

Paleoenvironmental factors and the distribution of conodonts in the Lower Triassic of Svalbard and Nepal

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Lower Triassic sections in Svalbard and Nepal contain markedly different conodont faunas. Each of the sections has yielded approximately 20 species but there are only two species in common. Associated megafauna confirms that a more or less complete Lower Triassic sequence exists in both sections, but if comparison of the sections were based exclusively on conodonts, little reliable correlation would be possible. The problem is solved by correlation of the conodonts of the Svalbard and Nepal sections with a third section, the comprehensive Lower Triassic of Utah and Nevada. Both Arctic and Tethyan sections have 7 species in common with that of Western U.S. and demonstration of equivalency of stages and zones is possible through use of the intermediate U.S. section. Possible explanations for lack of common species in two time-equivalent sections (Svalbard and Nepal) include such things as sampling and/or preservational problems at either or both sites, paleoclimatic differences for the two sections including latitudinal differences and a range of ecologic factors produced by different climates, provincialism because of paleogeographic barriers, and lithofacies and biofacies factors. Field and laboratory data are compelling evidence that the differences between conodont faunas in Svalbard and Nepal are due to lithofacies factors. Comparison of the conodonts with a previously established Lower Triassic biofacies model tends to confirm that faunal differences are related to distinct biofacies and suggests that there may be real value for the predictive power of conodonts for paleoenvironmental definition. □ *Conodonts, biogeography, ecology, Nepal, Svalbard, Triassic.*

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Lower Triassic rocks of Spitsbergen average approximately 450 m in thickness and consist of clastics with minor carbonates that have been organized into the Vardebukta, Sticky Keep and part of the Botneheia Formations.

In contrast, Lower Triassic rocks of Nepal average approximately 25 m in thickness, consist of shales and nodular carbonates and have been referred to the Panjang and Thinigaon Formations.

Both Arctic (Svalbard) and Tethyan (Nepal) sections include megafossils that indicate a more or less complete Lower Triassic sequence and demonstrate equivalency of the two geographically separated sections (Buchan *et al.* 1965 for Svalbard; Waterhouse 1977, Bassoullet & Colchen 1977, Bordet *et al.* 1971, for Nepal). Of some 100 samples taken from the two areas, 42 % yielded conodonts. Some 20 species are represented in the Nepal collections, whereas 18 species were identified in the collections from Spitsbergen (Table 1). The two Lower Triassic sections have only two clearly identifiable species in common, however. In spite of the general usefulness of conodonts in stratigraphic studies for most part of the Paleozoic and Triassic, it seems apparent that if comparison of the sections was based exclusively on conodonts, little reliable correlation would be possible. The absence of common species that could be used in precise correlation raises several classical stratigraphic problems.

For this study we have considered two questions: (1) How do we establish precise stratigraphic correlations between the two sections? and, (2) What are the best possible explanations for lack of common species in two time-equivalent sections?

Comparisons, correlations and coefficients

Lower Triassic sections containing conodonts are widespread. In addition to the sections discussed in this report, sections in the Salt and Trans-Indus Ranges of West Pakistan and at the Guryul Ravine of Kashmir have been discussed by Sweet (1970a, b). Considered on a world-wide basis, these sections and that from Nepal are so closely spaced geographically (and so obviously part of the same Tethyan belt) that similarities are expected. In fact, the Tethyan sections are lithologically and faunally the most similar of the worldwide sections available for this study. Most of the species represented in Nepal were described originally from Pakistan. For these reasons, the central Tethyan sections are not contrasted in the discussion that follows.

However, because so few species were found to be common to the Lower Triassic of Nepal and Spitsbergen, we decided to compare these faunas with Lower Triassic conodonts from other parts of the world. Faunas from a few important Lower

Table 1. Lower Triassic conodonts of Svalbard and Nepal. From Hatleberg (1982); Svalbard section from Spitsbergen, including southern shoreline of Van Keulenfjorden at Reinodden, Pitnerodden and Ahlstravdodden; Nepal section from Thakkhola Valley in central Himalaya above Jamsom (Hatleberg & Clark, in press).

Species	Svalbard	Nepal
<i>Hindeodus typicalis</i>		x
<i>Neogondolella carinata</i>		x
<i>N. milleri</i>		x
<i>N. jubata</i>	x	x
<i>N. aff. mombergensis</i>	x	x
<i>N. aff. timorensis</i>		x
<i>N. sp.</i>		x
<i>Neospathodus waageni</i>		x
<i>N. aff. waageni</i>		x
<i>N. conservativus</i>		x
<i>N. discretus</i>		x
<i>N. aff. spathi</i>		x
<i>N. homeri</i>	x	x
<i>N. triangularis</i>		x
<i>N. sp. a</i>		x
<i>N. sp. b</i>		x
<i>N. sp. c</i>		x
<i>N. sp. d</i>		x
<i>Ellisonia sp.</i>		x
<i>Ellisonia triassica</i>	x	
<i>Neogondolella elongata</i>	x	
<i>N. nevadensis</i>	x	
<i>N. regale?</i>	x	
<i>N? mombergensis</i>	x	
<i>N. sp. a</i>	x	
<i>N. sp. b</i>	x	
<i>Neospathodus dieneri</i>	x	
<i>N. cristagalli</i>	x	
<i>N. svalbardensis</i>	x	
<i>N. pakistanensis</i>	x	
<i>N. peculiaris</i>	x	
<i>N. collinsoni</i>	x	
<i>N. aff. triangularis</i>	x	
<i>Xaniognathus? sp.</i>	x	

Triassic sections are shown on Tables 1–4, and include those described in reports from western North America (Paull 1980; Carr 1981; Clark *et al.* 1979), South Primorye of the U.S.S.R. (Buriĭ 1979), and Australia (McTavish 1973). Comparison of number of species from these areas plus Japan (Koike 1979) is shown in Figure 1. These sections provide a good data base for world-wide Lower Triassic conodont distribution.

Because we have not examined all of the faunas reported and have relied on published illustrations and descriptions for species identification, some subjectivity is inherent in our comparisons (Tables 1–4). We have not included the Japanese report for these data. In order to establish some kind of uniform baseline for the comparisons, coefficients of similarity were calculated using the equation $2w/a+b$, in which w = number of conodont species common to two areas and $a+b$ = total species for the two areas. The results for the 5 areas (Tables 1–4) are shown in Fig. 2.

Both the Nepal and Spitsbergen sections have their greatest similarity with the section in the western U.S. Both the Arctic and the Tethyan sections have 7 species in common with the U.S. section.

Even this low similarity coefficient (0.35–0.36) is adequate for demonstration of equivalency of several stages and zones by use of the intermediate U.S. section.

Table 2. Lower Triassic conodonts from Australia. From McTavish (1973).

<i>Neogondolella carinata</i>
<i>N. elongata</i>
<i>N. jubata</i>
<i>N. planata</i>
<i>Neospathodus bicuspidatus</i>
<i>N. conservativus</i>
<i>N. dieneri</i>
<i>N. homeri</i>
<i>N. novaehollandiae</i>
<i>N. pakistanensis</i>
<i>N. timorensis</i>
<i>N. waageni</i>
<i>N. aff. discretus</i>
<i>Ellisonia sp.</i>
<i>Xaniognathus sp.</i>

Table 3. Lower Triassic conodonts from Western United States. From Carr (1981) and Paull (1980).

<i>Isarcicella sp.</i>
<i>Hindeodus typicalis</i>
<i>Ellisonia gradata</i>
<i>Ellisonia triassica</i>
<i>Neogondolella carinata</i>
<i>N. milleri</i>
<i>N. jubata</i>
<i>N. timorensis</i>
<i>N. n. sp. a</i>
<i>Neospathodus peculiaris</i>
<i>N. dieneri</i>
<i>N. bicuspidatus</i>
<i>N. waageni</i>
<i>N. triangularis</i>
<i>N. collinsoni</i>
<i>N. homeri</i>
<i>Furnishius triserratus</i>
<i>Pachycladina sp.</i>
<i>Platyvillosus asperatus</i>
<i>Parachirognathus ethingtoni</i>

Table 4. Lower Triassic conodonts from the U.S.S.R. From Buriĭ (1979).

<i>Ellisonia triassica</i>
<i>Ellisonia teichertii</i>
<i>Ellisonia gradata</i>
<i>Ellisonia robusta</i>
<i>Ellisonia delicatula</i>
<i>Ellisonia torta</i>
<i>Ellisonia clarki</i>
<i>Hindeodus typicalis</i>
<i>Neogondolella carinata</i>
<i>N. elongata</i>
<i>N. jubata</i>
<i>Xaniognathus curvatus</i>
<i>Xaniognathus defectens</i>
<i>Xaniognathus elongatus</i>
<i>Isarcicella sp.</i>
<i>Neospathodus kummeli</i>
<i>N. dieneri</i>
<i>N. cristagalli</i>
<i>N. peculiaris</i>
<i>N. pakistanensis</i>
<i>N. waageni</i>
<i>N. spathi</i>
<i>N. triangularis</i>
<i>N. homeri</i>
<i>N. timorensis</i>
<i>‘Prioniodella’ prioniodellides</i>

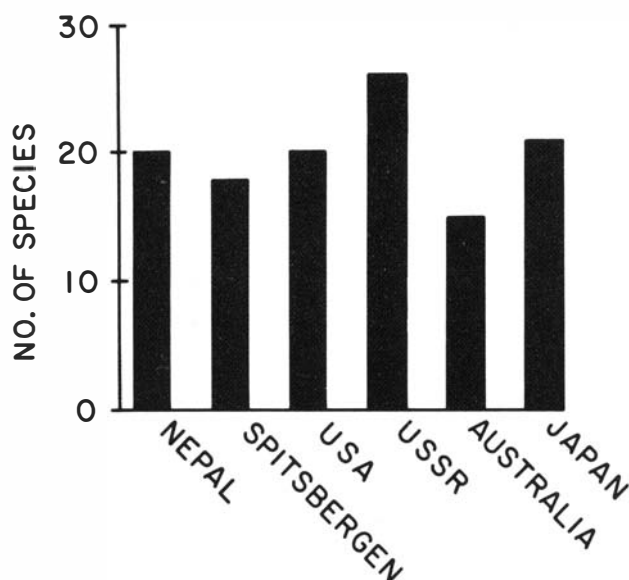


Fig. 1. Number of Lower Triassic conodont species in six key areas.

Greatest similarity for Lower Triassic conodonts is that indicated for the U.S.S.R.–western U.S. sections. A similarly strong coefficient exists for the Australia–U.S. sections. The lowest similarity of all Lower Triassic faunas is that between the Nepal and Spitsbergen sections. We address this problem in the following pages.

Interpretations

The extremes in similarity coefficients among the various Lower Triassic sections pose fundamental stratigraphic questions: Are there sampling and/or preservation problems? Are there latitudinal differences that could account for the range of ecologic factors produced by different climates? What is the role of provincialism, and what are the biofacies factors?

Sampling and preservation

The section in Spitsbergen and that in Nepal are difficult to study although exposures are good to excellent. In both sections every exposed carbonate bed was sampled. The interbedded clastics were also sampled but not uniformly. The clastic beds did not yield conodonts, therefore, we conclude that all exposed rocks with potential conodonts were sampled. Preservation of conodont elements in the two sections is similar. In both Nepal and Spitsbergen, CAI values of 1.5 to 5 were obtained. Element abundances are higher in Nepal and CAI values range in both sections. The question of sampling or preservation problems for these sections may be moot.

Latitude difference

Knowledge of the general paleogeography of Earth 220 to 200 million years ago (Early Triassic) is still sketchy but the best evidence at hand (e.g., Ziegler 1981) indicates that Nepal was part of the Tethyan sea and probably within 10° to 15° of the Triassic equator. Spitsbergen paleogeography is less well known. Although Birkenmajer (1977) suggests that Svalbard may have been between 28°–30° North, probably most of Svalbard was at least 60° North, and perhaps even higher,

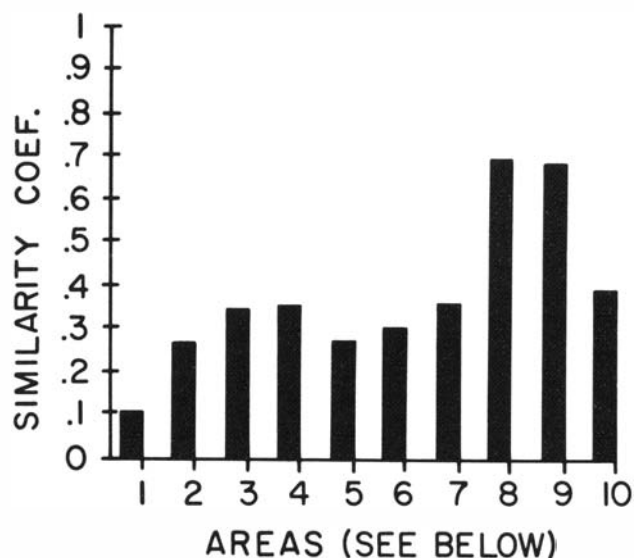


Fig. 2. Similarity coefficients for Lower Triassic conodonts in 5 areas. Data from Japan were not used. 1: Nepal–Svalbard. 2: Nepal–USSR. 3: Nepal–Australia. 4: Nepal–western US. 5: Svalbard–USSR. 6: Svalbard–Australia. 7: Svalbard–western US. 8: Western US–USSR. 9: Western US–Australia. 10: Australia–USSR.

although there is no widespread agreement on this (e.g., Frakes 1979). Therefore there may have been a minimum of 50° difference between the two sections during the Early Triassic. Although this latitude spread is significant by modern climate standards, there are suggestions that during the Triassic this may not have been as important. Invertebrate and plant assemblages from many Lower Triassic sections suggest that there were broad, warm climate zones for this period. Subtropical to warm, temperate conditions probably extended from 15 to 55° North Latitude. Most of the Earth probably had average temperatures 20° warmer than at present (Frakes 1979). The other Lower Triassic faunas (Tables 2–4) had more uniform latitude addresses than those of Nepal and Spitsbergen. Clearly the generally uniform world wide climate patterns interpreted for the Early Triassic do not indicate that latitude differences were the most important factors to explain faunal differences and the low similarity coefficient for Nepal and Svalbard.

Provincialism and paleogeographic barriers

There are presently known at least 40 conodont species for the Lower Triassic. Most of the species are known at several localities. In addition, similarity coefficient calculations do not support provincialism for the Lower Triassic. In fact there is no distinctive fauna with elements unique to any one area. The general withdrawal of seas from the shallow shelf areas during the earliest Triassic may have produced paleogeographic barriers that were not present before eustatic lowering. Nevertheless, during the Early Triassic there apparently was more or less free interchange of species in the oceans and it is safe to assume that geographic barriers were not a significant factor producing faunal differences.

Biofacies

The Lower Triassic section of Spitsbergen consists of clastics, many coarse, and a few thin interbedded carbonates. In

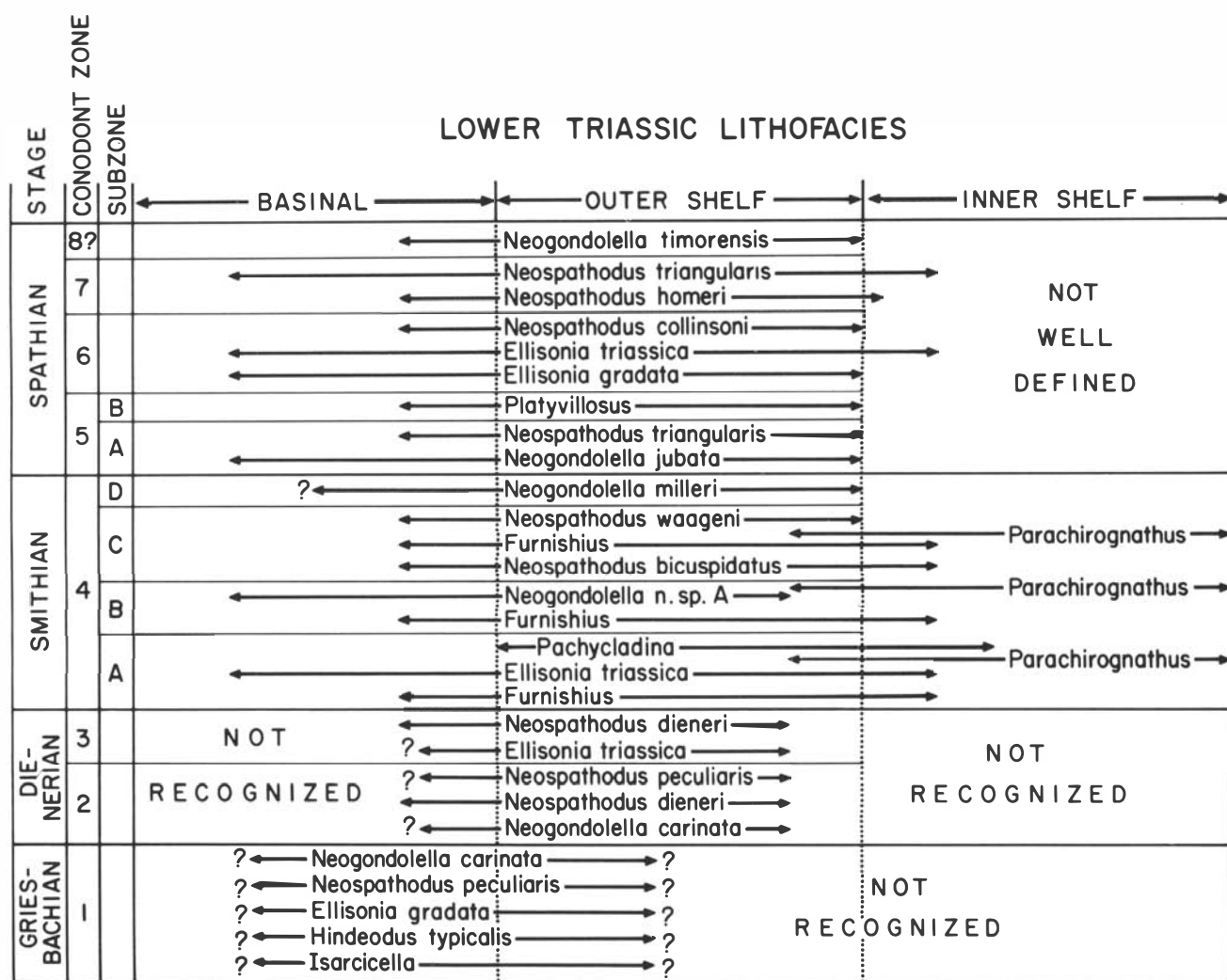


Fig. 3. Basinal, outer-shelf and inner-shelf conodont biofacies for western U.S. Lower Triassic. Environmental range of most species is approximate. Key species for biostratigraphy appear for intervals

representing stratigraphic range. This figure is the basis for the ecologic calculations referred to in text.

general, the section includes a greater proportion of clastics in the younger parts. Middle and Upper Triassic sections are predominantly clastic. Sixty-six samples were taken, of which 28 yielded conodont elements. The carbonates that yielded conodonts averaged 50 % insoluble material. Overall, 75 % insoluble residue was the average for all samples. The section has been studied by sedimentologists who generally have argued for a deltaic-tidal zone interpretation for environment of deposition (Buchan *et al.* 1965; Birkenmajer 1977; Gazdzicki & Trammer 1977). Our field and laboratory observations on percentage of coarse clastic material and rareness of open-marine invertebrates support these interpretations. In addition, we have attempted to classify the conodont species present in Spitsbergen by comparison with a 'North American Biofacies Standard' (Fig. 3), based on extensive collections whose paleogeography and carbonate petrology have been determined (Paull 1980; Carr 1981; Carr & Paull 1981). Six of the Spitsbergen species are the same as those interpreted to range (in the western North America section) from the outer shelf to the basin; a total of 46 % of the ecologically classifiable Spitsbergen species are the same that elsewhere are interpreted to range from outer shelf to basin. A single species from

Spitsbergen is the same as a western North America species that has been interpreted to range onto the inner shelf.

In contrast, the Lower Triassic section in Nepal consists of shales at the base and has thin nodular carbonates throughout. Most of the carbonates are fine grained, and ammonites and other pelagic and benthic fossils are present. The nodular carbonates have been interpreted to represent an environment that may include water depths of 375–500 m (Hatleberg 1982). Some 56 % of the samples yielded conodonts and less than 10 % insoluble material remained after acidization. Comparison of the species present shows that 78 %, are the same as those in western North America that have been interpreted to range from the outer shelf into the basin. No inner-shelf species are present.

The lithofacies clearly suggest different environmental parameters for the two sections. The Spitsbergen section probably represents shallow-marine (10–30 m) to deltaic deposits with little carbonate but abundant clastics. The Nepal section represents deeper basinal deposition (375–500 m) and consists of thin nodular carbonates with abundant pelagic and benthic fossils.

Comparison of the percentage of species classifiable with

North American species is more subjective but indicates that 46 % of the Spitsbergen species and 78 % of the Nepal species represent outer-shelf to basinal taxa. These different percentages are interpreted to indicate important biofacies difference. Taken together, the petrologic and faunal data argue for differences in environment of deposition for the sections; similarly coefficient calculations confirm that different conodont biofacies characterize the different lithofacies.

Conclusions

The faunal comparisons for several major Lower Triassic sections provide data that indicate the sections in Nepal and Svalbard are most dissimilar. Biofacies differences may be sufficient to account for this dissimilarity in spite of obvious latitudinal and possible climatic differences in the two sections. We suggest that the Svalbard section represents the inner part of the marine outer shelf environment during the Early Triassic, while the Nepal section represents more outer-shelf to basinal conditions.

The coefficient of similarity probably is a good expression of biofacies similarity. Sections that represent a basinal environment and an inner-shelf environment would have a similarity coefficient of 0 (i.e. no species in common) for the Lower Triassic. Sections from basinal and outer shelf edges would show higher coefficients. The USSR-US-Australia coefficients are very strong (Fig. 2) and probably indicate that very similar biofacies existed in the sampled areas during the Early Triassic. The very low coefficient for Nepal-Svalbard (0.10, Fig. 2), as is suggested in this report, indicates more dissimilar biofacies, perhaps toward the extremes of basinal and shelf.

Although documentation of biofacies differences in different sections is of considerable importance in understanding such things as low coefficient of similarity of the contained fauna, a second and perhaps more important conclusion results from these observations. This is the possibility that conodonts may have predictive power in biofacies definition. If a matrix could be arranged that included the biofacies range of various species based on reliable paleogeographic, faunal and petrologic studies, these species might then be used in biofacies interpretation of sections for which little petrologic or paleogeographic data are available. For a group such as conodonts whose members were predominantly parts of the pelagic realm, understanding of biofacies may account for most or all of the differences that are suggested by differences in similarity coefficients.

Clearly better data are needed for the basic biofacies matrix for each series or stage of the various periods during which conodonts were part of the marine fauna. Quantitative data for the various intervals could allow the use of species assemblages in biofacies definition of relatively poorly studied or understood sections. This is a well-defined challenge for the serious conodont student.

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