as between the Nansen and the coeval but basinal Otto Fiord and Hare Fiord formations. We also describe and document phylogenetic lineages that shed new light on the origin and early evolution of the Fusulinidae, further heightening the value of those fossils for high resolution biostratigraphy.

REGIONAL STRATIGRAPHIC SETTING

Carboniferous and Permian strata in the Canadian Arctic Archipelago are contained within the Sverdrup Basin (Fig. 1). The basin formed by rifting and collapse of Precambrian to Devonian basement rocks in the underlying Franklinian Mobile Belt. The oldest sedimentary unit in the basin is the Lower Carboniferous (Viséan) Emma Fiord Formation, a nonmarine (lacustrine) marlstone, shale, coal-bed unit

deposited before or contemporaneously with the onset of the initial episode of extension that caused the Sverdrup Basin. Following deposition of the Emma Fiord, basal deposits of the Sverdrup Basin—sandstone and conglomerates of the Serpukhovian Borup Fiord Formation—were laid down. Subsequently, approximately 3000 m of upper Paleozoic, mainly marine strata, ranging from Middle Carboniferous (Bashkirian) to middle Permian (Wordian) were deposited in the basin. The Bashkirian to Lower Permian (Artinskian) interval is characterized by carbonate rocks and associated evaporites, shale, siltstone, red-weathering sandstone, and basal conglomerate. Thorsteinsson (1974) recognized a number of depositional sequences in the basin and noted that Bashkirian to Artinskian strata are contained within a series of facies belts shown schematically in Figure 2 that are roughly parallel with the depositional and structural axis of the basin.

The younger, upper Artinskian to Wordian succession that overlies these facies belts contains mainly siliciclastic rocks, but includes significant components of limestone and chert. These strata were deposited in more widely transgressive seas and were not restricted to the earlier established facies belts (Thorsteinsson, 1974; Davies and Nassichuk, 1991).

Stratigraphic relationships of Middle Carboniferous strata in the report area are shown in Figures 2 and 3. The Borup Fiord Formation is characterized by basal and basin-margin transgressive-regressive clastic redbeds, the Nansen Formation by basin-rimming

platform carbonates, the Otto Fiord Formation by basin-centre, rift-controlled evaporites and carbonates, and the Hare Fiord Formation by slope and basal shales and carbonates.

Beauchamp et al. (1989) summarized the sequence framework for Viséan to Wordian strata in the Sverdrup Basin. Each sequence is bounded by unconformities at the basin margin. The first of these sequences is Viséan, corresponding to deposition of the Emma Fiord Formation; the second sequence ranges from Serpukhovian to Asselian. Accordingly, all the fusulinaceans and other foraminifers discussed in this report are from strata contained in the second sequence. Beauchamp (1987) suggested that there are several hundred smaller scale cycles in the Carboniferous to Lower Permian carbonate succession in the Sverdrup Basin. Each of these cycles was probably controlled by minor glaciostatic sea level fluctuations. Nassichuk and Davies (1980) reported numerous carbonate-anhydrite cycles, ranging in thickness from 8 m to more than 50 m in the type area of the Otto Fiord Formation. Several comparable cycles were also recognized in the upper Moscovian (Desmoinesian) interval in the type area of the Nansen Formation by Rui et al. (1991).

LOCALITIES, BIOSTRATIGRAPHY, AND DEPOSITIONAL ENVIRONMENTS

Fusulinaceans and other foraminifers discussed in this report were collected from the Borup Fiord, Nansen,

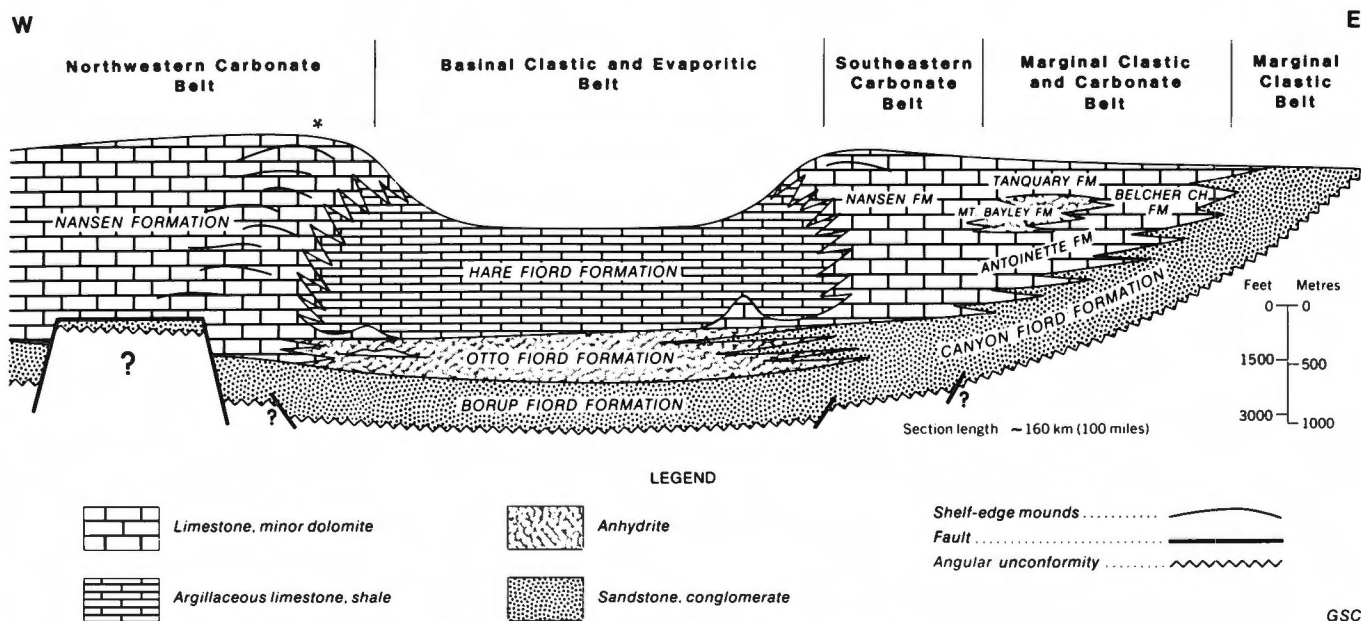


Figure 2. Schematic cross-section of northern Sverdrup Basin showing inferred relationships among Carboniferous and Lower Permian lithofacies. Type area of Nansen Formation marked by asterisk (after Nassichuk and Davies, 1992).

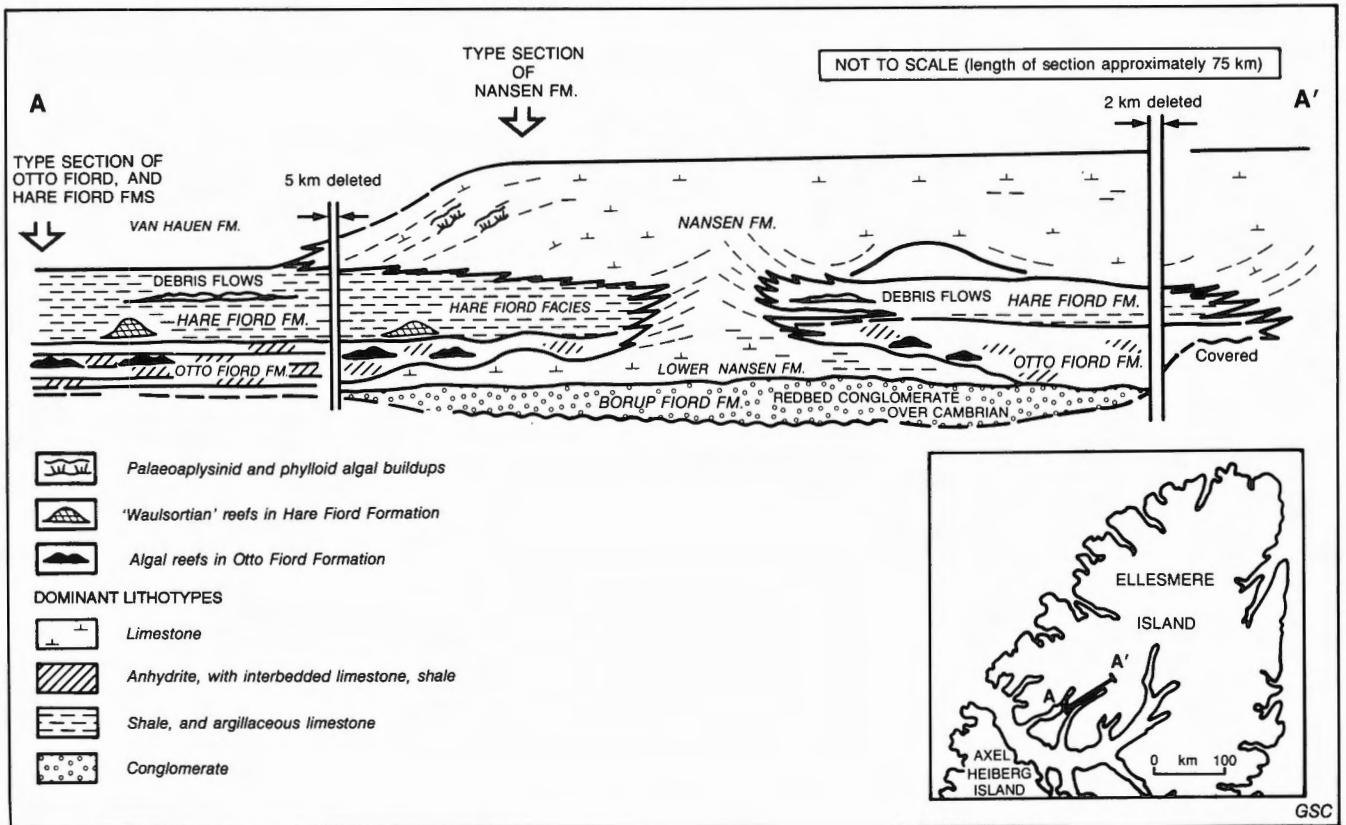


Figure 3. Schematic stratigraphic relationships between the Nansen Formation and basinal Otto Fiord and Hare Fiord formations along north side of Hare Fiord (from Davies and Nassichuk, 1991).

Otto Fiord, and Hare Fiord formations along the north side of Hare Fiord from the general vicinity of Van Hauen Pass to about 5 km east of the head of the Fiord (Fig. 4). The basal Borup Fiord Formation underlies both the Northwest Carbonate Belt, which contains the Nansen Formation, and the Basinal Clastic and Evaporitic Belt, which contains the Otto Fiord and Hare Fiord formations. The Borup Fiord Formation is cut out by faulting in the Van Hauen Pass area, but elsewhere in northern Ellesmere Island, and in northern Axel Heiberg Island, it outcrops beneath both belts. Along the north side of Hare Fiord, basinal anhydrite and limestone in the Otto Fiord and Hare Fiord formations interfinger intermittently with shelf carbonates of the Nansen Formation (Figs. 2, 3).

Borup Fiord Formation

Locality information

Type section at Stepanow Creek (Loc. 1, Fig. 4)

Foraminifers are present in three samples (Table 1) taken from a thin (11 m) bioclastic limestone in the

middle part of the type section of the Borup Fiord Formation at Stepanow Creek (Fig. 4). The type section is about 160 m thick, and consists mainly of red, quartzose sandstone and conglomerate. It rests unconformably on the Cambrian–Lower Ordovician Grant Land Formation and is capped by a covered interval thought to be a probable anhydrite tongue of the Otto Fiord Formation (Thorsteinsson, 1974). In his description of the type section, Thorsteinsson (*ibid.*) designated the fossil bearing limestone “Unit 3”.

Although the Borup Fiord Formation is widely distributed in axial regions of the Sverdrup Basin, the only fossils the formation has ever yielded are from Unit 3 in the type section. Mamet (*in* Thorsteinsson, 1974) reported an extremely diverse foraminiferal assemblage from Unit 3 in the type section but our collections do not show a comparable diversity.

Depositional environment

The Borup Fiord Formation is characterized by red and green-weathering conglomerate, sandstone, and siltstone, but locally there are interbeds and lenses of bioclastic limestone and dolomite in the upper part of

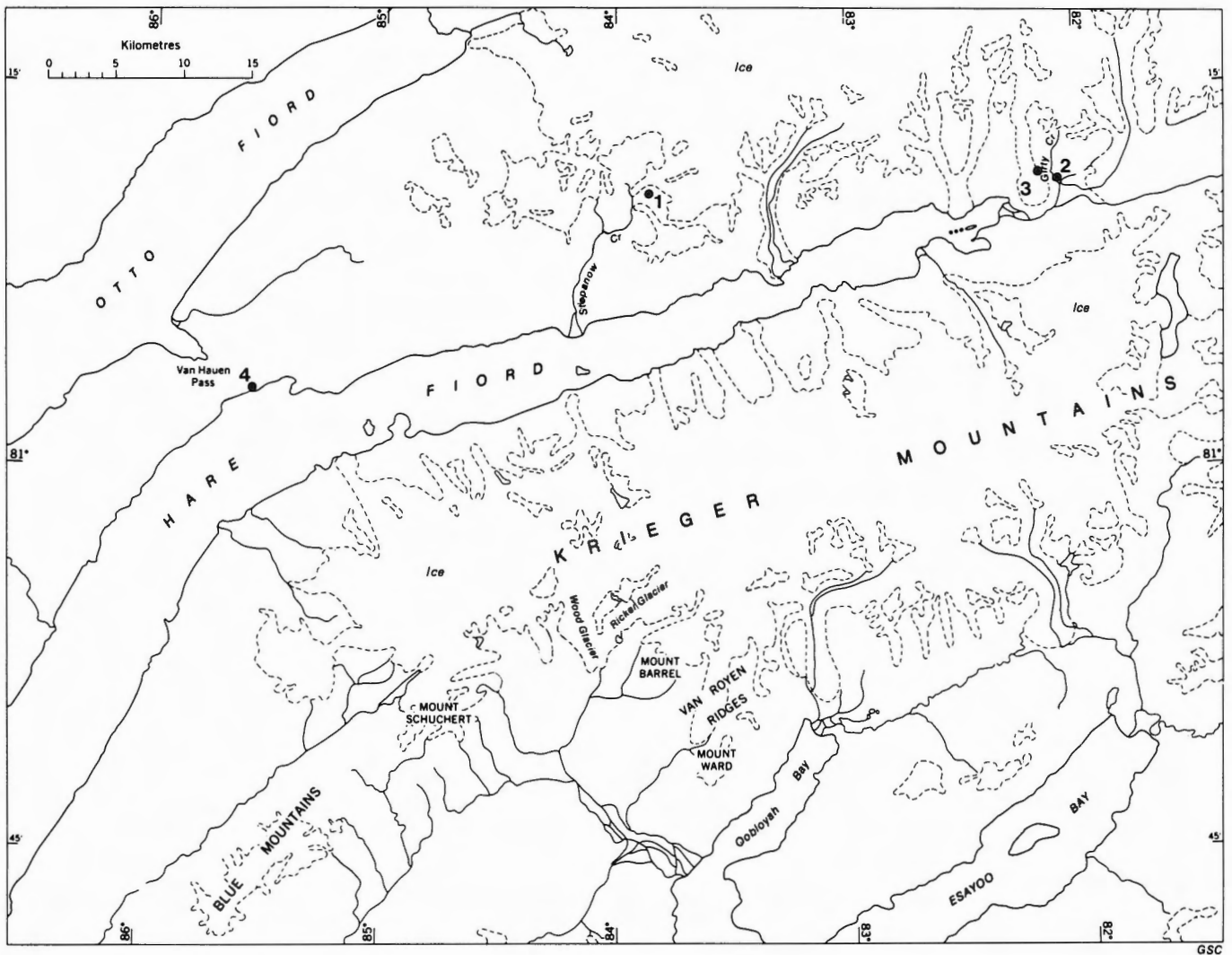


Figure 4. Index map of Hare Fiord area showing location of type section of Borup Fiord Formation (locality 1, near headwaters of Stepanow Creek), type section of Nansen Formation (locality 2, Girty Creek), principal reference section of Nansen Formation (locality 3, "glacier section"), and type sections of Otto Fiord and Hare Fiord formations (locality 4, vicinity of Van Hauen Pass).

the formation. Nassichuk and Davies (1980) suggested that in the Hare Fiord area, the lower part of the formation was probably deposited in coalescing alluvial fans, probably by intermittent streams that cut uplifted Cambrian rocks during a climatic regime characterized by distinctive seasonal contrasts (arid, hot summers; wet winters). Whereas the lower, clastic part of the Borup Fiord Formation, which is devoid of fossils, is undoubtedly nonmarine, limestones in the upper part, which contain the foraminifers discussed herein, are indicative of the first major marine transgression in the Sverdrup Basin.

Nassichuk and Davies (1980) noted limestone is particularly scarce in the Borup Fiord Formation at the head of Hare Fiord, where the formation attains its

maximum thickness (460 m) and where it is overlain by the Nansen Formation. Nevertheless, thin (1–2 m) limestone lenses interbedded with fine to very coarse (conglomeratic) siliciclastic rocks were examined at two levels in the Borup Fiord Formation, 133 m and 67 m, respectively, below the base of the type section of the Nansen Formation at Girty Creek. The lower of these limestone lenses is a fine, micritized algal-coated grain, peloidal packstone with an irregular fenestral fabric, whereas the higher is an algal-intraclastic floatstone containing large (3–8 mm) subangular intraclasts of subpeloidal packstone and algal boundstone. Both limestones probably record the onset of marine transgression, but the transgression is represented only by highly stressed, high-salinity tidal flat, or possibly very shallow peritidal environments.

TABLE 1
Foraminifers from type section of Borup Fiord Formation

| GSC locality | Stratigraphic position | Foraminifers and algae |
|--------------|------------------------|--|
| C-191081 | 72 m above base | <i>Archaeodiscus</i> of the group <i>A. krestovnikovi</i> Rauser-Chernousova <i>Biseriella?</i> sp. <i>Endothyra</i> spp. <i>Eostaffella</i> sp. <i>Eostaffellina</i> sp. intermediate <i>Biseriella-Globivalvulina</i> sp. <i>Janischewskina?</i> sp. <i>Tetrataxis</i> of the group <i>T. conica</i> Ehrenberg |
| C-191079 | 67 m above base | <i>Archaeodiscus?</i> sp. or primitive <i>Neoarchaeodiscus</i> sp. <i>Asteroarchaeodiscus baschkiricus</i> (Krestovnikov and Theodorovich) <i>Eolasiiodiscus?</i> sp. or <i>Monotaxinoides?</i> sp. <i>Neoarchaeodiscus postrugosus</i> (Reitlinger) <i>Neoarchaeodiscus subbaschkiricus</i> (Reitlinger) <i>Neoarchaeodiscus</i> spp. <i>Tetrataxis</i> of the group <i>T. angusta</i> Vissarionova |
| C-191078 | 65.5 m above base | <i>Archaeodiscus</i> of the group <i>A. krestovnikovi</i> Rauser-Chernousova <i>Asteroarchaeodiscus</i> sp. <i>Neoarchaeodiscus</i> of the group <i>N. parvus</i> (Rauser-Chernousova) |

Biostratigraphy

The Borup Fiord assemblage is dominated by archaeodiscaceans with subordinate endothyrids, biseriamminids, eostaffellids, and tetrataxids. Biostratigraphically useful archaeodiscaceans include *Archaeodiscus* of the group *A. krestovnikovi* Rauser-Chernousova, *Asteroarchaeodiscus postrugosus* (Reitlinger), *As. baschkiricus* (Krestovnikov and Theodorovich), *Neoarchaeodiscus subbaschkiricus* (Reitlinger), and *Neoarchaeodiscus* of the group *N. parvus* (Rauser-Chernousova). Documented concurrent ranges of these taxa in Europe and North America (including the Canadian Arctic) span the interval from late Viséan-early Serpukhovian at least through early Bashkirian (Pinard, 1989).

The highest sample (GSC loc. C-191081) contains certain of these archaeodiscaceans as well as *Eostaffellina* sp., *Biseriella?* sp., *Janischewskina?* sp., and a few specimens interpreted as being morphologically intermediate between *Biseriella* and *Globivalvulina*. *Eostaffellina* spp. are documented in

the Eurasian-Arctic realm in upper lower Serpukhovian (Steshevsky) through Bashkirian rocks (Wagner et al., 1979; Vdovenko et al., 1990). Species of *Biseriella* and *Janischewskina* are known to range from late Viséan to Permian, and late Viséan to early Bashkirian, respectively (Mamet and Pinard, 1985; Pinard, 1989; Vdovenko et al., 1990). *Globivalvulina sensu stricto* appeared in the late Serpukhovian (Zapaltyubinsky), and persisted into the Permian (Vdovenko et al., 1990). Thus, the age of our Borup Fiord samples can be no younger than early Bashkirian and probably no older than early Serpukhovian. The lower limit of the age range is problematic, however, depending to a great extent on the biostratigraphic significance of the biseriamminids thought to be transitional between *Biseriella* and *Globivalvulina*. In the absence of unequivocal *Globivalvulina*, we favour an undifferentiated, medial Serpukhovian (Steshevsky-Protvinsky) interpretation.

The Borup Fiord assemblage most likely indicates a correlation with the upper Chesterian Series of the North American Midcontinent (Fig. 5). Diverse

| W. AND MID-CONTINENTAL U.S.A. | | FORMER EUROPEAN U.S.S.R. | | | | | | NORTHERN ELLESMERE ISLAND | | | |
|-------------------------------|---------------------|--------------------------|----------|---------------------------------|---------------------------|------------------------------------|--|---|---|---|------------|
| SUB-SYSTEM | SERIES | SERIES | STAGE | URALS | E. EUROPEAN PLATFORM | DONETZ BASIN | CHARACTERISTIC TAXA | GLACIER SECTION | GIRTY CREEK | | |
| PENNSYLVANIAN (part) | DESMOINESIAN (part) | MIDDLE CARBONIFEROUS | UPPER | BOLSHEKYNSKY | MYACHKOVSKY | C ₃ ¹ (part) | <i>Fusulinella bocki</i> <i>Fusulinella eopulchra</i> <i>Fusulina cylindrica</i> | not sampled for this study | | | |
| | | | | | PODOLSKY | C ₂ ⁷ (M) | <i>Fusulina kamensis</i> <i>Fusulinella colaniae</i> <i>Fusulinella vozghalensis</i> | | | BLOCK 8 | |
| | | | | LOWER | KIROVSKY | KASHYRSKY | C ₂ ⁶ (L) | <i>Fusulina pseudoelegans</i> <i>Moellerites lопасniensis</i> | fault | remainder of section not sampled for this study | |
| | | | | | | TSNINSKY | C ₂ ⁵ (K) | <i>Ajjutovella priscoidea</i> <i>A. znensis</i> <i>Ajjutovella aljutovica</i> | | | |
| | | | | | VEREISKY | <i>Eoschubertella pauciseptata</i> | | BLOCK 7 | | | |
| | | | | | UPPER | ASATAUSSKY | MELEKESSKY | C ₂ ⁴ (J) | <i>Eofusulina triangula</i> <i>Ajjutovella tikhonovichi</i> | BLOCKS 5-6 | |
| | TASHASTINSKY | | UPPER | C ₂ ³ (H) | | <i>Profusulinella</i> spp. | | | | | |
| | MORROWAN | | MORROWAN | LOWER CARBONIFEROUS (part) | UPPER | LOWER | CHEREMSHANSKY | UPPER | C ₂ ² (G) | <i>Ozawainella</i> spp. | BLOCKS 1-4 |
| | | | | | | ASKYN-BASHSKY | PRIKAMSKY | C ₂ ¹ (F) | <i>Profusulinella staffellaeformis</i> <i>Ozawainella umbonata</i> <i>Ps. (Pseudostaffella) praegorskii</i> | | |
| | | | | | | AKAVASSKY | SEVERO-KELTMENSKY | C ₁ ⁵ (E) | <i>Ps. (Pseudostaffella) antiqua</i> | | |
| | | | | | | SYURANSKY | KRASNO-POLYANSKY | | <i>Eostaffella postmosquensis</i> | | |
| | | | | | | BOGDANOVSKY | VOZNESSENSKY | C ₁ ⁴ (D) | <i>Plectostaffella jakhensis (=bogdanovkensis)</i> | | |
| USTSAR-BAISKY | | ZAPAL-TYUBINSKY | | | | | <i>Monotaxinoides subplana</i> <i>Eosigmollina robertsoni</i> | | | | |
| MISSISSIPPIAN (part) | CHESTERAN (part) | LOWER (part) | UPPER | | PROTVINSKY | | | <i>Eostaffellina protvae</i> | BORUP FIORD FORMATION | | |
| | | | | | NIZHNE-GUBAKHINSKY (part) | STESHEVSKY (part) | C ₁ ³ (C) (part) | <i>Pseudoendothyra globosa</i> <i>Neoarchaedicus parvus</i> | | | |

Figure 5. Correlation of Girty Creek and glacier sections to standard reference sections of western and midcontinental United States and European part of C.I.S. No scale intended. Standard reference sections and characteristic taxa synthesized with modifications from Aisenverg et al. (1979, Fig. 1); Ross (1979, Fig. 1); Baxter and Brenckle (1982, Fig. 6); Groves (1983, Table 1; 1986a, Fig. 2; 1991, Fig. 3); Solov'eva (1986, Table 2); Sinitsyna and Sinitsyn (1987, Fig. 3); Vdovenko et al. (1990, Figs. 2, 3); Gibshman and Akhmetshina (1991, Fig. 6); and Brenckle (1991, Fig. 2).

asteroarchaediscids are known to occur in the Mississippi River Valley area at least as low as the Ste. Genevieve Limestone near the traditional Meramecian–Chesterian boundary. The appearance of *Asteroarchaediscus baschkiricus*, however, was reported by Baxter and Brenckle (1982) in the upper Batesville Formation of north-central Arkansas, a formation they considered approximately equivalent to the Menard Limestone of the lower upper type Chesterian succession. The middle Borup Fiord occurrence of *As. baschkiricus* therefore suggests a late Batesville/Menard or younger age.

Mamet (*in* Thorsteinsson, 1974, p. 88, 89) assigned the assemblage to his Zone 18 on the basis of *Asteroarchaediscus baschkiricus* and *Biseriella parva*, and considered the assemblage to be of early Namurian age within the upper *Eumorphoceras* ammonoid genozone (probably Protvinsky in the Russian sense).

Nansen Formation

Locality information

Type section at Girty Creek (Loc. 2, Fig. 4)

Twenty-four samples were collected from the lower 67 m of the type section of the Nansen Formation at Girty Creek (Fig. 4, loc. 2; Figs. 5, 6). The samples are from the basal lenticular carbonate unit that Rui et al. (1991) designated “Unit 1”. Thorsteinsson (1974), the only one to measure the type section in its entirety at Girty Creek, determined a thickness of approximately 2500 m (7780 ft.). As indicated earlier, we think that the thickness of the Nansen in the type area is likely exaggerated by stratigraphic repetition due to faulting. The Nansen Formation rests on the Borup Fiord Formation (Serpukhovian redbed conglomerate, sandstone and shale). Although the contact appears to be conformable and gradational upward into the Nansen carbonates at Girty Creek, local topographic relief is apparent on the Borup Fiord Formation surface directly north of Girty Creek, and accordingly, the contact is marked by an unconformity. The type section of the Nansen is directly overlain by basaltic volcanic flows and agglomerates of the Lower Permian Esayoo Formation.

The Nansen is the major shelf-forming carbonate succession around the margin of the Sverdrup Basin, and attains its maximum thickness in the type area where it is in a shelf-edge setting. The type section contains limestone, shale and anhydrite in its lower (Bashkirian, lower Moscovian) part, where interfingering with basin centre evaporite, argillaceous limestone, and shale of the Otto Fiord Formation and

overlying Hare Fiord Formation (Fig. 3) is apparent. The upper part of the Nansen (upper Moscovian to Sakmarian), however, consists almost entirely of light- to medium-grey limestone in multiple shallowing-up cycles.

“Glacier” section, 1.6 km west of Girty Creek (Loc. 3, Fig. 4)

Examination of all parts of the type section at Girty Creek are made extremely difficult by a narrow gorge in the lower part of the section, debris covered slopes, and steep cliffs near the top. The entire section is exposed and easily accessible, however, along the east side of a large, unnamed glacier 1.6 km to the west of Girty Creek (Fig. 4, loc. 3; Figs. 7, 8) (see also Thorsteinsson; 1974, Pl. II, p. 98). Sixty-seven samples were collected from the lower 350 m of this section (Fig. 7). The main lithotype is light-coloured bioclastic limestone, as at Girty Creek. The measured section is actually a composite of eight discrete blocks (Fig. 5) separated from each other by covered intervals, some of which undoubtedly conceal suspected faults. Blocks 1–4 appear stratigraphically and structurally undisturbed; that is, bedding attitude is similar below and above block boundaries and there is no evidence of significant displacement. Nevertheless, thin-section analysis of carbonates near the boundaries of blocks 2 and 3, and of blocks 3 and 4, show intensive micro-shearing and micro-fracturing that is suggestive of at least some scale of fault movement.

Blocks 4 and 5 are separated by a brecciated lime mudstone that forms a talus slope. Limestones making up block 5 are darker, and contain generally fewer bioclasts with a proportionately greater percentage of micritic matrix. Stratigraphic and structural relationships between block 5 and adjacent blocks are unclear, but apparently not greatly complicated.

The lower portion of block 6 includes approximately 75 m of a mostly covered interval, presumed to be dark shale with relatively thin, isolated exposures of dark calcilutite. This interval is, in turn, overlain by 15 m of massive anhydrite. These dark coloured and evaporitic lithotypes are interpreted as the record of a brief incursion of deeper Otto Fiord–Hare Fiord facies onto the shallower Nansen carbonate shelf. Fault emplacement of these more basinal deposits cannot be ruled out, although similar intertonguing relationships occur nearly 1.5 km to the west on the opposite side of the glacier. More typical, albeit somewhat thicker bedded to massive, Nansen limestones make up the remainder of the section in blocks 7 and 8. Sample spacing at the Girty Glacier locality is closest in blocks 1–5, becoming much wider thereafter.

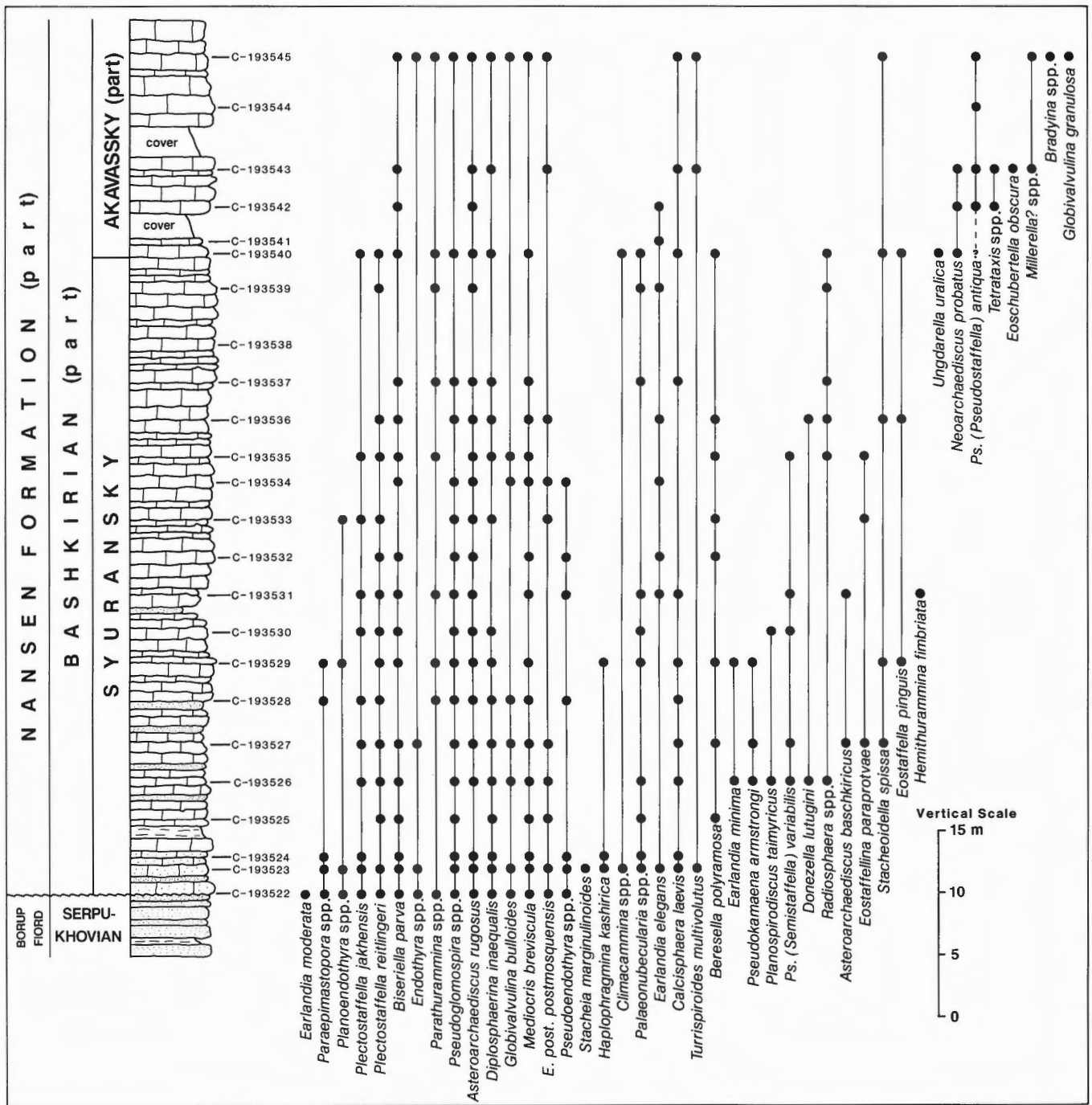


Figure 6. Stratigraphic columnar section and distribution of calcareous microfossils in the lower Nansen Formation at Girty Creek. (See Figure 2 for explanation of lithological symbols.)

Depositional environments

Type section at Girty Creek

Limestone at the base of the type section is oolitic grainstone with intermixed micritized bioclasts, foraminifers, ostracodes and calcispheres that appear to have been deposited in an oolitic shoal within the wave-break zone; that is, several metres or less of water depth. On the other hand, the highest rock

sample, collected 67 m above the base, is a subpeloidal, micritic grain, foraminifer, crinoid, algal grained packstone deposited in an open marine setting with considerable reef-like organic diversity. Thus, in general, the succession records a progression from basal saline shoals to shallow, open marine shelf environments. Strata in the lower 18 m of the section are interbeds of limestone, sandstone and conglomerate but, in the remaining 49 m of the measured succession, limestone is interbedded with finer

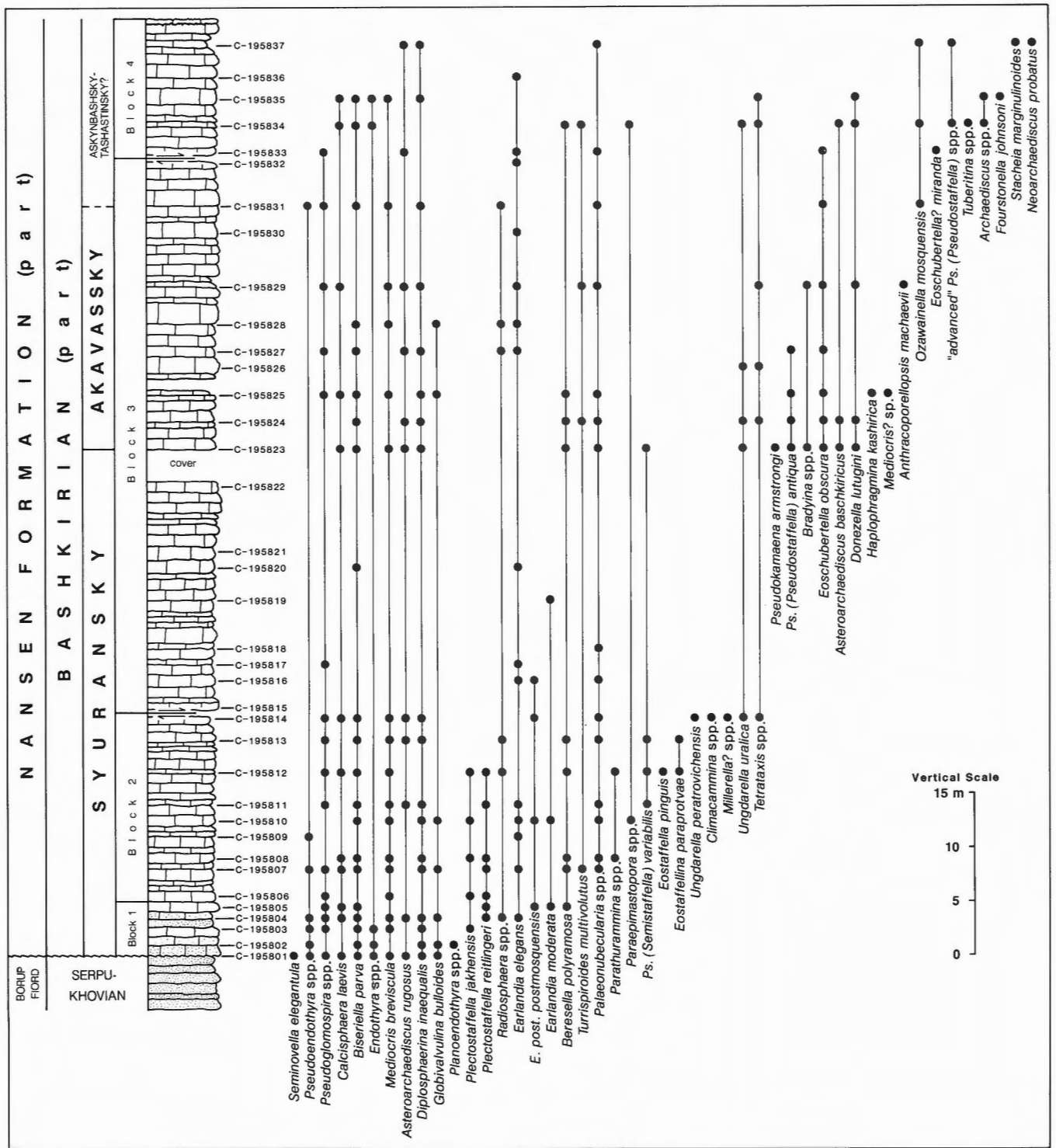


Figure 7. Stratigraphic columnar section and distribution of calcareous microfossils in blocks 1-4 of the lower Nansen Formation at the glacier section. (See Figure 2 for explanation of lithological symbols.)

siliciclastics; that is siltstone, claystone and shale. All these mixed lithotypes occur in parasequences, but our sampling control is insufficient to define the boundaries of these sequences.

“Glacier” section, 1.6 km west of Girty Creek

Sixty-seven samples were collected from eight discrete blocks separated by covered intervals in the lower

350 m of the Nansen Formation; some covered intervals undoubtedly conceal faults. Internally, the blocks are multicyclic, built up of many parasequences and larger scale sequences, mainly of shallowing-up type. Apparent movement between blocks has created a strong microfracture and microshear overprint, particularly in samples close to the inferred position of offsetting faults. Although the section lies in a thrust-faulted structural belt, repetition as defined biostratigraphically is limited to a faunal repeat at the top of block 8. Much of the faulting may be normal; however, some bed-parallel displacement may have occurred along shale and/or anhydrite bedding planes.

The Borup Fiord siliciclastic succession at the base of the section is overlain by oolitic grainstones that are very sandy, reflecting coastal reworking of underlying and shoreline siliciclastics. Quartz, sand, and silt

content show an overall upward decline from block 1 into the lower part of block 2. The interval from the base of block 1 into the lower part of block 2 generally records the deposition of oolitic grainstone shoals intermixed with reworked quartz, silt, and sand. Through the upper part of block 2, there is increasing marine influence, but the upper part is still relatively restricted environmentally. The uppermost sample of block 2 shows a marked increase in stenohaline forms; the increase in forms may record the transgressive, more open marine environment of a parasequence or sequence base.

The lower half of block 3 shows a consistent pattern of lime mudstone with limited biotic contribution, contrasting with the stenohaline assemblage at the top of block 2, and thus consistent with fault offset or displacement between blocks 2 and 3. The covered

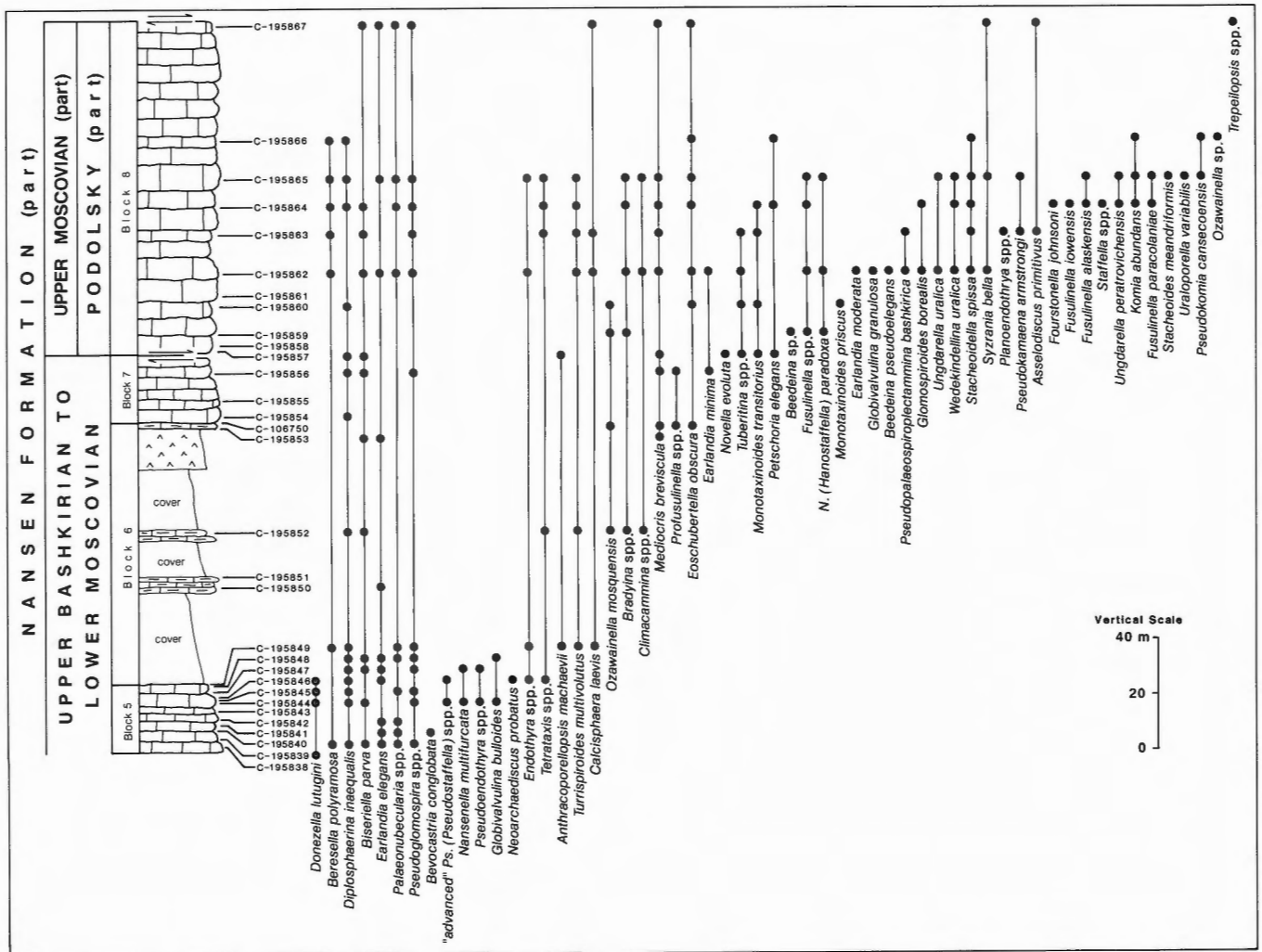


Figure 8. Stratigraphic columnar section and distribution of calcareous microfossils in blocks 5-8 of the lower Nansen Formation at the glacier section. (See Figure 2 for explanation of lithological symbols.)

interval just below the mid-point of block 3 may include another fault displacement, as there is a major lithofacies change above the covered interval, with the first introduction of large volumes of rhodophyte (red) algae in a variety of packstone, grainstone, and boundstone textures. The mid to upper part of the upper section of block 3 reflects an open to restricted marine shelf environment that became shallower, and possibly more restricted and saline at the top. Samples from the top of the section possibly contain relicts of syngedimentary anhydrite.

Lithofacies differences between the top of block 3 (with intense shearing and microfracturing) and the base of block 4, again is consistent with, but not proof of, a fault offset between the two sections. Block 4 becomes increasingly marine up-section, compared with the more restricted or interior shelf environments represented near the base. Brecciated limestone at the very top of the section suggests fault displacement at the top of the block.

In block 5, a variable but generally consistent lithology is recorded, similar to the Otto Fiord Formation type section at Van Hauen Pass. This similarity is supported by the repeated occurrence of large faecal pellets, and by the presence of probable pseudomorphs after halite crystals and relict textures after probable anhydrite nodules (now leached). Beds with more stenohaline associations, particularly in the upper part of block 5, are also consistent with more marine interbeds or sequences within the multicyclic Otto Fiord Formation.

The thick (33.5 m), covered interval in the lower part of block 6 is of unknown lithological type. It is capped by limestone beds and two samples of internally sheared and microfractured mudstone with algae below and crinoids and brachiopods above, a sequence suggesting an indistinct deepening-up trend. The limestone and mudstone beds are followed by 20 m of covered interval overlain by a thick anhydrite unit of Otto Fiord type. This is overlain directly by a limestone with faecal pellets and other characteristics similar to the restricted saline limestone facies of the Otto Fiord Formation.

Block 7 appears to represent a more open marine setting and stenohaline assemblages compared with the top of block 5, supporting, but not proving, fault displacement between the two blocks. Increasing sand content in some of the samples, with associated crinoids, and increased matrix-selective dolomitization, are consistent with either more open marine shelf or upper slope settings.

Block 8 is the thickest of the units in the measured section, and may have acted structurally as a single rigid block during displacement, although there is not a strong lithofacies support for displacement between blocks 7 and 8. In general, block 8 can be interpreted as recording a shallowing-up megasequence with mainly smaller-scale, shallowing-up cycles or para-sequences throughout. Algal contribution, particularly from rhodophytes, becomes more common toward the top of the interval; the entire thick limestone unit may record a shallowing-up shelf or upper slope environment.

Biostratigraphy

Foraminifer assemblages from the Nansen Formation show close affinities with those documented from elsewhere in the Eurasian-Arctic faunal realm, particularly Russia, Kazakhstan and the Ukraine. Paleogeographic similarities, including the common development of the primitive pseudostaffellin lineage, facilitate direct correlations between the lower Nansen and equivalents in those countries.

At both the Girty Creek and glacier sections, the basal beds of the Nansen contain *Eostaffella postmosquensis*, *Plectostaffella jakhensis*, and *Pl. reitlingerii*, as well as the biostratigraphically diagnostic nonfusulinacean foraminifers *Globivalvulina bulloides* (Brady) and species of the thick-walled *Palaeonubecularia*. In Russia and Kazakhstan, the lower concurrent ranges of these taxa are associated with the appearance of the conodont *Declinognathodus noduliferus* (Ellison and Graves) in rocks assigned to the lower *Homoceras* ammonoid genozone. This level occurs in the upper Zapaltyubinsky horizon of the Donetz Basin and Russian Platform (Vdovenko et al., 1990; Gibshman and Akhmetshina, 1991), the upper Brazhkinsky Horizon of the south Urals (Kulagina and Pazukhin, 1986, 1988 cited in Gibshman and Akhmetshina, 1991), and an unnamed subsurface interval penetrated by several boreholes in the North Caspian Syncline (Gibshman and Akhmetshina, 1991). The upper concurrent ranges of these taxa extend well into the Akavassky Horizon of the Bashkirian stratotype in the south Urals (Sinitsyna and Sinitsyn, 1987; Groves, 1988). Thus, on foraminiferal evidence, the age of the basal Nansen could be late Serpukhovian to early Bashkirian. An early Bashkirian, Syuransky, age is favoured, however, in light of the evolutionary appearance of *Pseudostaffella* (*Semistaffella*) *variabilis* relatively low in the section. *Pseudostaffella* (*S.*) *variabilis* appears 9 m above the base of the Nansen at

Girty Creek and 14 m above the base at the glacier section. These levels are confidently correlated to the Bashkirian stratotype where the appearance of *Ps. (S.) variabilis* is within the late Syuransky (Sinitsyna and Sinitsyn, 1987). Given this direct tie, it seems likely that the few underlying metres of Nansen are also equivalent to Syuransky rather than upper Serpukhovian strata.

Correlation of the basal Nansen with reference sections elsewhere in Sub-Arctic North America is less straightforward because of provincial differences in foraminifer assemblages. The pseudostaffellin lineage, in particular, is developed neither in the Midcontinent nor in the Cordillera and is therefore of little biostratigraphic value. Considering key taxa recovered from the base of the Nansen, only *Globivalvulina bulloides*, *Eostaffella postmosquensis*, and thick-walled *Palaeonubecularia* spp. have been documented in the conterminous United States. *Globivalvulina bulloides* and thick-walled *Palaeonubecularia* appear in rocks of early Morrowan age in association with the conodonts *Rhachistognathus primus* Dunn and *D. eclinognathodus noduliferus* (Brenckle et al., 1982; Groves, 1984b; Lane et al., 1985a; Skipp et al., 1985). The base of the Nansen is therefore at least early Morrowan or younger, but a more precise correlation is not possible without complementary evidence from other fossil groups.

The lower Nansen interval, containing *Pseudostaffella (Semistaffella) variabilis* up to the evolutionary appearance of *Ps. (Ps.) antiqua* is interpreted as being upper Syuransky. The appearance of the latter species defines the base of the Akavassky Horizon in the Bashkirian stratotype. On the basis of this evidence, the base of the Akavassky is correlated to a level 51 m above the base of the Nansen at Girty Creek and 46.5 m above the base of the formation at the glacier section. The remaining 16 m of strata measured at Girty Creek are considered to be Akavassky equivalents in the absence of post-Akavassky indices.

The range of *Pseudostaffella (Semistaffella) variabilis* below *Ps. (Ps.) antiqua* is interpreted as being middle to late Morrowan in terms of the sub-Arctic North American scale. Direct evidence for this interpretation is lacking since neither of the taxa in question has been observed in the conterminous United States. Indirect evidence, however, is derived from the association in the Eurasian-Arctic realm of *Ps. (Ps.) antiqua* with ammonoids and conodonts that can be correlated to the Midcontinent.

In the Donetz Basin, *Ps. (Ps.) antiqua* occurs in Limestone E8 and above, slightly below the appearance in Limestone F2 of the ammonoid *Branneroceras branneri* (Smith) as shown by Aisenverg et al. (1963 cited in Ramsbottom et al., 1978) and Aisenverg et al. (1979). In Arctic Canada, *B. branneri* and "primitive *Pseudostaffella* sp." were recovered approximately 175 m above the base of the Otto Fiord Formation near Van Hauen Pass (Mamet in Nassichuk, 1975). In northwest Spain, *B. branneri* has been recovered from the Villanueva beds, which are correlatives of the nearby Valdeteja Formation (Wagner and Bowman, 1983). The Valdeteja, in turn, has yielded *Ps. (Ps.) antiqua* (van Ginkel, 1965). These associations of *Ps. (Ps.) antiqua* and closely related forms with *B. branneri* are significant because *B. branneri* also characterizes the upper Brentwood Limestone Member (Bloyd Formation) of the upper type Morrowan Series in Arkansas and Oklahoma (McCaleb, 1968; Saunders et al., 1977). Thus, a late Morrowan age for the appearance of *Ps. (Ps.) antiqua* is established. Similarly, at the Bashkirian stratotype, the appearance of *Ps. (Ps.) antiqua* in the basal Akavassky coincides with the appearance of the conodont *Idiognathoides ouachitensis* (Harlton), above the appearance of *Idiognathodus parvus* (Dunn) (Furduj, 1975; Lane et al., 1985b). *Idiognathoides parvus* is not known to occur below the upper Morrowan in the Midcontinent (H.R. Lane, pers. comm.), and the appearance of *I. ouachitensis* was interpreted by Grayson (1984) as being latest Morrowan based on occurrences in the upper Wapanucka Limestone, which is unconformably overlain by the Atoka Formation in the Arbuckle Mountains of southern Oklahoma.

Our early Bashkirian (Morrowan) age interpretation for the lower approximately 50 m of the Nansen differs from previous conclusions by Mamet (*in Nassichuk, 1975*). Mamet (*ibid.*, p. 192–195) listed taxa recovered from 13 samples spanning the lower 515 m of the Nansen at Girty Creek. The lower eight samples range from the base of the section through approximately 86 m above the base. These eight were assigned to Mamet's zones 18 and 19?, which he considered equivalent to the upper *Eumorphoceras* and lower *Homoceras* ammonoid genozones: that is, Serpukhovian of the Russian Platform and Chesterian of the Midcontinent. Taxa that apparently influenced this interpretation include a variety of archaediscaceans, eostaffellids, *Biseriella parva* (Chernysheva), *Zellerina discoidea* (Girty), and "cf. *Eosigmoilina(?)–Quasiarchaediscus(?)* sp." Neither plectostaffelloids nor pseudostaffellins were identified by Mamet (*in Nassichuk, 1975*). Evidence for questioning the validity of Mamet's (*ibid.*) interpretations was first provided by

Bender (1980, p. 7), who recovered definitive Morrowan conodonts from the same interval. Our new collections of conodonts, identified by G.D. Webster (pers. comm., 1991), corroborate Bender's findings and data, and are entirely compatible with our foraminifer data. The apparent absence of plectostaffelloids and pseudostaffellins in Mamet's (*ibid.*) samples precluded their proper correlation to the lower Bashkirian. Moreover, the presence of eosigmoilinoids undoubtedly influenced Mamet's (*ibid.*) assignment of a zone 18-19? age, since those forms were not known to range above the middle part of the upper Serpukhovian (Brazhnikova et al., 1967). Recent work by Pinard (1989) and our new data confirm the presence of the eosigmoilinoid *Brenckleina rugosa* (Brazhnikova) at least as high as 86 m above the base of the type Nansen at Girty Creek. These occurrences significantly extend the upper range of that species, indicating pronounced interregional diachronism. Caution must therefore be exercised in basing long-range correlations on extinction events.

At the glacier section, correlation of the Nansen interval above strata containing *Pseudostaffella* (*Pseudostaffella*) *antiqua* is complicated by a generally poor retrieval of fusulinaceans, especially in blocks 5-7. In this section, the appearance of *Ps.* (*Ps.*) *antiqua* coincides with that of *Eoschubertella obscura*. The appearance of *Ozawainella mosquensis* Rauzer-Chernousova was noted 23 m higher at 69.5 m above the base of the section, followed by *Eoschubertella*(?) *miranda* (Leontovich) at 73.6 m above the base. Published occurrences of *E. obscura* range from lower Bashkirian through upper Moscovian, and those of *E.*(?) *miranda* from upper Bashkirian through lower Moscovian. The established range of *O. mosquensis* is uppermost Bashkirian or lower Moscovian through upper Moscovian, although morphologically similar species of *Ozawainella* are documented in rocks as low as upper lower Bashkirian (Sinitsyna and Sinitsyn, 1987). Accordingly, the interval from the joint appearances of *Ps.* (*Ps.*) *antiqua* and *E. obscura* up to *O. mosquensis* is tentatively considered lower Bashkirian (Akavassky-Askynbashsky), and the interval containing *O. mosquensis* and *E.*(?) *miranda* up to the base of block 5 (86 m above the base of the formation) is most likely equivalent to the upper Bashkirian to lower Moscovian interval.

Foraminifers from blocks 5-7, that is, 86.5-230.5 m above the base of the glacier section, are sparse and of minimal biostratigraphic value. Nevertheless, important foraminifers have been recovered from other samples in the Geological Survey of Canada collections taken from block 7. A sample collected by K. Osadetz in 1984 from GSC locality C-106750 at the base of

block 7, just above the highest anhydrite in block 6, contains *Profusulinella* sp., *Ozawainella* sp., *Eoschubertella* ex. gr. *obscura*, *Eostaffella* sp., *Mediocris breviscula*, *Staffella* sp., and *Millerella*; this assemblage is late Bashkirian to early Moscovian in the Urals and the Russian Platform, and Atokan in the midcontinental area of North America.

Beginning with sample C-195859, 6 m above the base of block 8 (236 m above the base of the Nansen) age-diagnostic fusulinaceans occur abundantly, and continue to occur through the remainder of the measured section. The assemblage from block 8 includes *Neostaffella* (*Hanostaffella*) *paradoxa* (= *Pseudostaffella greenlandica* Ross and Dunbar), primitive *Beedeina* sp., *B. pseudoelegans*, *Wedekindellina uralica* (= *W. dutkevitchi* Rauzer-Chernousova and Beljaev), *Fusulinella iowensis*, *F. paracolaniae*, and *F. alaskensis*. *Neostaffella* (*H.*) *paradoxa* and *W. uralica* are extensively documented throughout the Eurasian-Arctic faunal realm. The established range of *N. (H.) paradoxa* is Kashirsky through Myachkovsky, with specimens also reported from questionable Vereisky equivalents in Japan; the range of *W. uralica* is strictly upper Moscovian (Podolsky-Myachkovsky). *Fusulinella paracolaniae* and *Beedeina pseudoelegans* are known from the Urals and Russian Platform in rocks of Kashirsky and late Moscovian age, whereas *F. iowensis* is widespread in the midcontinental and eastern United States in uppermost Atokan to lower Desmoinesian rocks. From these occurrences, a late Moscovian, probably Podolsky, age for block 8 is interpreted, although there is insufficient evidence for correlating to discrete horizon boundaries at reference sections in the Russian Platform. This assemblage is assignable to the *Wedekindellina lata*-*W. uralica longa* Zone of Rui et al. (1991), recognized in Podolsky equivalents within the Nansen, higher in the section at Girty Glacier (see discussion, below). The concurrent ranges of species in *Fusulinella*, *Beedeina*, and *Wedekindellina* require correlation of block 8 to the lower Desmoinesian of sub-Arctic North America.

Our correlation of block 8 to the upper Moscovian poses an interesting local problem in that Rui et al. (1991) recently identified the base of the upper Moscovian at Girty Glacier approximately 1105 m above the base of the Nansen. This level falls 869 m above our lowest upper Moscovian assemblage, indicating an element of structural complexity not previously suspected. Samples collected by Osadetz in 1984 from localities above block 8 are clearly older than late Moscovian and resemble faunas collected from near the base of block 7; *Eoschubertella*? sp. and *Mediocris breviscula* (lower Bashkirian?) are from

GSC locality C-106756, 20 m above block 8, and *Eoschubertella* sp., *M. breviscula*, *Staffella* sp. (= *Pseudoendothyra* sp.), and *Fusulinella* sp. (lower Moscovian) are from GSC locality C-106758, 60 m above block 8. Accordingly, an explanation for this repetition invokes the presence of a thrust fault at the top of block 8.

Otto Fiord and lower Hare Fiord formations

Locality information

Van Hauen Pass area (Loc. 4, Fig. 4)

The type section of the Otto Fiord Formation underlies the type section of the Hare Fiord Formation only a few kilometres east of Van Hauen Pass (Thorsteinsson, 1974) and faunas were collected for comparison from a continuously exposed section about 1 km west of the type section (Fig. 4). In the type area, the Otto Fiord Formation contains up to 410 m of interbedded anhydrite, limestone and shale, and the base of the section is marked by a thrust fault; the Otto Fiord Formation was juxtaposed by faulting on the Triassic Blaa Mountain Formation. Basal beds of the Hare Fiord Formation, mainly argillaceous limestone with thin interbeds of argillite and calcareous siltstone, rest conformably on the Otto Fiord. For this study, 18 samples were collected from limestone within the Otto Fiord Formation and six samples were collected from the lower 30 m of the Hare Fiord Formation.

Depositional environments

In the type area, the Otto Fiord Formation contains up to 410 m of rhythmically interbedded limestone and bedded anhydrite. During the early Middle Carboniferous (Bashkirian), the Otto Fiord Formation formed part of the initial marine transgressive infill of the developing rift trough, the Sverdrup Basin. The marine limestone, and anhydrite cycles, described in detail by Nassichuk and Davies (1980), were deposited in a hypersaline subaqueous environment. In the middle part of the formation, one of the marine limestone units contains multicyclic algal boundstone reefs that were stabilized by pervasive submarine cement (Davies and Nassichuk, 1989).

The Otto Fiord Formation is conformably overlain by dark basin-fill argillite (distal turbidites) and argillaceous limestone of the Hare Fiord Formation. Locally, Waulsortian-type carbonate mounds that contain Atokan ammonoids (Nassichuk, 1975) and are constructed by fenestellid bryozoans occur near the

base of the formation in basinal or basin-slope settings. Near the head of Hare Fiord in the vicinity of Girty Creek (Fig. 4), tongues of shelf limestone in the Nansen Formation extend as debris flows or carbonate turbidites down the edge of the shelf, where they interfinger as interbedded units with anhydrite in the upper part of the Otto Fiord Formation, and with shale and siltstone in the lower part of the Hare Fiord Formation.

Biostratigraphy

Foraminifer occurrences in the darker basinal limestone of the Otto Fiord and lower Hare formations near Van Hauen Pass are so scarce and undiagnostic that only very generalized conclusions regarding the age of the host strata can be made. However, Mamet (*in* Nassichuk, 1975, p. 183) previously listed diverse foraminifer faunas from 14 stratigraphic levels in the upper half of the Otto Fiord Formation in the type area, and suggested a Morrowan to early Atokan age. Similarly, Nassichuk (1975) described the Morrowan (Bloydian) *Branneroceras branneri* from near the middle and top of the formation in the type area. Samples near the lowest exposed Otto Fiord strata in the type area, well below the ammonoid horizons, yielded asteroarchaeidiscids, *Biseriella parva*, thick-walled *Palaeonubecularia* sp., and *Globivalvulina bulloides*. As previously discussed, this assemblage is found in both upper Serpukhovian and lower Bashkirian rocks of the Russian Platform and Urals. An early Bashkirian (Morrowan) age for the lower Otto Fiord is suggested, however, on the assumption that the local appearances of these taxa are not evolutionary appearances but rather stratigraphically perched occurrences.

A specimen assigned questionably to the biserial ammonid *Tenebrosella asturica* Villa and Sanchez de Posada was recovered from an algal biostromal limestone approximately in the middle of the Otto Fiord (C-195882) within the interval known to contain *Branneroceras*. *Tenebrosella asturica* is known only from the Cantabrian Mountains of Spain, where it occurs with species of *Profusulinella*, *Aljutovella*, *Verella*, and *Eofusulina* in rocks of early Moscovian (Vereisky) age (Villa and Sanchez de Posada, 1986). The significance of the Otto Fiord specimen is questionable, however, because of its uncertain identification and the relatively poorly understood distribution of the species. Pinard (1989) documented morphologically similar specimens as *Globivalvulina granulosa* Reitlinger from early Moscovian and younger strata at various localities throughout the Sverdrup Basin.

Eoschubertella obscura and *Ozawainella mosquensis* occur in a thin limestone band near the top of the Otto Fiord (C-195887). These occurrences establish a probable minimum age of late early Bashkirian (Akavassky-Askynbashsky), but they may also signify an early Moscovian age. In sub-Arctic North American terms, this age is Atokan.

Samples from the lower Hare Fiord Formation did not yield biostratigraphically useful taxa apart from those already observed in the underlying Otto Fiord. Nevertheless, the following ammonoids are from the lower 30 m of the Hare Fiord Formation in the type area, and Nassichuk (1975) suggested an Atokan (Bashkirian or early Moscovian) age; *Metapronorites ellesmerensis* Nassichuk, *Phaneroceras lenticulare* Plummer and Scott, *Syngastrioceras smithwickense* (Plummer and Scott), *Diaboloceras involutum* Nassichuk, *Neogastrioceras arcticum* Nassichuk, and *Phaneroceras lenticulare* Plummer and Scott.

ORIGIN AND EARLY EVOLUTION OF THE FUSULINIDAE

A hypothesis for the origin and early evolution of the Fusulinidae was put forth by Groves (1988) on the basis of material from the stratotype of the Bashkirian Stage (western slope of south Urals), a global synthesis of primitive fusulinacean stratigraphic and paleogeographic distributions, and the previously published but less explicitly formulated ideas of Reitlinger (1971). The phylogenetic scenario suggested that *Eostaffella postmosquensis* plexus formed the root stock for the fusulinid clade (Fig. 9). An element of the plexus, most likely *E. postmosquensis postmosquensis*, gave rise to *Plectostaffella jakhensis* in late Serpukhovian time. The latter, in turn, gave rise to *Pseudostaffella (Semistaffella) variabilis* in the middle to late Syuransky (=Krasnopolyansky), followed shortly by the derivation of *Ps. (Ps.) antiqua*. The appearance of *Ps. (Ps.) antiqua* defines the base of the Akavassky (=Severo-Keltmensky) Horizon and is generally regarded as the catalyst for the adaptive radiation of diverse *Ps. (Pseudostaffella)* spp. and all subsequent pseudostaffellins. Advanced representatives of the genus were late Bashkirian (Tashastinsky-Cheremshansky) progenitors of *Neostaffella (Neostaffella)* spp., which gave rise to *N. (Hanostaffella)* spp. in the upper Moscovian, and eventually to bizarre *Xenostaffella* (Cheong, 1971, 1973, 1974, 1984).

A key aspect of the proposed phylogeny was that the component speciation events were thought to have

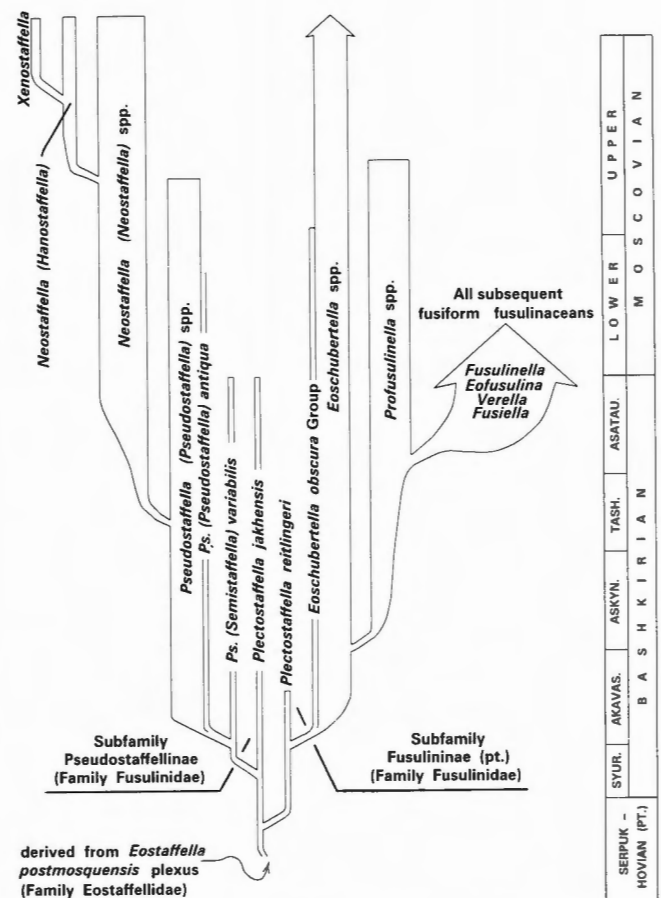


Figure 9. Origin and early evolution of Fusulinidae. *Eostaffellidae* root stock is inferred to have given rise to Fusulinidae through ***Plectostaffella jakhensis*** (to Subfamily Pseudostaffellinae) and ***Pl. reitlingerii*** (to Subfamily Fusulininae).

occurred exclusively in the Eurasian-Arctic faunal realm. *Plectostaffella jakhensis*, *Pseudostaffella (Semistaffella) variabilis*, *Ps. (Ps.) antiqua*, neostaffelloids, and xenostaffelloids are unknown in sub-Arctic North America. The earliest sub-Arctic North American pseudostaffellins, such as *Ps. (Ps.) atokensis* (Thompson) and *Ps. (Ps.) needhami* Thompson, are slightly more advanced morphologically than *Ps. (Ps.) antiqua*. In the absence of likely indigenous ancestors, they are considered to have appeared as immigrants or immediate descendants of immigrants. Hence, earliest sub-Arctic North American pseudostaffellins must occur later than the evolutionary appearance of *Ps. (Ps.) antiqua* in Eurasia and the Arctic. The duration of migratory diachronism was estimated by Groves (1988) to correspond roughly to the interval represented by the combined late Morrowan *Branneroceras branneri* and *Axinolobus modulus* ammonoid zones.

Phenotypic modifications between successive species in the lineage were described in terms of mosaic evolution in which morphological characters exhibited stasis or changed at varying rates independently of other characters (Groves, 1988). In general, pseudo-staffellin grade derived from eastaffellid grade as a consequence of lengthening of the axis, increase in the diameter of the proloculus, and development of more robust chomata. An architectural consequence of axial elongation is the progression from lenticular and discoidal shapes to sub-nautiloid, nautiloid, and subspherical shapes, in this case accompanied by an increase in size. Erratic coiling in *Plectostaffella jakhensis* and *Pseudostaffella (Semistaffella) variabilis* linked essentially planispiral *E. postmosquensis postmosquensis* with *Ps. (Ps.) antiqua* and later forms in which skew coiling is retained in juvenile stages only. Relative stasis in chamber counts also linked *Pl. jakhensis* and *Ps. (S.) variabilis* with presumed ancestors and descendants.

As far as we know, there are no published studies in which the integrity of the proposed phylogeny has been evaluated explicitly. Compatible observations, however, have emerged from unpublished studies of the Wahoo Limestone (Lisburne Group, Arctic Alaska) by Groves and P. L. Brenckle. Detailed collections of the Wahoo along Clarence River in the eastern Brooks Range yielded specimens of *Plectostaffella jakhensis*, *Pseudostaffella (Semistaffella) variabilis*, and primitive *Ps. (Pseudostaffella) sp.* in the stratigraphic order predicted by our evolutionary scheme.

The succession of fusulinaceans recovered from the present lower Nansen collections is almost identical to that in the lower Bashkirian stratotype. As discussed previously, basal Nansen samples at both Girty Creek and the glacier section yielded *Eostaffella postmosquensis postmosquensis* and *Plectostaffella jakhensis*. The joint first occurrences of these taxa suggest that the base of the Nansen is younger than strata containing their normally sequential appearances, and that the local appearances of both are stratigraphically perched as a consequence of paleoenvironmental exclusion from the underlying Borup Fiord Formation, and the hiatus at the Borup Fiord–Nansen contact. The lowest occurrence of *Pseudostaffella (Semistaffella) variabilis* was observed in GSC locality C-193526, 9 m above the base of the section at Girty Creek, and in C-195811, 14 m above the base at the glacier section. *Pseudostaffella (Ps.) antiqua* appears locally at Girty Creek in C-193540, 51 m above the base of the section, and at the glacier section in C-195823, 46.5 m above the base. Biometric data derived from specimens in the present collections are

presented in Figure 10. The data, when displayed with taxa arranged in order of stratigraphic appearance, show clear progressions in test width, width/diameter ratio, and development of chomata. Diameter of

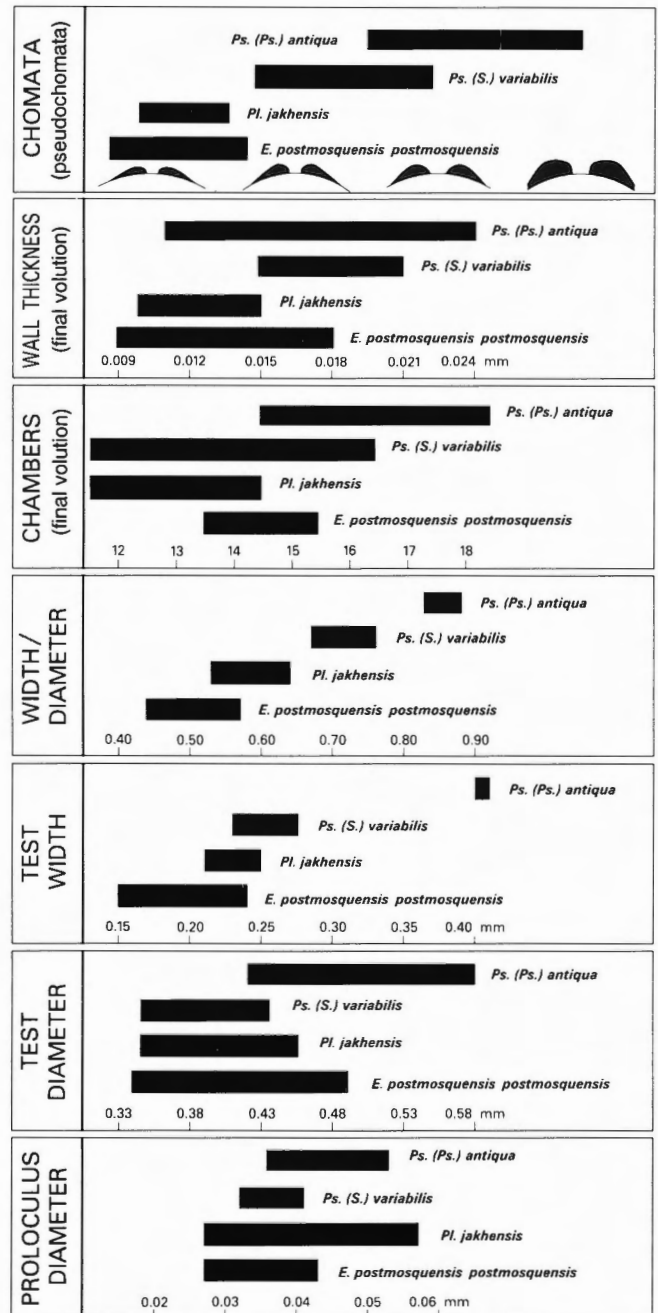


Figure 10. Comparison of morphological characters among species making up primitive pseudo-staffellin phylogeny. Taxa arranged in order of stratigraphic appearance as determined by evaluation of documented occurrences throughout paleogeographic range. Measurements derived exclusively from specimens in present study.

proloculus exhibits considerable overlap among species, but the minimum values increase with increasing evolutionary grade. Similarly, wall thickness varies considerably within and among species, but the greatest values are found in stratigraphically younger forms. Morphometric and stratigraphic documentation of this sequence of primitive pseudostaffellins further strengthens the probability of the inferred phylogeny. We consider this a positive test, consistent with previous observations and interpretations. Moreover, recognition of the widespread paleogeographic development of the lineage — extending at least from the southern Urals through the Sverdrup Basin and into northern Alaska — increases the area over which the development can be used for direct, high resolution biostratigraphic correlations.

The appearance of *Pseudostaffella* (*Pseudostaffella*) *antiqua* was observed near the top of the measured section at Girty Creek, and more advanced pseudostaffellins were not recovered. At the glacier section, however, large and robust *Ps.* (*Ps.*) spp. occur in the interval spanning GSC localities C-195834–C-195846; that is, 77–105 m above the base of the Nansen in blocks 4 and 5. These specimens record the continued development of the pseudostaffellin line, but they cannot be fitted directly into the phylogeny because they occur in rather small numbers from widely spaced collections. The paucity of well oriented specimens in our thin sections also precludes their identification at the species level.

Much higher in the section, in GSC localities C-195859, C-195862, and C-195865, 236–292 m above the base of the Nansen in block 8, *Neostaffella* (*Hanostaffella*) *paradoxa* occurs fairly abundantly. The abrupt appearance of this highly evolved form in the absence of intermediate *N.* (*Neostaffella*) spp. is attributed to the paleoenvironmentally governed paucity of fusulinaceans in blocks 5–7, and possibly also to faulting between blocks 7 and 8. Elsewhere in the Eurasian–Arctic faunal realm, almost uninterrupted fossiliferous sequences yield a continuum of diverse advanced *Pseudostaffella* (*Pseudostaffella*) spp. followed by *N.* (*Neostaffella*) spp. then *N.* (*Hanostaffella*) spp. (Rauser-Chernousova et al., 1951; Cheong, 1984).

The Pseudostaffellinae, although abundant and biostratigraphically useful, account for only a minor portion of the taxonomic diversity within the Fusulinidae. Representatives of the subfamily became extinct at or near the end of the Moscovian after having produced only four subgenera in three genera (Rozovskaya, 1975; Ross, 1979). Much greater adap-

tive potential was realized by the Fusulininae (including part of the Schubertellinae of previous authors), whose constituents are characterized by axial lengths generally exceeding test diameter and a variety of shapes, coiling types, wall structures, and secondary deposits. The earliest true fusulinins are representatives of *Eoschubertella* Thompson, which likely gave rise to *Profusulinella* Rauser-Chernousova and Beljaev and all subsequent members of the subfamily (Thompson and Riggs in Thompson et al., 1959; Groves and Sanderson, 1990). Advanced fusulinins, in turn, spawned the Schwagerinidae that became the most diverse and widespread of all fusulinaceans. Clearly an understanding of the origin of the Fusulininae is important to both evolutionary systematics and biostratigraphy. Previous investigations of fusulinacean phylogeny have concluded that the Fusulininae derived from an eostaffellid stock, either directly or through intermediate pseudostaffellins (Miklukho-Maklay et al. in Orlov, 1959, Fig. 211; Rozovskaya, 1975, Fig. 2). These studies were limited to the analysis of genus level and suprageneric relationships, however, and we are unaware of any deliberate attempts to identify actual species involved in the origin of new lineages.

The discovery in the lower Nansen of the new species *Plectostaffella reitlingeri* Groves may shed light on the question of early fusulinin origins. Adult specimens of *Pl. reitlingeri* are miniscule, discoidal to nautiloid, with very weakly developed chomata (pseudochomata?), relatively low chamber counts, and 3.5 to 4.5 variably skew-coiled volutions. Specimens differ from other validly described species in the genus in achieving only about half the normal size, and in possessing slightly fewer numbers of chambers. The derivation of this phenotype is unclear, but it may have stemmed from a more robust form such as *Pl. jakhensis* through any of a number of heterochronic processes.

Small size and low chamber counts are also characteristic of the group of primitive eoschubertelloids including *Eoschubertella obscura* (Lee and Chen), *E. mosquensis* (Rauser-Chernousova), and *E. bluensis* Ross and Sabins. Eoschubertelloids of the *E. obscura* group, however, exhibit slightly larger chomata (pseudochomata?), longer axes, and more thickly ovate, as opposed to nautiloid, shapes. Morphologically, *Plectostaffella reitlingeri* seems to represent an evolutionary grade only somewhat less advanced than that of the primitive eoschubertelloids, yet unmistakably linked by coiling and overall test architecture to the plectostaffelloids. Biometric comparisons among *Pl. reitlingeri*, *E. mosquensis*, *E. bluensis*, and *E. texana* Thompson are depicted in

Figure 11. Data for *Pl. reitlinger* are derived from 18 individuals in the present collections, whereas those for *E. mosquensis* and *E. bluensis* come from much larger numbers of specimens from the Marble Falls Limestone in central Texas (Groves, 1991). Measurements of *E. texana* are included to illustrate relatively advanced eoschubertelloid grade. These measurements also come from large numbers of specimens from the Marble Falls. Data for *E. obscura* are not presented because the few present specimens are not ideally oriented, and we have not independently confirmed previously published measurements. The comparisons show unequivocal patterns of increasing proloculus diameter, test width, and width/diameter ratio. The last characteristic fundamentally defines the threshold leading to fusulinin grade. Clear, but less dramatic, patterns emerge for increasing test diameter, wall thickness, and development of chomata (pseudo-chomata?). Chamber counts are higher in *E. texana* and *E. bluensis* than in *E. mosquensis* and *Pl. reitlinger*, but the degree of overlap among all four species is such that directional change cannot be demonstrated.

Specimens of *Plectostaffella reitlinger* were recovered from the base of the Nansen at Girty Creek through at least the next 51 m. At the glacier section, specimens were found in a more limited interval within the lower 17 m of the Nansen. These occurrences are considered to be lower Bashkirian. They coincide almost precisely with occurrences of *Pl. jakhensis*, and stratigraphically precede the local appearance of *Eoschubertella obscura*, which is 58 m above the base of the Nansen at Girty Creek and 46.5 m above the base at the glacier section. The only other documented occurrences of *Pl. reitlinger* are in upper Serpukhovian limestones D3–D5 of the Donbass, where specimens were invalidly described under the name “*Plectostaffella varvariensis* var. *pusilla*” by Brazhnikova and Vdovenko (in Aisenverg et al., 1983). Thus, *Pl. reitlinger* is known to have inhabited widely separated areas of the Eurasian–Arctic faunal realm in rocks spanning at least late Serpukhovian through early Bashkirian time. Earliest Eurasian–Arctic eoschubertelloids are widespread beginning in rocks of early, but not earliest, Bashkirian age.

The sum of morphological, stratigraphic, and paleogeographic evidence is consistent with the possibility of *Plectostaffella reitlinger* having been ancestral to primitive eoschubertelloids of the *E. obscura* group. An evolutionary scenario is presented in Figure 9 in which both the pseudostaffellin and fusulinin lineages are derived from the *Eostaffella postmosquensis* plexus through plectostaffelloids.

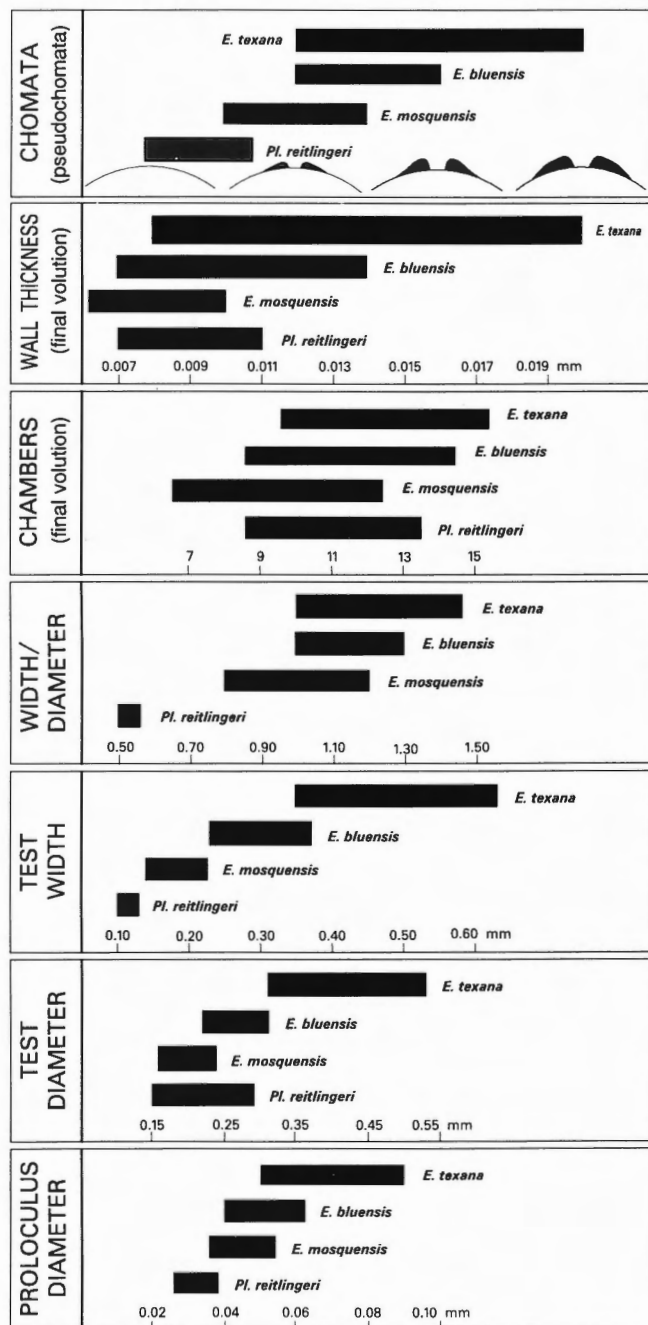


Figure 11. Comparison of morphological characters among species making up proposed primitive fusulinin phylogeny. *Plectostaffella reitlinger* Groves, n. sp., is known to occur stratigraphically lower than other considered taxa. Species of *Eoschubertella* arranged by morphological grade. Measurements for *Pl. reitlinger* derived exclusively from specimens in present study. Measurements for *E. mosquensis*, *E. bluensis*, and *E. texana* derived from Groves (1991). *Eoschubertella mosquensis* and *E. bluensis* considered representative of “*E. obscura* group.”

Whereas the pseudostaffellin lineage is strongly supported by homotaxial occurrences in the southern Urals, Arctic Canada, and Arctic Alaska, the complete sequence of species making up the proposed fusulinin phylogeny has not yet been documented at any locality. Evolutionary relationships among the early fusulinins must be more thoroughly investigated.

SYSTEMATIC PALEONTOLOGY

Systematic descriptions are limited to those Fusulinacea judged to be biostratigraphically most useful. Microproblematica, calcareous algae, nonfusulinacean foraminifers, and the remaining fusulinaceans are not described or illustrated, but their local occurrences are recorded (Table 1; Figs. 6–8). Type collections are housed at the Geological Survey of Canada in Ottawa.

Superfamily FUSULINACEA Möller, 1878

Family EOSTAFFELLIDAE
Mamet in Mamet et al., 1970

Genus *Eostaffella* Rauser-Chernousova, 1948

Type species. *Staffella (Eostaffella) parastruvei* Rauser-Chernousova, 1948.

Diagnosis. Planispirally and involutely coiled Eostaffellidae with straight to slightly curved, anteriorly directed septa. Test shape lenticular to discoidal. Secondary deposits limited to chomata or pseudo-chomata.

Eostaffella postmosquensis postmosquensis
Kireeva in Rauser-Chernousova et al., 1951

Plate 1, figures 17–20

For synonymy see Groves (1988, p. 388) and add:

Eostaffella postmosquensis Kireeva. Zhang and Sun, 1985, p. 209, Pl. 1, figs. 26, 36 (only); Matsusue, 1986, Pl. 6, fig. 8; Rui, 1987, p. 378, Pl. 2, figs. 10–13; (?)Delvolvé and Perret, 1987, Pl. 1, fig. 17; Sinitsyna and Sinitsyn, 1987, Pl. 4, fig. 5, Pl. 6, fig. 11; Groves, 1991, p. 79, Pl. 2, figs. 22–33.

Eostaffella cf. *postmosquensis* Kireeva. Niko, 1987, p. 125, 126, figs. 3I–K.

Eostaffella ex. gr. *postmosquensis* Kireeva. (?)Sinitsyna and Sinitsyn, 1987, Pl. 1, fig. 13.

Eostaffella postmosquensis evoluta Potievskaya.
(?)Ivanova, 1988, Pl. 1, fig. 15.

Description. Measured specimens have 4.5–5 volutions. Test discoidal with broadly rounded periphery and straight-sided to mildly umbilicate flanks. Expansion of spire moderate. Coiling slightly skewed in initial volution, but planispiral throughout remainder of growth. Chomata (pseudo-chomata?) low and asymmetrical. Outer diameter of proloculus 0.027–0.043 mm. Diameter of test 0.340–0.488 mm. Maximum width 0.150–0.242 mm. Width/diameter 0.44–0.57. Thickness of wall in outer volution 0.009–0.018 mm. Chamber count in final volution 14 to 15: n = 11.

Discussion. This subspecies is characterized by its low chamber count, rounded periphery, and relatively tight spire. The subspecies *E. postmosquensis acutiformis* Kireeva is very similar in all aspects except for the more angular periphery. See Groves (1988) for a discussion of the “*Eostaffella postmosquensis plexus*” and its evolutionary significance.

Age and distribution. Specimens are fairly abundant at GSC localities C-193522, C-193523, C-193525–C-193527, C-193533, C-193534, C-193536, C-193543, and C-193545 in the Nansen Formation at Girty Creek; and at C-195805, C-195810, C-195814, and C-195816 in the Nansen at the glacier section. The types are from the upper Bashkirian (Kayalian) in Molotov Oblast, C.I.S. Other documented occurrences, including those of suspected synonyms, span the lower Serpukhovian through lower Moscovian in the C.I.S. (Kolvo–Vishera region, Kuznetz Basin, Voronezhsky Massif, Donetz Basin, Uzbekistan, central and southern Urals), French Pyrenees, Japan, Guizhou (south China), Xinjiang (northwest China), and the south-central United States (see Groves, 1988).

Genus *Plectostaffella* Reitlinger, 1971

Type species. *Eostaffella?* (*Plectostaffella*) *jakhensis* Reitlinger, 1971.

Diagnosis. Eostaffellidae with variably skewed coiling. Secondary deposits limited to chomata (pseudo-chomata?).

Discussion. *Plectostaffella* is distinguished from all other Eostaffellidae by its shifting axis of coiling. The expression of this trait in *Plectostaffella* is thought to link *Eostaffella* phylogenetically with both the pseudostaffellin and fusulinin lineages of the Fusulinidae.

For synonymy see Groves (1988, p. 389) and add:

Eostaffella endothyroidea Chang, Zhang and Sun, 1985, p. 208, Pl. 1, figs. 16, 16 (only).

Description. Measured specimens possess 4–5 volutions. Test broadly discoidal to nautiloid with weakly umbilicate to convex flanks. Coiling strongly skewed throughout or initially skewed but nearly planispiral in outer volutions. Chomata (pseudochomata?) low, asymmetrical, restricted to paraequatorial zones. Expansion of spire moderate. Outer diameter of proloculus 0.027–0.057 mm. Diameter of test 0.332–0.457 mm. Maximum width 0.208–0.250 mm. Width/diameter 0.53–0.64. Thickness of wall in final volution 0.010–0.015 mm. Chamber count 12 to 14 in final volution: $n=8$.

Discussion. Groves (1988, p. 389) discussed taxonomic and nomenclatural difficulties in dealing with species in this genus: many of the published names are invalid, and many of the valid names are anchored by inadequate types. Moreover, there seems to be no agreement among workers about legitimate bases for species definition or acceptable limits for intraspecific variation. Gibshman and Akhmetshina (1991, p. 281) also acknowledged the abundance of species names, which they felt resulted “more from the description of poorly oriented material than from true diversity”. Unlike Groves (1988), however, Gibshman and Akhmetshina (1991) purported to discriminate *Plectostaffella jakhensis* from *Pl. bogdanovkensis* Reitlinger and *Pl. varvariensis* (Brazhnikova and Potievskaya) on both morphological and stratigraphic criteria. We reject their claims because their illustrated specimens do not convincingly fall into discrete groups and their biometric data are derived from only a fraction of the available parameters on only a few individuals, some of which are juveniles. Furthermore, the significance of the measurements by Gibshman and Akhmetshina (*ibid.*) is minimized by the same inconsistencies of orientation that plague all attempts to quantify the shape of irregularly coiled forms. We suspect that their putative stratigraphic separation between *Pl. jakhensis* and *Pl. varvariensis* reflects the identification of specimens by stratigraphic position rather than by objective morphological criteria. In the absence of a clear basis for species identification, we use the trivial name *jakhensis* to include representatives of the genus that are of normal size and have rounded peripheries. This is the earliest validly proposed name

founded on well illustrated specimens showing a variety of orientations.

Nomenclatural and taxonomic uncertainties notwithstanding, *Pl. jakhensis* and suspected synonyms have unquestioned stratigraphic value for characterizing the late Serpukhovian–early Bashkirian interval immediately prior to the emergence of the Fusulinidae (Reitlinger, 1971, 1980; Reitlinger *in* Einor, 1973; Groves, 1988; Orlova, 1990; Gibshman and Akhmetshina, 1991).

Age and distribution. Specimens were recovered locally from GSC localities C-193522–C-193524, C-193526–C-193528, C-193530, C-193531, C-193533, C-193535, and C-193540 in the Nansen Formation at Girty Creek; and C-195803, C-195806, C-195808, C-195810, and C-195812 in the Nansen at the glacier section.

The type specimens are from the lower Bashkirian Jakhinsky Horizon of Gornaya Bashkirian (Syuransky equivalent, eastern slope of south Urals). Other documented occurrences are from upper Serpukhovian through upper Bashkirian strata in the Donetz Basin, eastern Russian Platform, and south Urals (see references in Groves, 1988; Gibshman and Akhmetshina, 1991). Unpublished, but verified, specimens are known from the Lisburne Group of northern Alaska (Groves, work in progress; P.L. Brenckle, pers. comm.) and Morrowan equivalents in the Amazon Basin (D. Altiner, pers. comm.).

Plectostaffella reitlingeri Groves, n. sp.

Plate 1, figures 1–16

Plectostaffella varvariensis (Brazhnikova and Potievskaya) var. *pusilla* Brazhnikova and Vdovenko *in* Aisenverg et al., 1983, p. 65, Pl. 13, figs. 18–21.

Description. Measured specimens possess 3.5–4.5 volutions. Test broadly discoidal to nautiloid with rounded periphery and mildly umbilicate poles. Coiling highly variable, skewed throughout growth, or initially skewed then nearly planispiral. Coiling either involute throughout or involute in all but the final volution, where it is very slightly evolute. Chomata (pseudochomata?) very weakly developed to imperceptible. Outer diameter of proloculus 0.026–0.038 mm. Diameter of test 0.149–0.283 mm. Maximum width 0.099–0.132 mm. Width/diameter 0.49–0.56. Wall thickness in final volution 0.007–0.011 mm. Chamber count 9 to 13 in final volution: $n=18$.

Designation of types. The specimen illustrated in Plate 1, figure 15 is designated holotype (GSC 102976b). It comes from GSC locality C-193531, 24 m above the base of the Nansen Formation at the Girty Creek section. All other illustrated specimens are designated paratypes.

Etymology. The species is named after E.A. Reitlinger in recognition of her contributions to the study of upper Paleozoic foraminifers, particularly those comprising the phylogeny of primitive fusulinids.

Discussion. As noted in the synonymy, specimens considered to be conspecific with the present ones were described and illustrated by Brazhnikova and Vdovenko (*in Aisenverg et al.*, 1983) under *Pl. varvariensis* var. *pusilla*. Their material came from the upper Serpukhovian of the Donbass, with the "holotype" recovered from the D4 limestone of the Kal'mius River section. According to Article 16 of the International Code of Zoological Nomenclature (ICZN, 1985, p. 39), "A scientific name proposed expressly as the name of a 'variety' or 'form' after 1960 is infrasubspecific and excluded from zoological nomenclature". Such names become unavailable and the specimens on which they are based retain no stature as types. Whereas the present specimens would have been assigned to *Pl. varvariensis* var. *pusilla* without reservation, adherence to the code requires that a new name be erected.

Plectostaffella reitlingeri is readily distinguished from other valid species of the genus by its miniscule size. Apparently mature forms achieve only about half the diameter of most plectostaffelloids. Also, chomata (pseudochomata?) in *Pl. reitlingeri* are very weakly developed to imperceptible, in contrast to the low but conspicuous development of this feature in *Pl. jakhensis* and similar forms. The new species superficially resembles *Endostaffella discoidea* (Girty) (= *Zellerinella discoidea sensu* Mamet), particularly in sagittal and near sagittal sections. The new species differs from the latter, however, in being almost completely involute and possessing an eostaffellid wall (that is, protheca with tectorium on chamber floors). In *E. discoidea*, coiling may be highly evolute in outer volutions and the wall is undifferentiated microgranular calcite without secondary deposits.

As discussed in the evolutionary analysis, *Plectostaffella reitlingeri* is considered a likely ancestor of the group of small, primitive eoschubertelloids including *Eoschubertella obscura* (Lee and Chen), *E. mosquensis* (Rausser-Chernousova), *E. compressa* (Rausser-Chernousova) and *E. bluensis* Ross and Sabins (= *Schubertina circuli* Marshall). The main distinctions

between *Pl. reitlingeri* and the *E. obscura* group are the development in the latter of a slightly larger proloculus, relatively longer axis, and in some specimens, more pronounced chomata (pseudochomata?). An additional criterion for separating the taxa is the lower stratigraphic appearance of *Pl. reitlingeri* in the upper Serpukhovian (Morrowan) with the lowest known occurrences of primitive eoschubertelloids in upper lower Bashkirian (lower Atokan).

Age and distribution. Specimens were recovered from GSC localities C-193522, C-193523, C-193525-C-193533, C-193535, C-193536, C-193539, and C-193540 in the Nansen Formation at Girty Creek; and C-195804-C-195808, C-195811, and C-195812 in the Nansen at the glacier section. The only other documented occurrence of the species is for the invalidly named *Pl. varvariensis* var. *pusilla* from upper Serpukhovian limestones D3-D5 in the Donbass (Brazhnikova and Vdovenko *in Aisenverg et al.*, 1983). Accordingly, the minimum stratigraphic range of the species is upper Serpukhovian through the lower Akavassky portion of the lower Bashkirian.

Family OZAWAINELLIDAE
Thompson and Foster, 1937

Genus *Ozawainella* Thompson, 1935

Type species. *Fusulinella angulata* Colani, 1924.

Diagnosis. Discoidal to lenticular Ozawainellidae with angular to keeled equatorial periphery. Coiling planispiral.

Discussion. Representatives of the genus differ from other ozawainellids such as *Leella* Dunbar and Skinner, *Rauserella* Dunbar, and *Toriyamaia* Kanmera in their axially compressed, as opposed to elongate, shape. *Reichelina* Erk exhibits lenticular morphology, but becomes uncoiled in the mature stage. *Ozawainella* differs from *Eostaffella* and *Eostaffellina* in its massive chomata and angular to keeled periphery.

Ozawainella angulata, type species of the genus, was described from the Permian of Vietnam. Permian occurrences are essentially cosmopolitan. In contrast, Middle Carboniferous species are limited geographically to the Eurasian-Arctic faunal realm with no unquestioned occurrences in the conterminous United States (Rozovskaya, 1975). Specimens are known from rocks as old as lower Bashkirian (Askynbashsky), but they are more abundant in upper Bashkirian (Tashastinsky) and younger strata (Sinitsyna and Sinitsyn, 1987).

Ozawainella mosquensis Rauser-Chernousova in Rauser-Chernousova et al., 1951, p. 136, 137, Pl. 10, figs. 14–16; Grozdilova and Lebedeva, 1960, p. 121, 122, Pl. 14, fig. 12; Ross and Dunbar, 1962, p. 8, 9, Pl. 1, figs. 1–7; Lebedeva, 1966, p. 188, Pl. 3, fig. 6; Brazhnikova et al., 1967, Pl. 23, fig. 3; Sosipatrova, 1967, Pl. 6, figs. 5, 6; Rozovskaya, 1975, Pl. 1, fig. 35; Grozdilova et al., 1975, p. 47, Pl. 8, fig. 2; Niikawa, 1978, p. 540, Pl. 1, figs. 16–19; Chen, 1978, p. 18, Pl. 3, figs. 8, 9; Dzhentchuraeva, 1979, Pl. 9, figs. 1–5; Malakhova, 1980, Pl. 10, figs. 4–7; Rui, 1983, Pl. 1, fig. 21; Sakagami and Ueno, 1987, fig. 3.7; Zhang et al., 1987, p. 251, Pl. 1, fig. 29; Rui et al., 1991, p. 30, 31, Pl. 5, figs. 13–23.

Ozawainella vozhgatica Safonova in Rauser-Chernousova et al., 1951, p. 138, 139, Pl. 11, figs. 3, 4; Sheng, 1958, p. 73, 74, Pl. 1, figs. 30–34, Pl. 2, fig. 1; Sheng and Sun, 1975, p. 5, Pl. 1, fig. 19; Sheng et al., 1976, Pl. 1, figs. 1–4; Chen, 1978, p. 17, Pl. 3, fig. 2; Liu et al., 1978, p. 12, Pl. 1, fig. 2; Dzhentchuraeva, 1979, Pl. 9, fig. 10; Malakhova, 1980, Pl. 10, figs. 9–11; Rui, 1983, Pl. 1, figs. 18, 19; ?Sinityna and Sinityn, 1987, Pl. 13, fig. 11; Zhang et al., 1987, p. 250, 251, Pl. 1, figs. 10–13, 18–25, 30, 31.

Ozawainella spp. ?Forbes, 1960, p. 213, Pl. 30, figs. 1, 2.

Ozawainella cf. *vozhgatica* Safonova. van Ginkel, 1965, p. 65, 66, Pl. 16, fig. 12.

Ozawainella aff. *mosquensis* Rauser-Chernousova. van Ginkel, 1986, p. 207–212, figs. 2.1–2.19, 3.14–3.20.

Description. Measured specimens have 4.5–5.5 volutions. Test is lenticular to rhomboidal with acutely angular equatorial periphery and weakly convex to weakly concave flanks. Chomata massive, their height exceeding half the chamber height adjacent to the tunnel, extending uniformly to poles where they occlude the axial portion of the test. Tunnel narrow, its path straight to slightly irregular. Outer diameter of proloculus 0.033–0.041 mm. Maximum diameter of test 0.556–0.910 mm. Maximum length 0.259–0.439 mm. Length/diameter 0.44–0.52. Thickness of wall in final volution 0.015–0.021 mm. Chamber counts not available as no sagittal specimens were recovered: n=5.

Discussion. *Ozawainella mosquensis* was designated the type species of the new genus *Moscoviella* by Miklukho-Maklay (1952). The taxonomic validity of

Moscoviella was never widely accepted in the Soviet Union or elsewhere, leading to its placement in synonymy under *Ozawainella* by Rauser-Chernousova and Fursenko (in Orlov, 1959) and Thompson (in Loeblich and Tappan, 1964, p. C434, 435).

The present specimens compare favourably with the types, despite possessing generally fewer volutions. Larger specimens were recovered, but they are unsuitable for measuring and illustrating since they are tangential and/or oblique sections.

As indicated in the synonymy, we consider *Ozawainella mosquensis* and *O. vozhgatica* to be synonyms, with the former having nomenclatural priority. Both species were described in the same work. Priority is designated here in accordance with the “principle of the first reviser” (ICZN, 1985, Art. 24, p. 53). Our decision to favour *O. mosquensis* over *O. vozhgatica* is governed by the type series of *O. mosquensis* comprising more specimens and thus enabling better appreciation of the range of morphological variation. Also, the types of *O. mosquensis* are somewhat better documented stratigraphically and described in greater detail. Among other species of the genus, *O. mosquensis* strongly resembles *O. turgida* Sheng, 1958. Holotypes of the two species differ in the morphology of their polar regions; that in *O. mosquensis* is umbilicate, whereas that in *O. turgida* is convex. The figured paratypes of *O. mosquensis*, however, do not exhibit depressed umbilici and thus very strongly resemble all specimens in the type series of *O. turgida*. The trivial name *mosquensis* is here employed for specimens without depressed umbilici: that is, it encompasses the range of forms exhibited by the holotype and paratypes. We prefer this assignment in light of the nomenclatural seniority of *O. mosquensis* over *O. turgida*. The latter epithet would prove appropriate for the present specimens only upon demonstration of the clear value of umbilical morphology as a basis for taxonomic discrimination.

Age and distribution. Specimens occur fairly abundantly at GSC localities C-195831, C-195834, C-195837, C-195852, C-195859, C-195860, and C-106750 in the Nansen Formation at the glacier section.

The holotype is from the Kashirsky Horizon at the Lopasnya River locality in the Moscow Basin. Paratypes are from Vereisky through Myachkovsky equivalents elsewhere in the Moscow Basin. Other documented occurrences, including those of the proposed synonym *O. vozhgatica*, come from the Vereisky Horizon in the Krasnokamsk region of

Prikam'e (Grozdilova and Lebedeva, 1960); the Podolsky Horizon near Vozhgaly, Moscow Basin (Safonova in Rauser-Chernousova et al., 1951); Myachkovsky equivalents in the Dneipr-Donets Basin (Brazhnikova et al., 1967); the *Aljutovella aljutovica* and *A. priscoidea* Zones (Vereisky-Kashirsky) of the north slope of the Turkestan-Alaya (Dzhentchuraeva, 1979); the Lower Moscovian Substage of the southeastern Urals (Malakhova, 1980); the entire Moscovian of northern Timan (Lebedeva, 1966); the upper Moscovian Passage Beds of Spitsbergen (Forbes, 1960; Sosipatrova, 1967); the upper Moscovian Lower Marine Group of Holm Land and Amdrup Land, northeast Greenland (Ross and Dunbar, 1962); Podolsky equivalents in the upper Nansen (Rui et al., 1991); Kashirsky equivalents in the Cantabrian Mountains of Spain (van Ginkel, 1965); uppermost Bashkirian or basal Moscovian (undifferentiated) beds in the Oued el Hamar Formation, Algeria (van Ginkel, 1986); the Zone of *Beedeina* (Podolsky) in the Ichinotani and Mizuboradani River Valleys of Fukuji, Japan (Niikawa, 1978); the upper Moscovian of Shikoku, Japan (Sakagami and Ueno, 1987); the Podolsky and Myachkovsky portions of the Penchi Series in Shandong and Liaoning, north China (Sheng, 1958; Zhang et al., 1987); Vereisky through upper Moscovian (undifferentiated) strata of the Huanglong and Weining formations in south China (Sheng et al., 1976; Chen, 1978; Liu et al., 1978; Rui, 1983); and the upper Moscovian (undifferentiated) of Qinghai Province, China (Sheng and Sun, 1975). A specimen illustrated as *O. vozhgalyca*, but considered here to be questionably identified, was recovered from the Tashastinsky Horizon of the upper Bashkirian stratotype (Sinitsyna and Sinitsyn, 1987).

Ozawainella sp.

Plate 2, figures 27, 28

Discussion and occurrence. Three specimens, too poorly oriented for measuring and species-level identification, differ from those assigned to *O. mosquensis* in possessing keeled peripheries and decidedly concave lateral slopes. They come from GSC locality C-195866 in the Nansen Formation at the glacier section.

Family FUSULINIDAE Möller, 1878

Subfamily PSEUDOSTAFFELLINAE Putrya, 1956

Genus *Pseudostaffella* Thompson, 1942

Type species. *Pseudostaffella needhami* Thompson, 1942.

Diagnosis. Test broadly nautiloid to quadratic, commonly subspherical to subquadratic. Coiling skewed throughout or initially skewed then planispiral. Wall three layered. Chomata generally well developed.

Subgenus *Pseudostaffella* (*Semistaffella*)
Reitlinger, 1971

Type species. *Pseudostaffella variabilis* Reitlinger, 1961.

Diagnosis. Primitive, broadly nautiloid to subspherical *Pseudostaffella* with almost continuously skewed coiling.

Discussion. See Groves (1988, p. 391).

Pseudostaffella (*Semistaffella*) *variabilis* Reitlinger,
1961

Plate 2, figures 11-17

For synonymy see Groves (1988, p. 391, 392).

Description. Measured specimens possess 4-4.5 volutions. Test very broadly nautiloid with mildly depressed umbilici. Coiling strongly skewed in juvenarium, then less skewed to nearly planispiral in outer 1.5-2 volutions. Chomata moderately well developed, their height approximately one quarter to one third chamber height. Outer diameter of proloculus 0.032-0.041 mm. Test diameter 0.333-0.433 mm. Maximum width 0.234-0.274 mm. Width/diameter 0.67-0.76. Wall thickness in final volution 0.015-0.021 mm. Chamber count in final volution 12 to 16, typically 13 or 14; n=5.

Discussion. This species phylogenetically links the Eostaffellidae and Fusulinidae in that it is thought to have derived from *Plectostaffella jakhensis* and to have given rise to *Ps. (Pseudostaffella) antiqua*. It differs from *Pl. jakhensis* in its slightly more robust chomata, greater axial length, and more broadly nautiloid shape. The continued development of these same parameters separates *Ps. (S.) variabilis* from *Ps. (Ps.) antiqua*. The latter exhibits quite robust chomata and its axial length nearly equals the test diameter resulting in a more spherical overall shape. The reader is referred to

Groves (1988, p. 392) for nomenclatural and taxonomic remarks.

Age and distribution. Local occurrences were observed at GSC localities C-193526, C-193527, C-193530, C-193531, and C-193535 in the Nansen Formation at Girty Creek; and C-195811–C-195813 and C-195823 in the Nansen at the glacier section. Documented specimens range from middle to upper Syuransky (=Krasnopolyansky) through upper Bashkirian rocks at widespread localities throughout the former Soviet Union and Spain (Groves, 1988). Unpublished but verified occurrences are known from probable upper Syuransky equivalents in the Lisburne Group of the eastern Brooks Range, northern Alaska (observations by Groves; P.L. Brenckle, pers. comm.). Ivanova (1988, Pl. 2, fig. 11, Pl. 3, figs. 17a, b) illustrated upper Serpukhovian specimens under *Semistaffella variabilis*. These are misidentified individuals that probably should be reassigned to *Plectostaffella jakhensis*.

Subgenus *Pseudostaffella* (*Pseudostaffella*)
Thompson, 1942

Type species. *Pseudostaffella needhami* Thompson, 1942.

Diagnosis. Subspherical to quadratic *Pseudostaffella* with robust chomata. Coiling skewed in juvenarium then planispiral in outer volutions.

Discussion. See Groves (1984a, 1988).

Pseudostaffella (*Pseudostaffella*) *antiqua*
(Dutkevich, 1934b)

Plate 2, figures 1–10

For synonymy see Groves (1988, p. 392) and add:

Pseudostaffella antiqua (Dutkevich). (?)Malakhova, 1980, Pl. 4, figs. 9–15; Rui, 1983, p. 177, Pl. 1, fig. 31; Matsusue, 1986, Pl. 7, figs. 2, 3; Sinitsyna and Sinitsyn, 1987, Pl. 8, fig. 1, Pl. 9, fig. 13, Pl. 12, fig. 9; Ueno, 1989, Pl. 2, fig. 13.

Pseudostaffella ex. gr. *antiqua* (Dutkevich). Sinitsyna and Sinitsyn, 1987, Pl. 9, fig. 14.

Description. Measured specimens possess 4.5–6 volutions. Test is subspherical and has mildly depressed umbilici. Coiling initially skewed then planispiral in

outer 2–3 volutions. Chomata well developed, their height one third to one half that of corresponding chamber height. Outer diameter of proloculus 0.036–0.053 mm. Test diameter 0.419–0.578 mm. Maximum width 0.402–0.411 mm. Width/diameter 0.83–0.88. Wall thickness in final volution 0.011–0.024 mm. Chamber count in final volution 15 to 18: n=5.

Discussion. *Pseudostaffella* (*Pseudostaffella*) *antiqua* is the earliest and morphologically most primitive species in the subgenus. It differs from most others in its relatively small size and spherical shape. Most sub-Arctic North American forms are subquadratic to quadratic (for example, *Ps.* (*Ps.*) *needhami* Thompson, *Ps.* (*Ps.*) *atokensis* (Thompson)), whereas the more advanced Eurasian–Arctic forms may be spherical to quadratic, but are decidedly larger with more volutions (for example, *Ps.* (*Ps.*) *praegorskyi* Rauser-Chernousova, *Ps.* (*Ps.*) *proozawai* Kireeva). The latter distinction is confirmed by comparison of the present specimens of *antiqua* with those discussed below under “advanced” *Ps.* (*Pseudostaffella*). *Pseudostaffella* (*Ps.*) *antiqua* is among the most widely identified and biostratigraphically useful primitive fusulinids. Its appearance defines the base of the lower Bashkirian Akavassky Horizon and equivalents throughout Eurasia, North Africa, and the Arctic.

Age and distribution. Questionably identified specimens were recovered from GSC locality C-193540 in the Nansen Formation at Girty Creek. At this section, the lowest unquestioned occurrences are at locality C-193542, continuing through C-193543, C-193544 and C-193545. Specimens occur at GSC localities C-195823–C-195825 and C-195827 in the Nansen at the glacier section. The total stratigraphic range of the species is lower Bashkirian (Akavassky) through lower Moscovian. Details of geographic distribution may be found in Groves (1988, p. 394).

“Advanced” *Pseudostaffella* (*Pseudostaffella*) spp.

Plate 2, figure 18

Discussion and occurrence. Several large, morphologically advanced specimens were recovered from GSC localities C-195834, C-195837, C-195844, and C-195846 in the Nansen Formation at the glacier section, in strata higher than the appearance of *Ps.* (*Ps.*) *antiqua*. All are too poorly oriented for meaningful measurements, hence no attempt is made at species level identification. This notwithstanding, the specimens bear remarkable similarity to *Neostaffella* (*Neostaffella*) *sphaeroidea* Miklukho-Maklay, with the

exception of possessing an apparent three-layered, as opposed to four-layered, spirotheca.

Neostaffella (Hanostaffella) paradoxa
(Dutkevich, 1934a)

Plate 3, figures 13–18, 21

Genus *Neostaffella* Miklukho-Maklay, 1959

Type species. Neostaffella sphaeroidea Miklukho-Maklay, 1959.

Diagnosis. Subquadratic to spherical Fusulinidae with massive chomata and four-layered spirotheca, in which tectorium lines chamber floors, chamber ceilings, posterior and anterior sides of septa.

Discussion. Issues concerning authorship and typification of the genus were addressed by Groves (1988, p. 394). *Neostaffella* is distinguished from *Pseudostaffella (Pseudostaffella)* Thompson by its four-layered spirotheca, and from *Xenostaffella* Cheong by its involute coil. In *Xenostaffella*, outer volutions are evolute, which combined with extreme depression of the equatorial periphery, gives rise to an X-shaped or butterfly-shaped axial outline.

Two subgenera are recognized within the genus. *Neostaffella (Neostaffella)* Miklukho-Maklay includes forms with smooth to convex equatorial peripheries. In contrast, the periphery in *N. (Hanostaffella)* Cheong is weakly to strongly concave. This seemingly arbitrary distinction is justifiable on both stratigraphic and evolutionary grounds. Specimens of *N. (Neostaffella)* are known from rocks as old as early late Bashkirian (Tashastinsky), whereas the earliest *N. (Hanostaffella)* appeared in the Moscovian as direct descendants (Cheong, 1984). Species of both subgenera occur in Moscovian strata throughout the Eurasian–Arctic faunal realm. None is known south of Alaska in North America.

Subgenus *Neostaffella (Hanostaffella)* Cheong, 1984

Type species. Staffella paradoxa Dutkevich, 1934a.

Diagnosis. *Neostaffella* with depressed equatorial periphery and umbilicate poles.

Discussion. Taxa assigned to the subgenus by Cheong (1984) include the type species as well as *Pseudostaffella greenlandica* Ross and Dunbar, 1962, *P. dogensis* Cheong, 1973, *Neostaffella hanensis* Cheong, 1973, *N. papilioformis* Cheong, 1973, and *N. magna* Cheong, 1974.

Staffella paradoxa Dutkevich, 1934a, p. 14–17, 65–66, Pl. 1, figs. 9, 10, Pl. 2, figs. 1–10; Dutkevich, 1934b, p. 37, fig. 9.

Pseudostaffella paradoxa (Dutkevich). Grozdilova and Lebedeva, 1950, p. 42, 43, Pl. 5, figs. 5, 6; Safonova in Rauser-Chernousova et al., 1951, p. 112, 113, Pl. 10, fig. 1; Grozdilova and Lebedeva, 1960, p. 135–136, Pl. 18, fig. 2; Chang, 1974, p. 257, Pl. 130, fig. 11; Lin et al., 1977, p. 10, Pl. 1, fig. 22; Chen, 1978, p. 25, Pl. 4, fig. 8; Liu et al., 1978, p. 18, Pl. 1, fig. 30; Wang et al., 1982, p. 15, Pl. 2, fig. 23.

Pseudostaffella greenlandica Ross and Dunbar, 1962, p. 11–13, Pl. 1, figs. 8–13; Sosipatrova, 1967, Pl. 6, figs. 8, 9; Chang, 1974, p. 258, Pl. 130, fig. 13. (not) *Pseudostaffella paradoxa* (Dutkevich). Sosipatrova, 1967, Pl. 7, fig. 16.

Neostaffella hanensis Cheong, 1973, p. 64–65, Pl. 3, figs. 10–13; Cheong, 1974, p. 68–70, Pl. 1, figs. 14–21.

Pseudostaffella panxianensis Chang, 1974, p. 258, Pl. 130, fig. 12; Liu et al., 1978, p. 18, Pl. 1, fig. 23.

Pseudostaffella subquadrata Grozdilova and Lebedeva. Lin et al., 1977, p. 11, Pl. 1, fig. 25.

Pseudostaffella sphaeroidea var. *cuboides* Rauser-Chernousova. Lin et al., 1977, p. 10, Pl. 1, fig. 24.

Pseudostaffella paracuboides Chen, 1978, p. 24, Pl. 4, fig. 4.

Pseudostaffella bellus Lin et al., 1978, p. 19, Pl. 1, fig. 29.

(not) *Pseudostaffella greenlandica* Ross and Dunbar. Liu et al., 1978, p. 18, Pl. 1, fig. 22.

Neostaffella aff. *hanensis* Cheong. Niikawa, 1978, p. 546, Pl. 10, figs. 11, 12.

Neostaffella cf. *sphaeroidea* (Ehrenberg) var. *cuboides* (Rauser) (sic.). Dzhentchuraeva, 1979, Pl. 6, fig. 11 (only).

Pseudostaffella sphaeroidea cuboides Rauser-Chernousova. Wang et al., 1982, p. 15, Pl. 2, fig. 19.

Neostaffella (Hanostaffella) paradoxa (Dutkevich). Cheong, 1984, fig. 6.

Neostaffella (Hanostaffella) hanensis Cheong. Cheong, 1984, fig. 6.

Neostaffella (Hanostaffella) aff. hanensis Cheong. Cheong, 1984, fig. 6.

Neostaffella (Hanostaffella) greenlandica (Ross and Dunbar). Cheong, 1984, fig. 6.

Neostaffella panxianensis (Chang). Zhang et al., 1987, p. 254, 255, Pl. 2, fig. 4.

Neostaffella subquadrata (Grozdilova and Lebedeva).

Zhang et al., 1987, p. 255, Pl. 2, figs. 25, 29.

Neostaffella cuboides (Rauser-Chernousova). Zhang et al., 1987, p. 255, Pl. 2, figs. 11, 19, 22–24, 26–28.

Neostaffella cf. *greenlandica* (Ross and Dunbar).

Nakrem et al., 1991, p. 59, 60, figs. 7J–L, 8A.

Description. Mature specimens have 5 to 7 volutions. Axial outline subquadratic with mildly depressed equatorial periphery and poles. Coiling planispiral and involute throughout growth. Chomata massive, extending from near equatorial plane to near poles, with maximum height achieved in shoulder area where it may exceed two thirds of chamber height. Tunnel narrow. Septa plane, slightly anteriorly directed or perpendicular to spirotheca. Number of chambers 24 and 27 in outermost volutions of poorly oriented sagittal specimens with six and seven volutions, respectively. Outer diameter of proloculus 0.101–0.147 mm. Radius vectors for first through seventh volutions 0.090–0.131 mm, 0.131–0.222 mm, 0.226–0.342 mm, 0.318–0.469 mm, 0.445–0.586 mm, 0.563–0.628 mm, and 0.741–0.794 mm, respectively. Half lengths for first through seventh volutions 0.068–0.114 mm, 0.107–0.209 mm, 0.194–0.312 mm, 0.258–0.432 mm, 0.325–0.535 mm, 0.419–0.631 mm, and 0.483–0.722 mm, respectively. Form ratios for first through seventh volutions 0.65–1.11, 0.82–1.22, 0.86–1.29, 0.81–1.29, 0.73–1.18, 0.74–1.00, and 0.65–0.91, respectively. Wall thicknesses for first through seventh volutions 0.015–0.026 mm, 0.016–0.027 mm, 0.022–0.041 mm, 0.025–0.041 mm, 0.027–0.045 mm, 0.030–0.040 mm, and 0.030–0.035 mm, respectively: $n=5$.

Discussion. Ross and Dunbar (1962, p. 13) noted the similarity between their newly described *Pseudostaffella greenlandica* and *Neostaffella* (*Hanostaffella*) *paradoxa* (Dutkevich). They distinguished the species on the seemingly more depressed periphery and umbilici in *N. (H.) paradoxa*. Comparison of holotype specimens of the two species confirms that the equatorial periphery in *N. (H.) paradoxa* indeed is more depressed. Paratypes of both species, however, exhibit variation in the degree of equatorial depression. For example, equatorial depression in the paratype of *P. greenlandica* illustrated in Plate 1, figure 12 of Ross and Dunbar (1962) very closely approximates that in the holotype of *N. (H.) paradoxa*. Moreover, many of the types of *N. (H.) paradoxa* are abraded and/or corroded, imparting a more equatorially depressed appearance for outer volutions than is developed in unaltered inner volutions. Specimens in both type series exhibit very similar dimensions and degrees of umbilical depression. On morphological criteria, and

because of the very close ages of the two collections, we consider *P. greenlandica* to be a junior synonym of *N. (H.) paradoxa*.

Cheong (1973, 1974) likewise erected a new species, *Neostaffella hanensis*, while noting its striking similarity to *N. (H.) paradoxa*. Cheong distinguished *Neostaffella hanensis* on the basis of its greater number of volutions and tighter coil. We reject the validity of these bases for species discrimination since the types of *N. (H.) paradoxa* are clearly worn and possibly juveniles, and no significant difference in coiling tightness can be demonstrated with the limited available quantitative data. *Neostaffella hanensis* is regarded as a junior synonym of *N. (H.) paradoxa*. Similar lines of reasoning lead us to consider the following species also as junior synonyms of *N. (H.) paradoxa*: *Pseudostaffella panxianensis* Chang, 1974; *P. paracuboides* Chen, 1978; and *P. bellus* Liu et al., 1978.

In contrast, Cheong's species *Neostaffella magna* and *N. papilioformis* are readily distinguished from *N. (H.) paradoxa* by their very markedly depressed equatorial peripheries. Constriction of the periphery in these species is so exaggerated that they can be clearly identified as direct ancestors of *Xenostaffella*.

Age and distribution. Specimens occur locally at GSC localities C-195859, C-195862, and C-195865 in the Nansen Formation at the glacier section. The type series comes from the upper Middle Carboniferous "limestone-dolomite complex" of Verkhne-Chussovskye Gorodki on the western slope of the middle Urals. Other conspecific specimens are known from the Kashirsky through Myachkovsky horizons of the Molotov pre-Urals, and the Myachkovsky Horizon of the western Urals (Grozdilova and Lebedeva, 1950); the Kashirsky through Myachkovsky horizons of the Russian Platform (Safonova in Rauser-Chernousova et al., 1951); the lower Moscovian (undifferentiated) *Aljutovella priscoidea* Zone of the northern slope of the Turkestan-Alaya (Dzhentchuraeva, 1979); Kashirsky through Podolsky equivalents in the Lower Marine Group of northeast Greenland (Ross and Dunbar, 1962); the upper Moscovian (Podolsky equivalent) "transition layers" of the *Cyathophyllum* Limestone of Spitsbergen (Sosipatrova, 1967); the Myachkovsky *Neostaffella sphaeroidea cuboides* Subzone of the Geumcheon Formation, Samcheog Coalfield, Korea (Cheong, 1973, 1974, 1984); the lower Zone of *Fusulinella-Fusulina* (Vereisky?-Kashirsky) in the Mizuboradani Valley of Fukuji, Japan (Niikawa, 1978); the upper part of the Huanglung and Weining formations of south China (Chang, 1974; Lin et al.,

1977; Liu et al., 1978; Chen, 1978); and the *Fusulina cylindrica*-*Fusulina quasicylindrica* subzone of the Penchi Formation of north China (Wang et al., 1982; Zhang et al., 1987). Questionably conspecific specimens have been documented from probable Kashirsky equivalents on Novaya Zemlya (Nakrem et al., 1991).

Subfamily FUSULININAE Möller, 1878

Genus *Eoschubertella* Thompson, 1937

Type species. *Schubertella lata* Lee and Chen in Lee et al., 1930.

Diagnosis. Subspherical to ovate Fusulininae with three-layered spirotheca. Coiling skewed throughout or initially skewed then planispiral. Chomata weakly to moderately developed.

Discussion. The reader is referred to Groves (1991, p. 80, 81) for a discussion of the systematics of the genus, particularly its taxonomic relationship with *Schubertella* Staff and Wedekind.

Eoschubertella obscura (Lee and Chen in Lee et al., 1930)

Plate 3, figures 8-12

Schubertella obscura Lee and Chen in Lee et al., 1930, p. 112, 113, Pl. 6, figs. 12-22; Rauser-Chernousova and Fursenko, 1937, p. 166, fig. 107; Rauser-Chernousova in Rauser-Chernousova et al., 1951, p. 71, 72, Pl. 2, fig. 22; Grozdilova and Lebedeva, 1954, p. 130, 131, Pl. 14, fig. 21; Putrya, 1956, p. 409, 410, Pl. 6, figs. 5-8; Sheng, 1958, p. 78, 79, Pl. 2, figs. 21-26; Grozdilova and Lebedeva, 1960, p. 136, 137, Pl. 18, fig. 3; Bogush, 1963, p. 62, 63, Pl. 2, fig. 13; ?Brazhnikova et al., 1967, Pl. 27, fig. 8, Pl. 29, fig. 9, Pl. 34, fig. 9, Pl. 36, fig. 1; Cheong, 1973, p. 59, Pl. 2, figs. 9, 10; Grozdilova et al., 1975, p. 55, Pl. 11, fig. 4; Lin et al., 1977, p. 32, Pl. 6, fig. 14; Dzhentchuraeva, 1979, Pl. 1, figs. 1, 2; Malakhova, 1980, Pl. 1, figs. 26-29; Wang et al., 1982, p. 17, Pl. 2, fig. 32; Sinitsyna and Sinitsyn, 1987, Pl. 14, figs. 1, 2.

Eoschubertella obscura (Lee and Chen). Brazhnikova, 1939, p. 246, 247, Pl. 1, fig. 5a; Toriyama, 1947, p. 36, 37, Pl. 9, figs. 3, 4; Igo, 1957, p. 187, 188, Pl. 3, figs. 9-11; (?)Cheong, 1971, Pl. 1, fig. 19; Niikawa, 1978, Pl. 5, fig. 8; Sakagami and Ueno, 1987, fig. 3.13; Ueno, 1989, Pl. 4, fig. 8.

Eoschubertella sp. cfr. *Eoschubertella obscura* (Lee and Chen). Ishii, 1962, p. 8, 9, Pl. 6, figs. 41-44. *Schubertella* cf. *obscura* Lee and Chen. van Ginkel, 1965, p. 87, Pl. 22, figs. 5-12. *Schubertella* ex. gr. *obscura* Lee and Chen. (?)Sinitsyna and Sinitsyn, 1987, Pl. 11, fig. 11, Pl. 14, fig. 7; (?)van Ginkel, 1987, p. 212, 213, figs. 4.3, 4.4.

Description. Measured specimens have 3 to 3.5 volutions. Axial outline spherical to thickly ovate with weakly umbilicate to truncate poles. Coiling skewed in initial 1 to 1.5 volutions, then planispiral throughout remainder of growth. Chomata weakly to very weakly developed. Chamber count 11 to 13 in ultimate volution. Outer diameter of proloculus 0.050-0.073 mm. Maximum diameter of test 0.300-0.378 mm. Wall thickness 0.008-0.019 mm in ultimate volution: n = 5.

Discussion. Considerable latitude is employed in determining the range of morphological variation within the species concept. This is partly a consequence of the wide range of morphotypes illustrated by Lee and Chen (in Lee et al., 1930) in their original description. No holotype was designated, so our species concept embraces the full range of forms within the type series. In general, the types exhibit somewhat more elongate axes and higher chamber counts than the present specimens, which, however, possess fewer whorls but compare favourably with the types at corresponding ontogenetic stages. Also, none of the present specimens is perfectly oriented axially, resulting in an apparent foreshortening of the axial dimension.

As noted by van Ginkel (1965, 1987), *Eoschubertella obscura* strongly resembles *E. mexicana* Thompson, *E. diminutiva* (Thompson), and *E. bluensis* Ross and Sabins, from the United States, as well as several other nominal species from the former European U.S.S.R., Japan, and China. Groves (1991) interpreted *E. bluensis* as a senior synonym of *Schubertina circuli* Marshall, and he placed *Schubertina* in synonymy under *Eoschubertella*. There is little doubt that the genus presently contains too many species, but no further attempt is made here to reconcile taxonomic inconsistencies. *Eoschubertella obscura* differs from *E. miranda* in its smaller size and more tightly coiled spire. It is readily distinguished from *E. texana* Thompson, which is much more robust with a larger proloculus, and from *E. mosquensis* (Rauser-Chernousova) (= *E. compressa* (Rauser-Chernousova)), which is smaller. Specimens queried in the above synonymy may be referable to the latter.

Entries in the synonymy represent an incomplete inventory of bibliographic citations. Kahler and Kahler (1966, 1967) identified the following additional reports of *E. obscura* that we have not verified: Dutkevich and Chabakov (1934); Putrya (1938, 1939); Toriyama (1941, 1944); Deleau and Marie (1959); and Ishizaki (1963).

Age and distribution. Specimens come from GSC locality C-193543 in the Nansen Formation at Girty Creek; and C-195823–C-195825, C-195827, C-195829, C-195831, C-195833, C-195860, C-195862, C-195864–C-195867, and C-106750 in the Nansen at the glacier section.

The types are from the Middle Carboniferous lowest fossiliferous horizon of the Huanglung Limestone in Lungtan and Chuanshan, southeastern China. Other documented occurrences span upper lower Bashkirian through upper Moscovian strata in the Sub-Moscow Basin (Rauser-Chernousova et al., 1951); Kolvo-Vishera region (Grozdilova and Lebedeva, 1954); central and eastern Donbass (Brazhnikova, 1939; Putrya, 1956); Dniepr–Donets Basin (Brazhnikova et al., 1967); southern, middle, and northern Urals (Grozdilova and Lebedeva, 1960; Grozdilova et al., 1975; Sinitsyna and Sinitsyn, 1987); southeastern Urals (Malakhova, 1980); eastern Alaiskogo–Khrebta (Bogush, 1963); northern slope of the Turkestan–Alaya (Dzhentchuraeva, 1979); Penchi Limestone (Penchi Series) in Taitzeho Valley of Liaoning, China (Sheng, 1958); Samcheog and Danyang coalfields of Korea (Cheong, 1971, 1973); Kwanto Mountains, Japan (Toriyama, 1947); Akiyoshi Limestone Group, Japan (Ueno, 1989); Ichinotani Formation of Fukuji, Japan (Igo, 1957; Niikawa, 1978); Itadorigawa Group, western Shikoku, Japan (Ishii, 1962); Sakawa Basin, Shikoku, Japan (Sakagami and Ueno, 1987); and the Lena and Curavacas Formations in the Cantabrian Mountains of Spain (van Ginkel, 1965, 1987).

Eoschubertella? miranda

(Leontovich in Rauser-Chernousova et al., 1951)

Plate 3, figures 19, 20, 22–24

Schubertella pauciseptata Rauser-Chernousova var. *miranda* Leontovich in Rauser-Chernousova et al., 1951, p. 76, 77, Pl. 2, figs. 35–38; Malakhova, 1980, Pl. 3, fig. 3.

(?)*Schubertella* aff. *pauciseptata miranda* Leontovich. Sinitsyna and Sinitsyn, 1987, Pl. 14, fig. 11.

(?)*Schubertella pauciseptata miranda* Leontovich. Sinitsyna and Sinitsyn, 1987, Pl. 19, fig. 10.

Discussion. No formal description is offered, because specimens are generally too poorly oriented for measurements. Nevertheless, these specimens are highly distinctive in their relatively thin walls, large proloculi, weakly developed chomata and rather loose coiling. Obliquely oriented sections suggest the very low chamber count characteristic of the types. Assignment of *miranda* to the genus *Eoschubertella* is questioned because of a tendency in many specimens toward a spherical to nearly subquadratic axial outline as is common among pseudostaffellins. Other features of the species noted above, however, are not characteristically pseudostaffellin.

Age and distribution. Specimens occur locally in a single sample, GSC locality C-195833 in the Nansen Formation at the glacier section. The types are from the upper Vereisky Horizon of the Russian Platform. Malakhova (1980) illustrated a single specimen from undifferentiated lower Moscovian strata in the southeastern Urals. Other specimens, questionably considered conspecific, are from the upper Bashkirian Tashastinsky and lower Moscovian Solontsovskii horizons at the Bashkirian stratotype, western slope of south Urals (Sinitsyna and Sinitsyn, 1987).

Genus *Profusulinella* Rauser-Chernousova and Beljaev in Rauser-Chernousova et al., 1936

Plate 4, figures 1, 2

Type species. *Profusulinella pararhomboides* Rauser-Chernousova and Beljaev in Rauser-Chernousova et al., 1936.

Discussion and occurrence. Species-level identifications and formal descriptions are precluded by imperfect orientations of the few specimens recovered. These specimens are nevertheless assigned confidently to the genus on the basis of their fusiform shape and three-layered wall. They occur at GSC localities C-195856 and C-106750 in the Nansen Formation at the glacier section where their presence is interpreted to indicate a late Bashkirian or early Moscovian age. The total stratigraphic range of the genus is upper lower Bashkirian to lower upper Moscovian in the Eurasian–Arctic realm and middle Atokan in the Midcontinent–Andean realm (Rozovskaya, 1975; Groves and Sanderson, 1990).

Genus *Fusulinella* Möller, 1877

Type species. *Fusulinella bocki* Möller, 1878.

Diagnosis. Gibbose to fusiform Fusulininae. Spirotheca four-layered, consisting of protheca with tectorial linings on chamber floors and ceilings, and both posterior and anterior sides of septa. Septal fluting restricted to poles. Chomata well developed.

Discussion. Representatives of *Fusulinella* are the most abundant fusulinins encountered in this study. They differ from *Beedeina* in their incompletely fluted septa, and from *Wedekindellina* in lacking axial fillings. It is almost universally considered that *Fusulinella* was derived from *Profusulinella* via the progressive addition of tectorial deposits on chamber ceilings and septa. In *Profusulinella*, the tectorium is present on chamber floors only, giving rise to a three-layered spirotheca.

Fusulinella alaskensis Douglass, 1971

Plate 3, figures 1-7

Fusulinella alaskensis Douglass, 1971, p. 12-16, Pl. 4, figs. 4-30, Pl. 5, figs. 1-8, Pl. 6, figs. 1-15.

Description. Measured specimens possess up to seven volutions. Axial outline is rhomboidal to fusiform with broadly rounded to truncate poles. Chomata well developed, highly asymmetrical, their height up to or exceeding half chamber height near equator then tapering gradually toward polar extremities. Tunnel moderately narrow, its path straight. Septa weakly fluted near poles. Outer diameter of proloculus 0.060-0.125 mm. Radius vectors for first through seventh volutions 0.056-0.096 mm, 0.085-0.149 mm, 0.120-0.216 mm, 0.186-0.381 mm, 0.284-0.460 mm, 0.408-0.648 mm, and 0.591-0.762 mm, respectively. Half lengths for first through seventh volutions 0.052-0.077 mm, 0.103-0.158 mm, 0.193-0.353 mm, 0.335-0.573 mm, 0.568-0.778 mm, 0.730-1.045 mm, and 1.015-1.293 mm, respectively. Form ratios for first through seventh volutions 0.69-1.14, 0.93-1.42, 1.24-1.80, 1.64-2.23, 1.66-2.19, 1.61-1.92, and 1.70-1.78, respectively. Wall thicknesses for first through seventh volutions 0.007-0.012 mm, 0.007-0.016 mm, 0.012-0.028 mm, 0.018-0.036 mm, 0.025-0.051 mm, 0.023-0.041 mm, and 0.026-0.037 mm, respectively. Chamber counts for fourth through seventh volutions 18, 21, 20, and 26, respectively, from a single sagittal specimen: n = 6.

Discussion. Among the present specimens, there are morphotypes with small and large proloculi. The ones with smaller proloculi generally exhibit more elongate inner volutions. At maturity, however, form ratios vary only within a narrow range, regardless of early

ontogenetic development. On this basis, the specimens are believed to represent one and not two species. See Douglass (1971, p. 13-16) for detailed comparisons of *alaskensis* with similar species.

Age and distribution. Specimens occur locally at GSC localities C-195864 and C-195865 in the Nansen Formation at the glacier section. The types are from undifferentiated Middle Pennsylvanian strata in southeastern Alaska. To the best of our knowledge, no other representatives of the species have been documented.

Fusulinella iowensis Thompson, 1934

Plate 5, figure 1

Girtyina ventricosa (Meek and Hayden). Morningstar, 1922, p. 153, Pl. 6, fig. 4.

Fusulinella iowensis Thompson, 1934, p. 296, 297, Pl. 20, figs. 28-30; Thompson, 1936, p. 675, 676, Pl. 90, figs. 12-16; Dunbar and Henbest, 1942, p. 93-95, Pl. 3, figs. 10-25; Thompson, 1948, Pl. 26, fig. 12; Smyth, 1957, p. 262, 263, Pl. 1, figs. 5-7 (only); Thompson and Riggs in Thompson et al., 1959, p. 777-780, Pl. 105, figs. 1-11; Douglass, 1987, p. 34, 35, Pl. 6, figs. 1-16, Pl. 15, figs. 14-26.

Description. Specimen possesses 7.5 volutions. Axial outline is highly inflated with very broadly rounded poles. Chomata well developed, generally greater than half chamber height, highly asymmetrical, extending from near midplane to near poles, overhanging tunnel in places. Tunnel narrow, its path broadly sigmoidal, reflecting slight inclination of axis in early volutions relative to later volutions. Septa planar. Outer diameter of proloculus 0.089 mm. Radius vectors for first through eighth volutions 0.062 mm, 0.095 mm, 0.140 mm, 0.218 mm, 0.330 mm, 0.486 mm, 0.680 mm, and 0.879 mm, respectively. Half lengths for first through eighth volutions 0.050 mm, 0.099 mm, 0.191 mm, 0.291 mm, 0.424 mm, 0.633 mm, 0.816 mm, 1.058 mm, respectively. Form ratios for first through eighth volutions 0.81, 1.04, 1.36, 1.33, 1.28, 1.30, 1.20, and 1.20, respectively. Wall thicknesses for first through eighth volutions 0.008 mm, 0.009 mm, 0.011 mm, 0.026 mm, 0.045 mm, 0.047 mm, 0.051 mm, and 0.032 mm, respectively. Chamber counts not available because no sagittal sections recovered: n = 1.

Discussion. The species is readily distinguishable by its highly gibbose axial outline. Few other species in the genus approach *Fusulinella iowensis* in degree of

equatorial inflation. Among the closest are *F. pinguis* and *F. alaskensis*, both described by Douglass (1971) from southeastern Alaska. These forms are more elongate, however, with less well developed chomata. Solov'eva (1955) assigned *F. iowensis* to her newly erected genus *Dagmarella* (type species *D. prima* Solov'eva, 1955). This assignment is not tenable since *D. prima* (and hence, the genus) is characterized by septa, which in the outermost volution are fluted across their entire length.

In his original description of the species, Thompson (1934) designated all recovered specimens as "cotypes". These include 16 sectioned and 187 whole individuals (catalogue nos. SUI 996-1000, University of Iowa Paleontology Collection). Thompson (1948, p. 155) later designated as "holotype" (*recte*, lectotype) that specimen illustrated in Plate 26, figure 12 (*ibid.*), corresponding to Plate 20, figure 28 of Thompson (1934) and SUI 997.

Age and distribution. GSC locality C-195864 in the Nansen Formation at the glacier section. The types come from a calcareous horizon within the lower "Cherokee Shale" approximately 90 ft. (27.5 m) below the Whitebreast Coal in Jefferson County, Iowa. This horizon probably falls within the Floris Formation (Cherokee Group, Des Moines Supergroup) of more recent nomenclature (Ravn et al., 1984). Other specimens are from the Seville Limestone Member of the Spoon Formation in Illinois (Dunbar and Henbest, 1942); the Boggs and Mercer Limestone members of the Pottsville Formation in Wayne, Portage, Tuscarawas, Muskingum, and Mahoning counties, Ohio (Morningstar, 1922; Thompson, 1936; Smyth, 1957; Douglass, 1987); and the Curlew Limestone Member of the Tradewater Formation in Union, Webster, and Christian counties, Kentucky (Thompson et al., 1959; Douglass, 1987). These occurrences represent latest Atokan(?) and early Desmoinesian ages according to midcontinent chronostratigraphic terminology.

Fusulinella paracolaniae

Safonova in Rauser-Chernousova et al., 1951

Plate 4, figures 3-5

Fusulinella paracolaniae Safonova in Rauser-Chernousova et al., 1951, p. 219, Pl. 30, figs. 7-9; Grozdilova and Lebedeva, 1960, p. 152, Pl. 22, fig. 3, Pl. 23, fig. 2.

Description. Measured specimens possess up to 7 volutions. Axial outline fusiform with slightly vaulted

median area, mildly convex lateral slopes, and blunt poles. Chomata well developed, highly asymmetrical, their height equal to or greater than one third chamber height near equator then tapering gradually toward poles. Tunnel low and moderately narrow with slightly irregular path. Septa weakly fluted near poles. Outer diameter of proloculus 0.060-0.070 mm. Radius vectors for first through seventh volutions 0.050-0.060 mm, 0.080-0.110 mm, 0.130-0.180 mm, 0.210-0.270 mm, 0.310-0.380 mm, 0.440-0.470 mm, and 0.630 respectively. Half lengths for first through seventh volutions 0.040-0.090 mm, 0.090-0.190 mm, 0.270-0.370 mm, 0.420-0.600 mm, 0.630-0.790 mm, 0.950-0.970 mm, and 1.300 mm, respectively. Form ratios for first through seventh volutions 0.80-1.50, 1.13-1.73, 2.06-2.08, 2.00-2.22, 2.03-2.08, 2.02-2.20, and 2.06, respectively. Wall thicknesses for first through seventh volutions 0.010 mm, 0.010-0.014 mm, 0.014 mm, 0.021-0.025 mm, 0.029 mm, 0.018-0.040 mm, and 0.029 mm, respectively. Chamber counts not available because no sagittal sections recovered: n=3.

Discussion. The present specimens are identical to typical representatives of *F. paracolaniae* in size, shape, and internal features. This species resembles *F. colaniae* Lee and Chen in some respects, but differs from that species in its narrower tunnel and less fusiform shape with convex lateral slopes and blunt poles. It is also similar in general shape to *F. vozhdgalensis devexa* Rauser-Chernousova, but the latter has better developed chomata.

Age and distribution. GSC localities C-195864 and C-195865 in the Nansen Formation at the glacier section. The types are from the uppermost Kashyrsky Horizon and the Podolsky Horizon of the Molotov, Mordov, and Kuibyshev "oblasts", C.I.S. The only other verified occurrences are those in Kashyrsky and Podolsky strata on the western slope of the Urals in Timan and Povolzh'ya (Grozdilova and Lebedeva, 1960).

Genus *Beedeina* Galloway, 1933

Type species. *Fusulinella girtyi* Dunbar and Condra, 1928.

Diagnosis. Gibbose to fusiform Fusulininae in which septal fluting extends from poles across equatorial portion of test. Spirotheca four-layered, as in *Fusulinella*. Chomata well developed. Axial fillings absent.

Discussion. In the present taxonomy, we employ the name *Beedeina* for those fusulinins with strongly fluted

septa, distinct chomata, and no axial fillings. These forms differ from *Fusulina* Fischer de Waldheim, in which chomata are weak or absent and axial fillings are moderately to extensively developed. Additional differences between the genera include a somewhat thicker protheca and larger mural pores in *Fusulina*, although observation of these features is dependent on good preservation. Prior to the late 1950s, the name *Fusulina* was used for virtually all fusulinins presently assigned to *Beedeina* and *Fusulina*. The name *Beedeina* came into general use beginning with a series of articles by Ishii (1958a, b, c), van Ginkel (1965), and Ross (1969), who identified clear morphological criteria for separating the genera. Ishii (1958c) also attempted to establish a phylogenetic basis for the distinction, in which he suggested separate evolutionary origins for *Beedeina* and *Fusulina* at different stratigraphic levels. Whereas some aspects of Ishii's proposed phylogeny appear suspect, it does seem likely that two groups of species arose independently from unique ancestors and hence warrant separation under different genera. Kahler and Kahler (1966, 1967) raised the issue of possible objective synonymy between *Beedeina* and *Girtyina* Staff. This issue was settled by Ross (1969); see Ross (*ibid.*) for an insightful discussion.

Beedeina pseudoelegans

(Chernova in Rauser-Chernousova et al., 1951)

Plate 5, figures 6-11

Fusulina pseudoelegans Chernova in Rauser-Chernousova et al., 1951, p. 282, 283, Pl. 44, fig. 10, Pl. 45, figs. 1-3; Bogush, 1963, p. 103, 104, Pl. 9, fig. 10.

Description. Measured specimens possess up to six volutions. Axial outline fusiform with broadly rounded to bluntly pointed poles. Chomata well developed, their height equal to or greater than half chamber height, overhanging tunnel in places. Tunnel moderately wide and straight. Septa strongly fluted across entire test; folds extend vertically from distal ends to more than three-quarters of chamber height. Outer diameter of proloculus 0.142-0.175 mm. Radius vectors for first through sixth volutions 0.087-0.161 mm, 0.157-0.259 mm, 0.241-0.387 mm, 0.374-0.582 mm, 0.541-0.773 mm, and 0.760-0.765 mm, respectively. Half lengths for first through sixth volutions 0.098-0.239 mm, 0.247-0.437 mm, 0.439-0.788 mm, 0.719-1.132 mm, 1.092-1.647 mm, and 1.597-1.783 mm, respectively. Form ratios for first through sixth volutions 0.83-1.81, 1.34-2.07, 1.52-2.12, 1.71-2.37, 1.91-2.40, and 2.09-2.35, respectively. Wall thicknesses for first through sixth

volutions 0.010-0.020 mm, 0.011-0.025 mm, 0.013-0.032 mm, 0.020-0.055 mm, 0.026-0.054 mm, and 0.032-0.040 mm, respectively. Chamber counts not available because no sagittal sections were recovered: n=4.

Discussion. The characteristic features of this species are its relatively abbreviated fusiform shape, vaulted median area, slightly convex lateral slopes, and bluntly pointed poles. *Beedeina pseudoelegans* very closely resembles *B. paraozawai* (Rauser-Chernousova in Rauser-Chernousova et al., 1951), with the principal difference being the slightly less vaulted midplane in the latter.

Age and distribution. Specimens come from a single GSC locality, C-195862, in the Nansen Formation at the glacier section. The holotype is from the Podolsky Horizon near Kurdyum on the Russian Platform. Paratypes come from upper Kashyrsky and lower Podolsky equivalents in the same area. Other documented specimens are from undifferentiated upper Moscovian strata along the Dzhilgin-sai River in Kara-Chat'r, Alaiskogo Khrebta, C.I.S. (Bogush, 1963).

Beedeina sp.

Plate 5, figures 2-5

Description. Measured specimens possess six volutions. Axial outline rhomboidal to fusiform, with very slightly concave lateral slopes, and broadly rounded to bluntly pointed poles. Chomata well developed, equal to or greater than half chamber height, overhanging tunnel in places. Tunnel moderately wide and straight. Septa strongly fluted in polar extremities of outer volutions, with both frequency and height of folds decreasing toward midplane. Septa planar to weakly fluted in inner volutions. Outer diameter of proloculus 0.096-0.113 mm. Radius vectors for first through sixth volutions 0.070-0.095 mm, 0.127-0.160 mm, 0.217-0.241 mm, 0.349-0.366 mm, 0.508-0.540 mm, and 0.739-0.787 mm, respectively. Half lengths for first through sixth volutions 0.088-0.103 mm, 0.172-0.248 mm, 0.392-0.418 mm, 0.624-0.649 mm, 0.938-1.119 mm, and 1.421-1.519 mm, respectively. Form ratios for first through sixth volutions 1.08-1.26, 1.35-1.55, 1.73-1.81, 1.77-1.79, 1.85-2.07, and 1.92-1.93, respectively. Wall thicknesses for first through sixth volutions 0.012-0.014 mm, 0.016-0.024 mm, 0.019-0.023 mm, 0.026-0.029 mm, 0.035-0.038 mm, and 0.037-0.040 mm, respectively. Chamber counts not available because no sagittal specimens were recovered: n=2.

Discussion and occurrence. These specimens differ from *Beedeina pseudoelegans* primarily in their less intensely fluted septa. Also, they are somewhat less elongate. Their occurrence, at GSC locality C-195859 in the Nansen Formation at the glacier section, is approximately 23 m below that of *B. pseudoelegans*, suggesting a possible ancestor-descendant relationship.

Genus *Wedekindellina*

Dunbar and Henbest in Cushman, 1933

Type species. *Fusulinella euthysepta* Henbest, 1928.

Diagnosis. Elongate fusiform Fusulininae with unfluted septa and well developed axial deposits. Coiling planispiral. Spirotheca four-layered, as in *Fusulinella*.

Discussion. *Wedekindellina* differs from other fusiform fusulinaceans encountered in this study in possessing axial fillings. Other genera with axial fillings include *Pseudowedekindellina* Sheng, *Fru mentella* Stewart, *Parawedekindellina* Safonova, *Verella* Dalmatskaya, and *Fusiella* Lee and Chen. Thompson (in Loeblich and Tappan, 1964) considered *Parawedekindellina* to be a junior synonym of *Wedekindellina*. He placed *Fru mentella* in synonymy under *Pseudowedekindellina*, which is distinguished from *Wedekindellina* by its three-layered wall and much smaller shell. *Wedekindellina* differs from *Fusiella*, which has skew coiled early volutions and a three-layered wall; and from *Verella*, which is extremely elongate with variably developed septal fluting in outer volutions. All of these genera appeared in the Middle Carboniferous. It is unclear whether they form a clade or originated independently from separate ancestors.

The stratigraphic appearance of *Wedekindellina* throughout much of North America falls slightly above that of *Beedeina*. In practice, strata containing *Beedeina* through the concurrent ranges of the two genera are assigned to the lower Desmoinesian Series ("Cherokee") (Moore and Thompson, 1949; Clopine, in press). Unquestioned species of *Wedekindellina* are restricted to the upper lower and upper Moscovian in the Russian Platform and Urals regions of the C.I.S. (Rozovskaya, 1975).

Wedekindellina uralica (Dutkevich, 1934a)

Plate 5, figures 12-17

Fusulinella uralica Dutkevich, 1934a, p. 47-52, 84-87, Pl. 5, figs. 6-16; Dutkevich, 1934b, p. 38, 39, fig. 13.

Wedekindellina uralica Dutkevich (*sic.*). Rauser-Chernousova et al., 1936, p. 183-185, Pl. 2, figs. 5-7.

Wedekindellina uralica (Dutkevich). Rauser-Chernousova and Fursenko, 1937, p. 195, 196, fig. 140; Safonova and Rauser-Chernousova in Rauser-Chernousova et al., 1951, p. 237, 238, Pl. 36, figs. 1, 2; Grozdilova and Lebedeva, 1960, p. 158, 159, Pl. 26, fig. 1; Lebedeva, 1966, p. 201, 202, Pl. 9, fig. 6; Grozdilova et al., 1975, p. 52, Pl. 11, fig. 1; Rui et al., 1991, p. 46, 47, Pl. 7, figs. 1-7.

Wedekindellina dutkevitchi Rauser and Beljaev, ms. Rauser-Chernousova and Fursenko, 1937, p. 194, 195, fig. 139.

Wedekindellina dutkevitchi Rauser-Chernousova et al., 1940, p. 21-23, Textfig. 5, Pl. 4, figs. 4-7.

Wedekindellina dutkevitchi Rauser and Beljaev. Rauser-Chernousova and Safonova in Rauser-Chernousova et al., 1951, p. 239, Pl. 36, figs. 8, 9; Miklukho-Maklay et al. in Orlov (ed.), 1959, Pl. 7, fig. 6; Grozdilova and Lebedeva, 1960, p. 159, Pl. 25, fig. 4; Ross and Dunbar, 1962, p. 31-33, Pl. 4, figs. 6-12.

Wedekindellina spp. Forbes, 1960, p. 215, Pl. 30, figs. 14, 15.

Wedekindellina dutkevitchi Rauser-Chernousova and Beljaev. Sosipatrova, 1967, Pl. 6, fig. 12.

Parawedekindellina uralica (Dutkevich). Solov'eva, 1984, p. 138-140, Pl. 1, figs. 13, 14, 18.

Wedekindellina uralica longa (Dutkevich). Rui et al., 1991, p. 44-45, Pl. 7, figs. 8-18.

Description. Measured specimens possess up to six complete volutions (fragmentary specimens, unsuitable for measuring, reach up to 7.5 volutions). Axial outline elongate fusiform with bluntly pointed poles. Chomata weakly developed, generally less than half volution height, restricted to paraequatorial region. Tunnel narrow, its path straight. Septa planar. Axial fillings well developed, generally occluding more than half chamber volume in polar areas. Outer diameter of proloculus 0.079-0.111 mm. Radius vectors for first through sixth volutions 0.057-0.079 mm, 0.090-0.118 mm, 0.132-0.172 mm, 0.194-0.260 mm, 0.274-0.365 mm, and 0.356-0.473 mm, respectively. Half lengths for first through sixth volutions 0.069-0.085 mm, 0.122-0.238 mm, 0.265-0.483 mm, 0.463-0.730 mm, 0.654-0.996 mm, and 0.917-1.311 mm, respectively. Form ratios for first through sixth volutions 0.87-1.31, 1.36-2.29, 1.84-3.06, 2.20-3.26, 2.23-3.11, and 2.58-2.99, respectively. Wall thicknesses for first through sixth volutions 0.006-0.012 mm, 0.006-0.017 mm, 0.011-0.021 mm, 0.015-0.020 mm, 0.017-0.023 mm, and 0.017-0.024 mm,

respectively. Chamber counts not available because no sagittal sections were recovered: $n = 6$.

Discussion. The concept of *Wedekindellina uralica* employed here includes the range of morphology encompassed by the holotype and paratypes as well as associated specimens designated by Dutkevich (1934a) as *Fusulinella uralica* var. *longa* and *F. uralica* var. *inflata*. All of Dutkevich's specimens came from a relatively thin stratigraphic interval at a single locality. Rauser-Chernousova et al. (1936, p. 183, 185) subsequently mentioned an undescribed and unillustrated specimen, which they called "*W. dutkevitchi*" and considered possibly conspecific with *W. uralica* var. *longa*. This specimen was described and illustrated by Rauser-Chernousova and Fursenko (1937, p. 194, 195, fig. 139) who questionably placed *W. uralica* var. *longa* (Dutkevich) in synonymy with it. Although adequately described, Rauser-Chernousova and Fursenko (*ibid.*) cited the species as a manuscript name only. The name "*W. dutkevitchi*" was first explicitly designated a new species by Rauser-Chernousova et al. (1940, p. 21-23). The specimen selected as holotype is the same illustrated by Rauser-Chernousova and Fursenko (1937), and presumably the same discussed by Rauser-Chernousova et al. (1936). Consequently, there is some uncertainty regarding authorship, spelling, and date of the name "*dutkevitchi*". There is no question, however, as to the species concept or type specimen. No attempt is made here to unravel the nomenclatural complexities associated with "*dutkevitchi*" inasmuch as we consider it synonymous with *W. uralica*. The supposed differences between *W. uralica* and *W. uralica* var. *longa*, and between *W. uralica* and *W. "dutkevitchi"*, are a consequence of the holotype of *W. uralica* possessing only 5.5 volutions and hence appearing somewhat less elongate than specimens with six or more volutions. Minor differences in robustness of axial fillings may similarly be attributed to stage of ontogenetic development. *Wedekindellina uralica* differs from *W. lata* Thompson, 1961, described from the upper Moscovian of Ward Hunt Island, in its heavier axial fillings. The types of *W. lata*, despite having up to seven volutions, exhibit weakly developed axial deposits that occlude only minor portions of chambers in the polar extremities. Distinctions between *W. uralica*, *W. euthysepta*, *W. henbesti* (Skinner, 1931), *W. dunbari* Thompson, 1934, *W. uniformis* Thompson, 1934, *W. elfina* Thompson, 1934 and other similar midcontinental American forms are unclear and require further investigation. cursory analysis suggests that these relatively elongate and primitive representatives of the genus have been separated into many species and taxonomic review is required.

Age and distribution. GSC localities C-195862, C-195864, and C-195865 in the Nansen Formation at the glacier section. The types are from the subsurface upper Middle Carboniferous "limestone-dolomite complex" of "Verkhne-Chussovskye Gorodki", western slope of the middle Urals, where they occur in the same depth interval as the types of *N. (Hanostaffella) paradoxa* (Dutkevich). Other documented specimens are from the Moscovian (undifferentiated) of the "Pechoran margin" (Rauser-Chernousova et al., 1936); the uppermost Podolsky and Myachkovsky horizons of the Krasnokamsk, Polazna, and Severokamsk regions of Prikam'e (Rauser-Chernousova et al., 1951); the same interval in the Vozhgalakh region of Pritiman'e (*ibid.*); the upper Moscovian Sul'skii Horizon of northern Timan (Lebedeva, 1966); and the Pechoromorskaya Suite (Myachkovsky) on Cape Tumba-Sale, Yugorsky Peninsula (Solov'eva, 1984). Specimens reported under "*W. dutkevitchi*", here considered conspecific with *uralica*, come from the upper Moscovian (undifferentiated) of the Samara Bend, C.I.S. (Rauser-Chernousova et al., 1940); the Podolsky and Myachkovsky horizons of Pritiman'e (Rauser-Chernousova et al., 1951); and the upper Moscovian (Podolsky) of Spitsbergen (Forbes, 1960; Sosipatrova, 1967) and northeast Greenland (Ross and Dunbar, 1962).

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PLATE 1

Figures 1–16. *Plectostaffella reitlingerii* Groves, n. sp., x150.

1. Oblique section, paratype GSC 102966a (GSC loc. C-193540).
2. Oblique section, paratype GSC 102967a (GSC loc. C-193529).
3. Axial section, paratype GSC 102968a (GSC loc. C-195811).
4. Oblique section, paratype GSC 102969a (GSC loc. C-193535).
5. Axial section, paratype GSC 102970a (GSC loc. C-193536).
6. Oblique section, paratype GSC 102971a (GSC loc. C-195812).
7. Sagittal section, paratype GSC 102972a (GSC loc. C-193522).
8. Near sagittal section, paratype GSC 102973a (GSC loc. C-193533).
9. Oblique section, paratype GSC 102974a (GSC loc. C-195804).
10. Sagittal section, paratype GSC 102967b (GSC loc. C-193529).
11. Sagittal section, paratype GSC 102975a (GSC loc. C-193527).
12. Near axial section, paratype GSC 102966b (GSC loc. C-193540).
13. Oblique section, paratype GSC 102976a (GSC loc. C-193531).
14. Sagittal section, paratype GSC 102973d (GSC loc. C-193533).
15. Axial section, holotype GSC 102976b (GSC loc. C-193531).
16. Sagittal section, paratype GSC 102975b (GSC loc. C-193527).

Figures 17–20. *Eostaffella postmosquensis postmosquensis* Kireeva in Rauser-Chernousova et al., 1951, x100.

17. Axial section, hypotype GSC 102970b (GSC loc. C-193536).
18. Axial section, hypotype GSC 102970c (GSC loc. C-193536).
19. Axial section, hypotype GSC 102977a (GSC loc. C-195814).
20. Sagittal section, hypotype GSC 102978a (GSC loc. C-193523).

Figures 21–23. *Eostaffellina paraprotvae* (Rauser-Chernousova, 1948b), x100.

21. Axial section, hypotype GSC 102973b (GSC loc. C-193533).
22. Sagittal section, hypotype GSC 102969b (GSC loc. C-193535).
23. Axial section, hypotype GSC 102975c (GSC loc. C-193527).

Figures 24–32. *Plectostaffella jakhensis* Reitlinger, 1971, x100.

24. Oblique section, hypotype GSC 102978b (GSC loc. C-193523).
25. Near axial section, hypotype GSC 102969c (GSC loc. C-193535).
26. Axial section, hypotype GSC 102973c (GSC loc. C-193533).
27. Near axial section, hypotype GSC 102978c (GSC loc. C-193523).
28. Oblique section, hypotype GSC 102966c (GSC loc. C-193540).
29. Sagittal section, hypotype GSC 102978d (GSC loc. C-193523).
30. Sagittal section, hypotype GSC 102971b (GSC loc. C-195812).
31. Sagittal section, hypotype GSC 102969d (GSC loc. C-193535).
32. Near axial section, hypotype GSC 102978e (GSC loc. C-193523).

Figures 33–35. *Eostaffella pinguis* (Thompson, 1944), x100.

33. Sagittal section, hypotype GSC 102966d (GSC loc. C-193540).
34. Axial section, hypotype GSC 102970d (GSC loc. C-193536).
35. Tangential axial section, hypotype GSC 102971c (GSC loc. C-195812).

Figures 36–38. *Millerella?* spp., x100.

36. Tangential axial section, hypotype GSC 102979a (GSC loc. C-193543).
37. Tangential axial section, hypotype GSC 102979b (GSC loc. C-193543).
38. Axial section, hypotype GSC 102977b (GSC loc. C-195814).

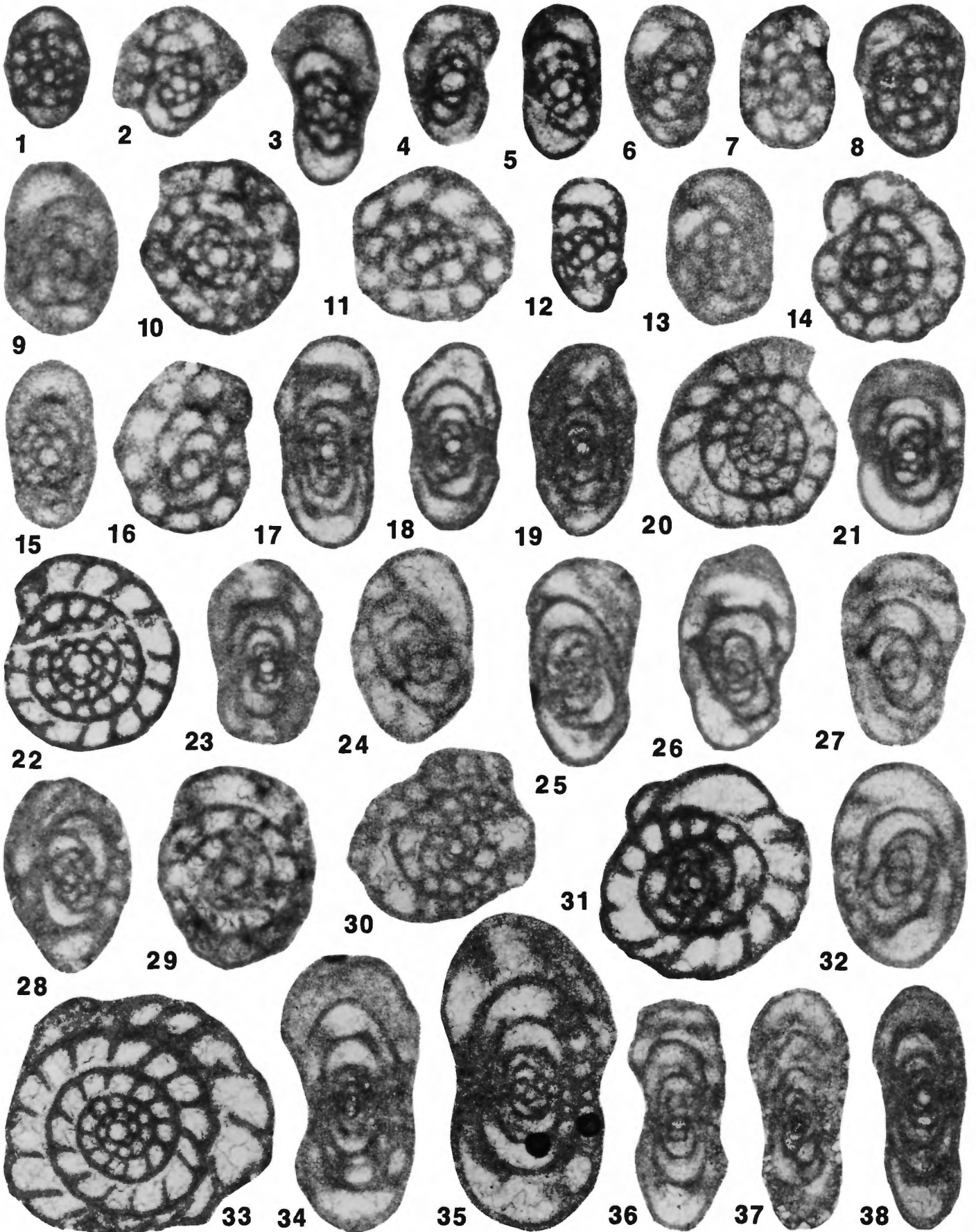


PLATE 2

Figures 1–10. *Pseudostaffella* (*Pseudostaffella*) *antiqua* (Dutkevich, 1934b), x60, all from GSC loc. C-193543.

1. Sagittal section, hypotype GSC 102979c.
2. Axial section, hypotype GSC 102979d.
3. Axial section, hypotype GSC 102979e.
4. Axial section, hypotype GSC 102979f.
5. Oblique section, hypotype GSC 102979g.
6. Near sagittal section, hypotype GSC 102979h.
7. Axial section, hypotype GSC 102979i.
8. Sagittal section, hypotype GSC 102979j.
9. Sagittal section, hypotype GSC 102979k.
10. Sagittal section, hypotype GSC 102979l.

Figures 11–17. *Pseudostaffella* (*Semistaffella*) *variabilis* Reitlinger, 1961, x100.

11. Tangential section, hypotype GSC 102980a (GSC loc. C-195823).
12. Near axial section, hypotype GSC 102968b (GSC loc. C-195811).
13. Axial section, hypotype GSC 102975d (GSC loc. C-193527).
14. Near sagittal section, hypotype GSC 102975e (GSC loc. C-193527).
15. Tangential axial section, hypotype GSC 102975f (GSC loc. C-193527).
16. Near axial section, hypotype GSC 102975g (GSC loc. C-193527).
17. Oblique section hypotype GSC 102975h (GSC loc. C-193527).

Figure 18. “Advanced” *Pseudostaffella* (*Pseudostaffella*) sp., x60, tangential axial section, hypotype GSC 102981a (GSC loc. C-195834).

Figures 19–26. *Ozawainella mosquensis* Rauser-Chernousova *in* Rauser-Chernousova et al., 1951, x60, all axial and tangential axial sections.

19. Hypotype GSC 102982a (GSC loc. C-195837).
20. Hypotype GSC 102982b (GSC loc. C-195837).
21. Hypotype GSC 102982c (GSC loc. C-195837).
22. Hypotype GSC 102982d (GSC loc. C-195837).
23. Hypotype GSC 102982e (GSC loc. C-195837).
24. Hypotype GSC 102981b (GSC loc. C-195834).
25. Hypotype GSC 102982f (GSC loc. C-195837).
26. Hypotype GSC 102983a (GSC loc. C-195852).

Figures 27, 28. *Ozawainella* sp., x60, both tangential axial sections from GSC loc. C-195866.

27. Hypotype GSC 102984a.
28. Hypotype GSC 102984b.

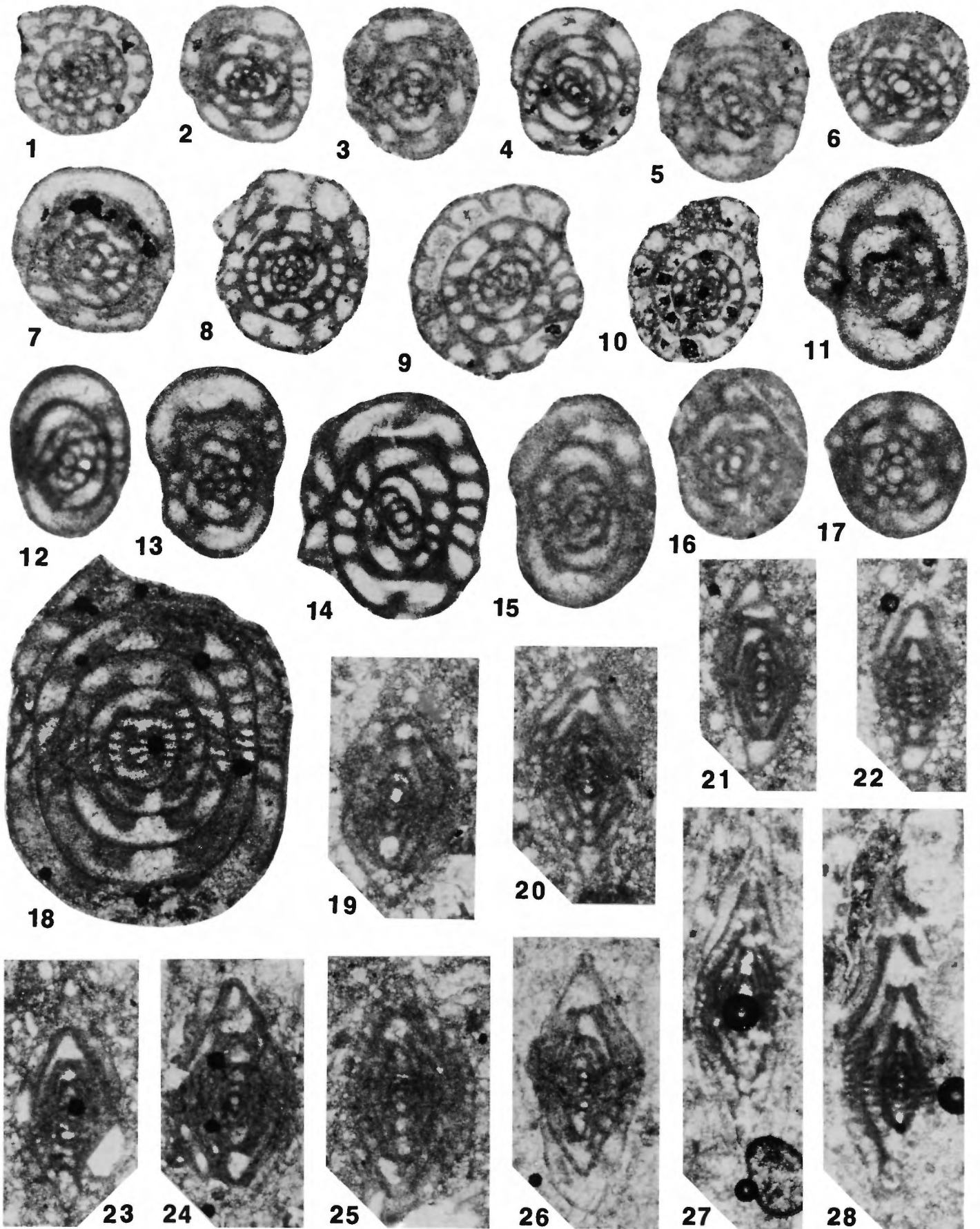


PLATE 3

Figures 1–7. *Fusulinella alaskensis* Douglass, 1971, x20.

1. Tangential axial section, hypotype GSC 102985c (GSC loc. C-195864).
2. Axial section, hypotype GSC 102986c (GSC loc. C-195865).
3. Axial section, hypotype GSC 102986a (GSC loc. C-195865).
4. Axial section, hypotype GSC 102985d (GSC loc. C-195864).
5. Sagittal section, hypotype GSC 102985b (GSC loc. C-195864).
6. Axial section, hypotype GSC 102985a (GSC loc. C-195864).
7. Axial section, hypotype GSC 102986b (GSC loc. C-195865).

Figures 8–12. *Eoschubertella obscura* (Lee and Chen *in* Lee et al., 1930), x100.

8. Near sagittal section, hypotype GSC 102979m (GSC loc. C-193543).
9. Sagittal section, hypotype GSC 102987a (GSC loc. C-195864).
10. Oblique section, hypotype GSC 102984c (GSC loc. C-195866).
11. Oblique section, hypotype GSC 102988a (GSC loc. C-195862).
12. Sagittal section, hypotype GSC 102989a (GSC loc. C-195831).

Figures 13–18, 21. *Neostaffella* (*Hanostaffella*) *paradoxa* (Dutkevich, 1934a), x30.

13. Axial section, hypotype GSC 102990a (GSC loc. C-195859).
14. Axial section, hypotype GSC 102990b (GSC loc. C-195859).
15. Axial section, hypotype GSC 102990d (GSC loc. C-195859).
16. Near sagittal section, hypotype GSC 102990c (GSC loc. C-195859).
17. Sagittal section, hypotype GSC 102990f (GSC loc. C-195859).
18. Axial section, hypotype GSC 102991a (GSC loc. C-195864).
21. Axial section, hypotype GSC 102990e (GSC loc. C-195859).

Figures 19, 20, 22–24. *Eoschubertella? miranda* (Leontovich *in* Rauser-Chernousova et al., 1951), all from GSC loc. C-195833, x100.

19. Near axial section, hypotype GSC 102992a.
20. Tangential axial section, hypotype GSC 102992b.
22. Oblique section, hypotype GSC 102992c.
23. Near axial section, hypotype GSC 102992d.
24. Oblique section, hypotype GSC 102992e.

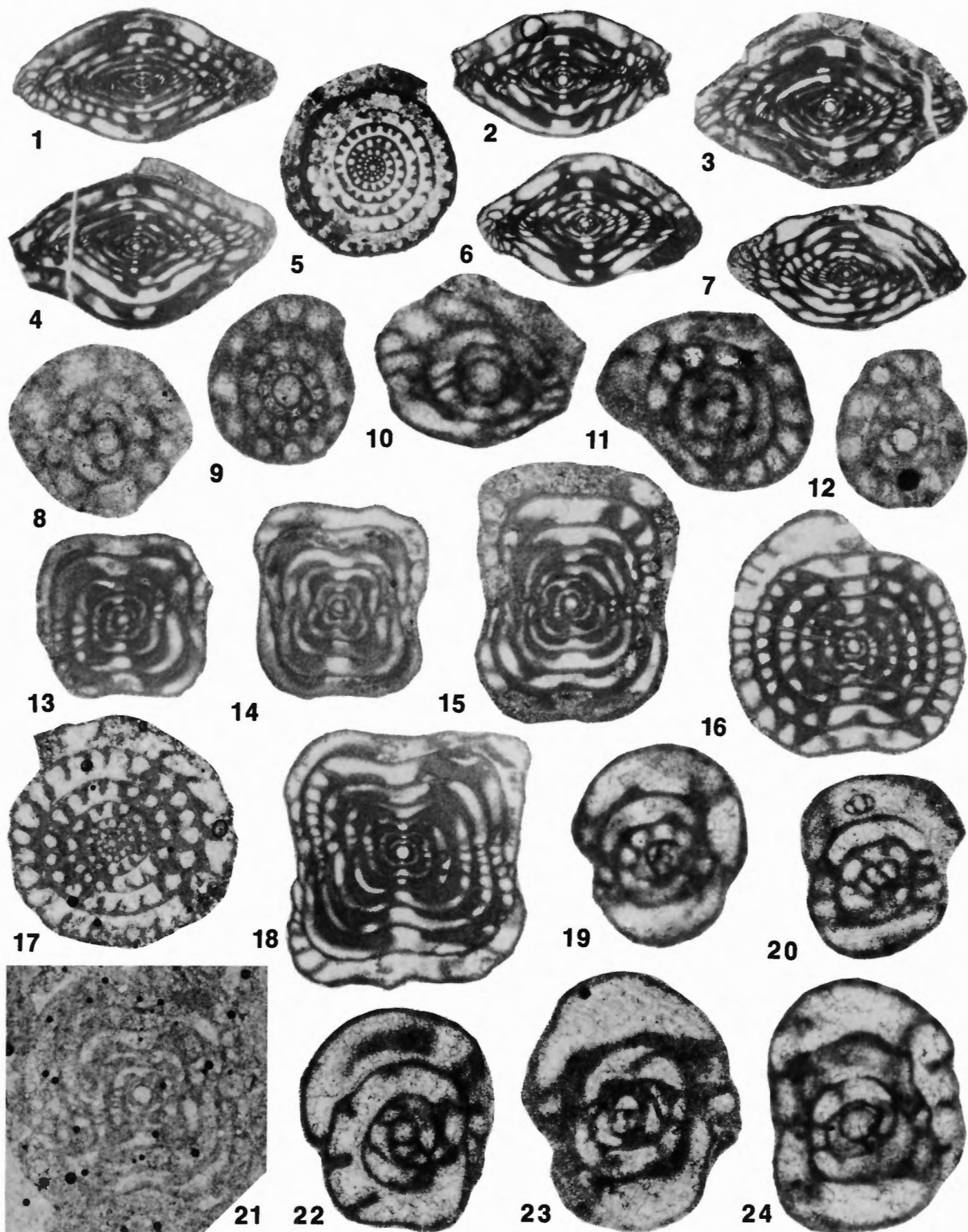


PLATE 4

Figures 1, 2. *Profusulinella* sp., both from GSC loc. C-106750, x35.

1. Oblique axial section, hypotype GSC 102993a.
2. Sagittal section, hypotype GSC 102993b.

Figures 3–5. *Fusulinella paracolaniae* Safonova in Rauser-Chernousova et al., 1951, x20.

3. Axial section, hypotype GSC 102994a (GSC loc. C-195865).
4. Axial section, hypotype GSC 102994b (GSC loc. C-195865).
5. Tangential axial section, hypotype GSC 102995a (GSC loc. C-195864).

PLATE 4

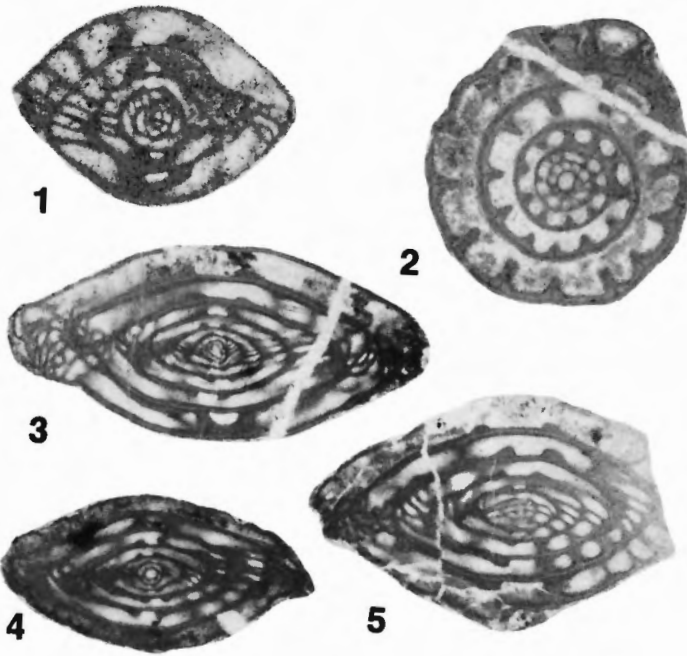


PLATE 5

Figure 1. *Fusulinella iowensis* Thompson, 1934, axial section, hypotype GSC 102996a (GSC loc. C-195864), x20.

Figures 2–5. *Beedeina* sp., all axial sections from GSC loc. C-195859, x20.

2. Hypotype GSC 102997a.
3. Hypotype GSC 102997c.
4. Hypotype GSC 102997b.
5. Hypotype GSC 102997d.

Figures 6–11. *Beedeina pseudoelegans* (Chernova in Rauser-Chernousova et al., 1951), all axial sections from GSC loc. C-195862, x20.

6. Hypotype GSC 102998d.
7. Hypotype GSC 102998b.
8. Hypotype GSC 102998e.
9. Hypotype GSC 102998a.
10. Hypotype GSC 102998f.
11. Hypotype GSC 102998c.

Figures 12–17. *Wedekindellina uralica* (Dutkevich, 1934a), all axial sections.

12. Hypotype GSC 102999c (GSC loc. C-195862), x30.
13. Hypotype GSC 102988b (GSC loc. C-195862), x40.
14. Hypotype GSC 102999d (GSC loc. C-195862), x30.
15. Hypotype GSC 102999b (GSC loc. C-195862), x30.
16. Hypotype GSC 103000a (GSC loc. C-195865), x30.
17. Hypotype GSC 102999a (GSC loc. C-195862), x30.

Figure 18. *Staffella* sp., tangential axial section, hypotype GSC 102996b (GSC loc. C-195864), x40.

Figures 19–22. *Pseudoendothyra* spp., x100.

19. Tangential axial section hypotype GSC 102972b (GSC loc. C-193522).
20. Tangential axial section, hypotype GSC 102978f (GSC loc. C-193523).
21. Tangential axial section, hypotype GSC 102972c (GSC loc. C-193522).
22. Sagittal section, hypotype GSC 102972d (GSC loc. C-193522).

