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H. Kozur¹ and W. W. Nassichuk
Institute of Sedimentary and Petroleum Geology, Calgary

Introduction

Biostratigraphic and chronostratigraphic relationships of Permian rocks in the Sverdrup Basin have been interpreted, in the main, through studies of fusulinaceans, ammonoids and brachiopods. Fusulinaceans are particularly abundant in strata of Asselian to early Artinskian ages which represent an interval of widespread carbonate deposition in the basin, but they are absent from all younger Permian rocks in the basin; that is, these ranging from middle Artinskian to Kazanian. Rocks of the latter ages are predominantly sandstones with minor limestones and they contain abundant brachiopods and fewer ammonoids, all indicative of a Boreal Province. Little is known of the distribution and diversity of Permian conodonts within the Sverdrup Basin but Bender (1973) reported the presence of well-preserved but unidentified representatives of the group from several Lower Permian localities in Ellesmere Island and Axel Heiberg Island. Similarly, Uyeno (pers. comm., 1968) identified a single specimen of *Gondolella* sp. from Upper Permian strata near M'Clintock Inlet, northern Ellesmere Island. In the present study, single samples from the Assistance Formation (Kungurian) near the eastern edge of the Sverdrup Basin and from the lowest part of the Degerbøls Formation (Kungurian-Kazanian) in the interior of the basin have yielded several species of the cosmopolitan *Gondolella* Stauffer and Plummer which can be identified readily by the outline and sculpture of the platform. The purpose of this report is to compare representatives of *Gondolella* from the Assistance and Degerbøls formations with species that occur in nearly contemporaneous strata in the Phosphoria Formation in Idaho and Wyoming and the Road Canyon Formation in Texas. Conodonts are documented insufficiently from the type Permian near the Lower-Upper boundary in the Ural Mountains and, thus, age relationships cannot be compared directly. Conodonts from the Assistance Formation (Boreal), however, appear to be considerably younger than those from the lowermost Kungurian. They resemble species from Chihsonian or Kubergandinian strata (Tethyan) in the Pamir Mountains in the southern Soviet Union (Tadzik SSR) directly north of Afghanistan. According to Leven (1967), the boundary between the Lower Permian and Upper Permian series lies above the Chihsonian and below the Kubergandinian.

Assistance Formation and equivalent strata - biostratigraphic review

The Assistance Formation was defined by Harker and Thorsteinsson (1960) for a succession of sandstones,

¹Democratic Republic Germany, Meiningen, Staatliche Museen

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siltstones and minor limestones at Grinnell Peninsula, Devon Island near the southern margin of the Sverdrup Basin. Complementary information concerning relationships of the Assistance Formation was provided by Thorsteinsson (1974) and Nassichuk (1975). The formation extends discontinuously along the southern margin of the basin where, generally, it is less than 60 m thick. Along the eastern margin of the basin the formation contains a greater proportion of limestone and thicknesses may exceed 300 m. In the type area, the Assistance Formation overlies the Belcher Channel Formation (Asselian-Artinskian) which contains skeletal limestone and minor sandstone. Locally, on parts of Melville Island and Ellesmere Island, a deltaic succession of quartzose sandstones, the Sabine Bay Formation (Artinskian), occurs between the Belcher Channel and Assistance formations. Basinward, the Assistance Formation grades to the van Hauen Formation (Artinskian-Kungurian) which contains dark grey shales, siltstones and bedded chert. The van Hauen is overlain by the Degerbøls Formation but, locally, where the van Hauen is absent, the lower part of the Degerbøls may be equivalent to the van Hauen Formation.

The Assistance Formation is replete with a great variety of fossils, some of which have been described in the literature; included are brachiopods (Harker and Thorsteinsson, 1960; Waterhouse, 1969, 1971; Sarytcheva and Waterhouse, 1972), ammonoids (Nassichuk *et al.*, 1966; Nassichuk, 1970), scaphopods (Nassichuk and Hodgkinson, in press), nautiloids, gastropods, conularids, foraminifers and plants. A single fragmentary conodont specimen, *Gondolella* sp. indet. has been found in the type section of the Assistance Formation but the state of preservation of the specimen precludes more than simple documentation of the occurrence.

The age of the Assistance Formation is latest Early Permian (*sensu* Furnish, 1973) but correlation with successions in the type area for the Permian remains obscure. In the latter area, that is, in the Ural Mountains, uppermost Lower Permian strata are assigned to the Kungurian Stage and lowermost Upper Permian to the Ufimian Stage. Stratotypes for the Kungurian and Ufimian Stages contain beds of lagoonal and continental origin with only few strata reflecting open-marine conditions between the western edge of Priurals and the eastern edge of the Russian Platform. With the exception of ostracodes and brachiopods at particular levels, both stratotypes lack distinctive marine faunas suitable for intercontinental correlation over much of their extent; ostracode zonation was summarized by Gorsky and Guseva (1973) and brachiopod zonation by Waterhouse (1976).

Various suggestions have been made in the literature to combine the Kungurian and Ufimian stages into a single stage (Stepanov, 1967; Gorsky, and Guseva, 1973)

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but the paucity of marine faunas, particularly in the upper half, reduces effectiveness of the interval as a standard for correlation. Waterhouse (1976) favours combining Kungurian and Ufimian into a single stage for which the name "Kungurian" is retained and, on the basis of brachiopods, which may be identified on a global basis, recognizes two substages; a lower substage (Fillipovian) and an upper substage (Irenian). In the Waterhouse (*ibid.*) scheme, Ufimian beds are contained within the upper Irenian. Nassichuk *et al.* (1966) examined Permian ammonoids from Arctic Canada, including *Daubichites fortieri* (Harker) and *Sverdrupites harkeri* (Ruzhencev) from the type section of the Assistance Formation and concluded that the Assistance probably was equivalent to Kungurian strata in the Urals. Similarly, these authors related the Assistance Formation to the Leonardian Road Canyon and Brushy Canyon Formations in West Texas and to the Meade Peak Member of the Phosphoria Formation in Idaho. According to Pnev (pers. comm., 1975) and others, numerous Soviet stratigraphers hold the opinion that much of the Kungurian in the Urals may be equivalent to "Artinskian" outside of the Urals.

Ammonoids are exceedingly rare in Kungurian (*sensu stricto*) strata in the Urals and only three occurrences are known from the middle part of the stage; included are *Paragastrioceras*, *Uraloceras* and ?*Daubichites*. According to Bogoslovskaya (pers. comm., 1975), Kungurian ammonoids can be distinguished from Artinskian ammonoids only at the species level. Nassichuk (1970) suggested that certain ammonoids from typical Assistance rocks show affinities with Roadian species from the Phosphoria Formation (*Daubichites fortieri* and *Sverdrupites harkeri*), whereas others show affinities with slightly older Leonardian species [*Synartinskia belcheri* Nassichuk, *Medlicottia* aff. *M. orbignyana* (Verneuil) and *Popanoceras* cf. *P. sobolewskyum* (Verneuil)]. Waterhouse (1976) suggested that brachiopods from the type Assistance Formation are early Kungurian (Fillipovian) in age and can be distinguished clearly from older Artinskian species. Brachiopods from the type section of the Assistance Formation include: *Arctitreta pearyi* (Whitfield), *Neochonetes* spp., *Thuleproductus arcticum* (Whitfield), *Muirwoodia mammatus* (Keys.), *Pseudosyrinx* spp., *Spiriferella loveni* (Diener) and *Neospirifer striatoplicatus* (Gobbett).

In the Pamir Mountains, as is the case in the Ural Mountains, Artinskian strata can be identified on the basis of ammonoids and fusulinaceans. Unlike the Urals succession, however, where Artinskian strata are overlain by sparsely fossiliferous lagoonal and continental deposits with only few limestone beds, post-Artinskian strata in the Pamirs, consisting mainly of limestones, contain an abundant and varied Tethyan fusulinacean fauna (Leven, 1967). Leven (*ibid.*) placed the Lower-Upper Permian boundary above the fusulinacean Zone of *Misellina* and below the Zone of *Cancellina*. The *Misellina* and *Cancellina* Zones correspond to the Chihisian and Kuberganian Stages, respectively (Leven, 1975).

GSC locality C-32487 occurs in the Assistance Formation on Hamilton Peninsula, north of Canon Fiord, west-central Ellesmere Island (Lat. 80°02'N, Long. 81°44'W) (Fig. 28.1). Conodonts were recovered from a large talus block situated 40 m above the base of the formation; the talus block originated from a prominent ledge 43 m above the base of the formation. The same horizon yielded the Roadian ammonoid *Daubichites fortieri* which also occurs in the type section of the Assistance Formation. In the vicinity of locality C-32487, the Assistance Formation is 110 m thick and contains recessive, glauconitic and quartzose sandstones and an equal proportion of more resistant thin to medium bedded sandy limestone intervals. Sandstone beds contain *Spirophyton* and limestone beds contain abundant brachiopods and bryozoans. The Assistance Formation rests on quartzose sandstones of the Sabine Bay Formation and is overlain by glauconitic sandstones, and lesser amounts of conglomerates and limestones of the Trold Fiord Formation.

Residues from 10 kg of limestone yielded 6 conodont specimens. Included are well-preserved specimens of *Gondolella idahoensis* Youngquist, Hawley and Miller, 1951, as well as 3 fragments which are determined to be morphologically intermediate between *G. idahoensis* and *G. nankingensis* Cheng, 1960 or *G. serrata* Clark and Ethington, 1962. One of the latter fragments has a serrate margin and, therefore, more closely resembles *G. nankingensis* or *G. serrata* than it does *G. idahoensis*. A second fragment consists of a small middle portion of platform; the margin is non-serrate but shallow transverse ribs are developed. Since none of the fragmentary serrate or weakly ribbed specimens shows posterior regions, it cannot be determined whether they are more closely related to *G. nankingensis* or to *G. serrata*.

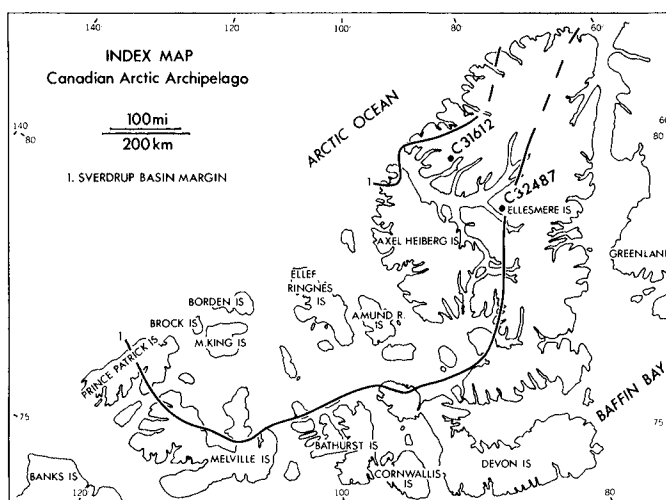


Figure 28.1. Index map showing conodont localities C-32487 (Assistance Formation) and C-31612 (Degerbøls Formation).

In stratigraphic sections in Pamir, *Gondolella idahoensis* is the most abundant conodont in the uppermost Lower Permian *Misellina* Zone (Chihhsian Stage). In Leonardian beds below the *Misellina* Zone, that is, in the upper part of the ammonoid-bearing "Buz-tere" beds, highly developed representatives of *Gondolella bisselli* Clark and Behnken, 1971 occur. Many of the latter are in fact morphologically intermediate between *G. bisselli* and *G. idahoensis*; *Gondolella bisselli sensu stricto* generally ranges from Sakmarina to lower Kungurian in the Soviet Union. In Spitzbergen, *G. bisselli* occurs in lower Svalbardian (=lower Kungurian) strata in the *Spirifer* Limestone (Malkowski and Szaniawski, in press). Thus, conodonts from GSC locality C-32487 appear to postdate Leonardian, lower Kungurian and lower Svalbardian.

The highest occurrence of *Gondolella idahoensis* in North America is in the upper Bone Spring Formation (Roadian). Similar forms are known from the lower and middle Kufeng Formation in southern China. The Meade Peak Member of the Phosphoria Formation in Idaho, Wyoming and the Cutoff Shale in Texas have yielded *Gondolella nankingensis*, an important index for the *Cancellina* Zone (Kubergandinian). Pertinent discussion of correlation of the Cutoff Shale was provided by Furnish (1973). *Gondolella serrata* makes its first appearance at the same stratigraphic level as *G. nankingensis* but ranges considerably higher, through the Wordian.

In conclusion, the conodont fauna from locality C-32487 can be placed near the boundary between the *Misellina* and *Cancellina* Zones of Asia; which is now the Chihhsian-Kubergandinian boundary in Tethyan regions. In terms of an important stratigraphic scheme proposed by Furnish (1973), this fauna can be placed in the Upper Roadian.

Conodonts from GSC locality C-31612 - Degerböls Formation

GSC locality C-31612 occurs 45 m above the base of the Degerböls Formation on the north side of Otto Fiord, northern Ellesmere Island (Lat. 81°17'N, Long. 85°58'W) (Fig. 28.1). In this area, the van Hauen Formation (shales, siltstones, chert) is absent from its typical position beneath the Degerböls Formation and the latter rests directly on shelf-deposited carbonate rocks of the Nansen Formation; uppermost Nansen rocks locally contain fusulinaceans of Sakmarian age and of early Artinskian age on northern Ellesmere Island. The Degerböls Formation has a thickness of 240 m north of Otto Fiord. The lowest 45 m of the formation, including beds containing conodonts in this report, are atypical for the formation and contain reddish-weathering crinoidal limestones and shales; these beds probably are equivalent to the van Hauen and Assistance formations as indicated by conodonts in the following paragraphs. The remainder of the formation contains thin bedded, grey weathering, cherty limestones, all replete with bryozoans, crinoid columnals and brachiopods. Although brachiopods have not been studied yet from the Degerböls Formation north of Otto Fiord, those that occur in the

type-section of the formation, 22 km farther to the south of the locality discussed herein, are diverse and show a Kungurian-Kazanian range.

Several fragmentary conodont specimens from GSC locality C-31612 all belong to a single species *Gondolella* cf. *G. gracilis* Clark and Ethington, 1962. The platform is elongate and extremely narrow and tapers gradually toward the anterior end of the carina. The platform has a square posterior end; platform margins are slightly up-turned, and the upper surface is pitted but without transverse ridges. The carina has more than 12 low, somewhat elongated denticles and does not reach the posterior margin. The first 3 denticles at the anterior end of the carina are relatively shorter and broader than the others. The posterior denticle is markedly rounded and pointed. *Gondolella* cf. *G. gracilis* is morphologically intermediate between the more highly developed *G. gracilis* Clark and Ethington from the Meade Peak Member of the Phosphoria Formation in Idaho and Wyoming and the more primitive *G. idahoensis* Youngquist, Hawley and Miller. Whereas the slope of the platform of the Arctic species resembles *G. gracilis*, the denticulation of the carina as well as the form of the posterior end of the platform and the posterior end of the carina more closely resemble *G. idahoensis*. *Gondolella gracilis* characterizes the upper part of the Meade Peak Member of the Phosphoria Formation in Idaho and Wyoming where it is associated with *G. serrata*, and *G. nankingensis* as well as with representatives of *Neostreptognathodus*. As discussed previously, *G. idahoensis* occurs in the Assistance Formation on Ellesmere Island, the Bone Spring Formation in Texas and in the *Misellina* Zone (Chihhsian Stage of Leven, 1975) in the Pamirs. No older or younger representatives of *Gondolella* resemble *G. cf. G. gracilis*. *Gondolella bitteri* Kozur, 1975 and other Middle and Late Permian species of *Gondolella* are clearly distinguished from *G. cf. G. gracilis* by the form or sculpture of the platform. *Gondolella bisselli* Clark and Behnken from Sakmarian, Artinskian and Leonardian strata (*sensu* Furnish, 1973) has a platform that is narrow and elongate compared to the Arctic species but which is more arched and has a different denticulation of the carina.

In conclusion, conodonts from the basal Degerböls Formation (C-31612) indicate correlation with the Meade Peak Member of the Phosphoria Formation. According to Behnken (1975), conodonts from the Meade Peak Member correspond to conodont faunas from the Cutoff Shale and from the basal Brushy Canyon Formation in Texas. In all of those American faunas, association of *Gondolella serrata serrata*, *G. nankingensis* and *Neostreptognathodus* spp. is characteristic. This fauna seems to be younger than the type Roadian (Road Canyon Formation) but older than Wordian *sensu stricto* (*Waagenoceras* Zone) faunas. According to Kozur (in press), this fauna indicates correlation with the Kubergandinian Stage (*Cancellina* Zone) of Central Asia. The upper part of the Meade Peak Member appears to be younger than the type Roadian (equivalent to the upper *Misellina* Zone or uppermost Lower Permian) and is certainly older than the Wordian. (*Waagenoceras* Zone) and should be correlated, therefore, with the

Cancellina Zone. The lower part of the Meade Peak Member, however, whose conodont fauna was investigated by Youngquist *et al.* (1951) is older than the association with *Gondolella serrata serrata*, *Gondolella nankingensis* and *Neostreptognathodus* of the *N. clinei* group and can be correlated with the type Roadian (association with *G. idahoensis* and *Neostreptognathodus* of the *N. sulcopicatus* and *N. leonovae* groups). According to Leven (1975), the *Misellina* Zone and, therefore, also the Roadian should be regarded as Middle Permian. Kozur (in press), however, correlates the type Roadian (Road Canyon Formation) with the upper Chihhsian (upper *Misellina* Zone) and regards the whole Chihhsian (and, therefore, also the type Roadian) as uppermost Lower Permian. He regards the Kubergandinian (*Cancellina* fauna) as basal Middle Permian. *Gondolella* cf. *G. gracilis* seems to be somewhat more primitive than *Gondolella gracilis* from the conodont fauna with *G. serrata serrata*, *G. nankingensis* and highly developed *Neostreptognathodus*, but somewhat more highly developed than *G. idahoensis* from the lower Chihhsian (Sul-Istyk fauna of Pamir). Therefore, the conodont fauna in the lower Degerböls should be placed near the Chihhsian-Kubergandinian boundary and therefore near the Lower-Middle Permian boundary.

Additional conodont studies are required to determine whether the Degerböls fauna with *Gondolella* cf. *G. gracilis* belongs to the type Roadian (Upper Chihhsian, uppermost Lower Permian) or to the Kubergandinian (basal Middle Permian). At the present stage of our knowledge, it belongs to the upper type Roadian and, therefore, to the highest Lower Permian.

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