LATEST TRIASSIC CONODONTS AND RADIOLARIAN-BEARING SUCCESSIONS IN BAJA CALIFORNIA SUR

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Abstract—Late Triassic (late Norian-Rhaetian) conodonts and radiolarians are reported from three members of the San Hipólito Formation of Baja California Sur, part of the Vizcaíno Sur terrane. The (lower) limestone member is late Norian based on conodonts of the bidentata Zone, and sparse radiolarian fauna of the Betracium deweveri Zone. The overlying breccia member includes re-worked upper Norian limestone and questionably includes basal Rhaetian radiolarians. The sandstone (upper) member is Rhaetian in age based on common and variably preserved radiolarians of the Proparvicinugla moniliformis Zone (lower to middle Rhaetian), and abundant and well preserved radiolarian faunas assigned to the Globolaxtorum tozeri Zone (upper Rhaetian). Conodont faunas from the sandstone member include Rhaetian Epigondolella mosheri, well known in North America, and species of Misikella, Oncodella, and Zieglericonus that are better known from low latitude Eurasian Tethys. The radiolarians from the sandstone member compare closely with the Rhaetian faunas from the Sandilands Formation of Queen Charlotte Islands (QCI), British Columbia but there is minor variation in the range of a few species, and other low latitude, Tethyan taxa occur that are unknown in QCI. The Baja faunas appear to be intermediate in character between those of eastern Panthalassa and Tethys, which may reflect the relative paleogeographic position of the Vizcaíno Sur terrane. Conodont ranges are calibrated with the Rhaetian radiolarian zonation, and one new conodont, Bajadontus unicornis gen. et sp. nov., is described.

INTRODUCTION

The marine sedimentary rocks of the San Hipólito Formation at Punta San Hipólito on the Vizcaíno Peninsula of Baja California Sur (Fig. 1) were formally named by Mina (1957) and described in detail by Finch and Abbott (1977) and Finch et al. (1979), who studied the petrology and sedimentology of the formation. The formation is exposed over a 20 km² area and is inferred to be in fault contact with the overlying Cretaceous Valle Formation, a unit that covers much of the Vizcaíno Peninsula. The formation is approximately 2400 m thick with good outcrops along the coast and inland; the exact thickness is unknown because the upper part is concealed beneath the sea.

Finch and Abbott (1977) divided the San Hipólito Formation into four informal members (from the base): chert, limestone, breccia, and sandstone (Fig. 2). The oldest member is a radiolarian-bearing chert, which rests on mafic pillow basalts (La Costa Ophiolite of Moore, 1985...
The oldest conodonts recovered from the San Hipólito Formation are from the *Monotis*-bearing limestone member. Those from sections INA, IND, and COA typically comprise *Epigondolella bidentata* Mosher, *E. carinata* Orchard, *Norigondolella steinbergensis* (Mosher) and *Parvigondolella* sp. A. The named species are well known and widespread in *Monotis*-bearing upper Norian strata in British Columbia (Orchard and Tozer, 1997). In one collection from IND, *Bajadontus unicornis* gen et sp. nov., *Norigondolella* sp. A, and *Parvigondolella* sp. B also occur; this fauna is not known elsewhere. In both INA and IND, limestone member strata also contain radiolarians of the *Betraccium deweveri* Zone (Fig. 3).

Conodonts from clasts within the breccia member in both INA and COB are the same as those from the limestone member. This is consistent with a derivation of the clasts, some of which contain *Monotis*, from the underlying limestone member, although a radiolarian collection from the breccia member in INA yielded questionable Rhaetian Assemblage I radiolarians. The highest occurrences of both *Epigondolella carinata* and *Norigondolella steinbergensis* are from clasts within this unit, whereas both *E. bidentata* and *Parvigondolella* sp. A range higher.

**TECTONIC SETTING**

Major structural units in the disrupted Mesozoic oceanic rocks in the western part of Baja California are recognized by Sedlock (1993, 2003): an upper plate of amalgamated arc and ophiolitic terranes of Triassic and Jurassic age overlapped by Cretaceous turbidites (Valle Formation) that were most likely deposited in a forearc basin; and a lower plate of blueschist-facies and metasedimentary rocks (the Puerto Nuevo melange). The arc and ophiolite rocks of the upper plate are recognized in three different terranes in western Baja: Choyal, Vizcaino Norte, and Vizcaino Sur (Moore, 1985; Kimbrough, 1985; Kimbrough and Moore, 2003). Sedlock (1993, 2003) considered these three terranes as subterranes of the Cochimí terrane.

The tuffaceous cherts, limestones, and volcaniclastic sandstones of the San Hipólito Formation at Punta San Hipólito, part of the Vizcaino Sur terrane, overlie the La Costa Ophiolite, the structurally lowest and oldest unit in the terrane. The composition of the volcanic and tuffaceous rocks above the ophiolite (mafic to intermediate, with no continentally derived debris) indicates that both the ophiolite and San Hipólito Formation were deposited adjacent to an active oceanic volcanic arc (Barnes, 1984).

The rock assemblages have been regarded as exotic to North America. Engebretson (1982) and Moore (1985) suggested original deposition several thousand kilometers to the southwest of their present position, with subsequent transportation and accretion to North America due to motion of the Farallon and North American plates. Paleomagnetic studies of the San Hipólito Formation by Hagstrum et al. (1985) inferred 18° ± 11.3° of northward latitudinal displacement since the time of magnetization. Sedlock (1993) concluded that the oceanic rocks on the western edge of Baja California moved northward about 1500 km during the Late Cretaceous and Early Tertiary. Kimbrough and Moore (2003) disagreed and argued that evidence has yet to prove that any of the terranes in the Baja region are far-traveled with respect to one another. The distinct Triassic-Jurassic assemblages are interpreted by these authors to be facies of a single oceanic volcanic arc rather than disjunct terranes; they propose geographic continuity of these terranes in the same paleogeographic setting beginning in Late Triassic time.

**CONODONT BIOSTRATIGRAPHY**

In this account, conodonts of the San Hipólito Formation are described and their association with radiolarian faunas are noted; the latter are mostly referred to in terms of the numbered assemblages shown in Figure 3. Information on the sampled sections, prefixed IN (inland) and CO (coastal), are given in the Appendix and in Figures 4-6. The conodonts are illustrated in Figures 7 and 8. Authorship of conodont species is given at first mention.

The limestone member varies in thickness from 95 to 210 m and consists of finely recrystallized limestone with volcaniclastic sandstone. Chaotic folds and autobreccias, locally common, suggest syndepositional sliding on a depositional slope (Finch and Abbott, 1977). Abundant but poorly preserved calcified radiolarians co-occur with *Halobia*? sp. (Carnian to middle Norian) in the lower part and *Monotis* sp. cf. *M. subcircularis* in the upper part (Finch et al., 1979), implying a middle to late Norian age range for the unit. This constrains the top beds of the limestone member to the upper Norian, equivalent in age to ammonites of the Cordilleran Zone of Tozer (1979, 1994).

The contact between the limestone and overlying breccia is a submarine erosional surface with considerable relief; the breccia member varies in thickness from 0 m at the coast to 105 m inland. Shallow water reefoid organisms - corals, mollusks, foraminifers and calcareous algae - are present in the thickest of the formation and consists of poorly sorted volcaniclastic debris (Finch and Abbott, 1977; Finch et al., 1979). Stanley (1979) noted the similarity of the fauna in the limestone blocks to those in allochthonous Upper Triassic reefs of western North America.

The overlying sandstone member, measuring over 1840 m, is the thickest of the formation and consists of poorly sorted volcaniclastic sandstone. Rhaetian radiolarians and conodonts reported here are present in interbedded, thin limestone beds and concretions near the base of the member. Other radiolarian faunas recovered from about 700-900 metres higher in the sandstone member are Lower Jurassic (late Pliensbachian; Whalen and Pessagno, 1984; Whalen and Carter, 2002). Hence, the Triassic-Jurassic boundary may be present in the intervening beds, which appear to be continuous.

The radiolarian data presented here are preliminary (Whalen et al., 1998). They largely utilize the zonation (Fig. 3) developed by Carter (1993) in Queen Charlotte Islands (QCI). The samples were collected during two visits to Baja: P. Whalen and J. Helwig in 1982, accompanied by E.S. Carter in 1996. Conodont samples were processed at GSC Vancouver.

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In the zonation presented by Kozur and Mock (1991), the disappearance of *Epigondolella bidentata* marks the base of the *Misikella hernsteini* – *Paragondolella andrusovi* Zone. More recently, Channel et al. (2003, p. 89) revised the definition of the base of that zone to include the predominance of *P. andrusovi* Kozur and Mock over *E. bidentata*. This is confirmed by Krystyn and Kuerschner (2005), who showed *Epigondolella bidentata* extending into the succeeding *M. posthernsteini* Zone at Steinbergkogel, Austria. In collections from British Columbia and Nevada (see below), *E. bidentata* extends into the Amoenum Zone but is not known to co-occur with *Misikella posthernsteini* Kozur & Mock anywhere in North America. In Baja, *E. bidentata* ranges upwards into the sandstone member of the San Hipólito Formation and is associated with radiolarians of Assemblage 2b in COC, and 2b-c in INB and COB.

*Norigondolella steinbergensis* is a cosmopolitan, long-ranging species that is strongly facies-controlled and prefers fully pelagic conditions. It appears in the middle Norian and is found as high as the late Rhaetian *ultima* Zone at Csővár, Hungary (Pálfy et al., 2006). In North America, it also has a long range in the Sandilands Formation on QCI, extending to within a few metres of the Triassic-Jurassic boundary, above the only record of *M. posthernsteini* known from the formation (Tipper et al., 1994). *Norigondolella steinbergensis* appears to be absent from the Gabbas Formation in Nevada, as it is from the sandstone member in Baja; these units were evidently not favorable facies for the taxon.

The other element of the upper Norian fauna that ranges from the limestone into the sandstone member is *Parvigondolella* sp. A, which is associated with radiolarians indicative of 2a-b in INB, and of 2b-d and 3 in COC. This taxon bears some resemblance to *P. andrusovi*, the upper range of which is the base of the *posthernsteini* Zone (Kozur and Mock, 1991). Additional uncommon species of *Parvigondolella* have uncertain stratigraphic utility: *P. sp. B* is confined to the limestone member, whereas *P. sp. C* occurs only with radiolarians of 2b in section COC. Both species have comparable occurrences in the Gabbas Formation in Nevada (Orchard et al., 2007).

At the base of the sandstone member in section INB, *Epigondolella mosheri* (Kozur and Mostler) is well established in western North America. *E. mosheri* appears with *Oncodella paucidentata* (Mostler) and radiolarians of 2a. In higher beds in sections INB/INC, additional epigondolellids that resemble *E. englandi* also occur with 2a-b and 2b-c radiolarians. Similar elements occur in section COB/_COD with 2b-2c radiolarians, and in COC with 2b and 3 radiolarians.

*Epigondolella mosheri* was recognized by Orchard (1991a) as being typical of those from collections from the *Cassianella* beds of Tyaughton Creek in south-central British Columbia (Umhoefer and Tipper, 1998), the type section for the *Cochloceras amoenum* Zone (Tozer, 1994). *Epigondolella mosheri* also appears above upper Norian *Mononis* beds in both the Pardonet Formation and Bocock Limestone in northeast British Columbia (Orchard, 1991a), and in the Sandilands Formation at both Kennecott Point and Kunga Island on QCI (Orchard, 1991b). *E. mosheri* was originally described from the Nun Mine Member of the Gabbas Formation in Nevada (Mosher, 1968; Kozur and Mostler, 1976; Orchard et al., 2007). The Rhaetian age of *E. mosheri* is thus well established in western North America. The upper limit of *E. mosheri* at both Tyaughton Creek and Kennecott Point is below single occurrences of *Misikella posthernsteini* in the Crickmayi Zone. However, on Kunga Island (QCI), *E. mosheri* occurs with radiolarians of the *Globolaxtorum tozeri* Zone, which is regarded as equivalent to the Crickmayi Zone. This suggests that the latter radiolarian zone ranges below the Crickmayi Zone, or that *E. mosheri* ranges into it (Fig. 3). *Epigondolella englandi*, originally described from Late Triassic strata of the Lewes River Group in Yukon (Orchard, 1991a), also occurs in the Amoenum Zone of Tyaughton Creek, Queen Charlotte Islands, and the Gabbas Valley Range.

*Oncodella paucidentata* was originally described from Hallstatt Limestone at Hernstein, Austria (Mostler, 1967). Typical of pelagic sequences, the species ranges in Europe through the Rhaetian and up to the upper *posthernsteini* Zone (Kozur and Mock, 1991). In North America the species is known from a single specimen recovered from Kunga Island on QCI (Carter, 1993, fig. 9, section 3, sample 89/13), where it is found in association with radiolarians from 2a. In Baja, *Oncodella paucidentata* occurs with Assemblage 2b radiolarians in section COC,
Oncodella paucidentata is accompanied by the first occurrences of both *Misikella hernsteini* and *Zieglericonus rhaeticus* Kozur and Mock at ~10 m above the base of the sandstone member in COB. All these taxa are typical of low latitude “Tethyan” faunas. In common with *Oncodella*, *Misikella hernsteini* was originally described from the latest Sevatian of Hernstein, Austria (Mostler, 1967). The species apparently ranges into the uppermost part of the *posthernsteini* Zone in Europe, disappearing just before the appearance of *M. ultima* Kozur and Mock at Csővár, Hungary (Pálfy et al., 2006). In Baja, it occurs with 2b-d radiolarians in COC, and with those of 2b-c in COB and INC.

*Zieglericonus rhaeticus* was first described from Csővár, Hungary, where it occurs only in the upper subzone of the *Misikella posthernsteini* Zone, and possibly the terminal Triassic *M. ultima* Zone (Kozur and Mock, 1991). In England, the species also occurs at very high in the Late Triassic in the Langport Member of the Lillstock Formation in the Normanton Hills (Swift, 1995). In North America, *Zieglericonus rhaeticus* has recently been reported, with *M. posthernsteini*, from the upper part of the Mount Hyatt Member of the Gabbs Formation at the proposed GSSP site at Ferguson Hill in the Gabbs Valley Range of Nevada, where it occurs with radiolarians of the *Globolaxtorum tozeri* Zone (Orchard et al., 2007). In Baja, the species occurs with radiolarians of 2a-b in INB, 2b-c in COB, and 2b-d and 3 in COC, which includes a lower range than seen in Hungary. The report of *Zieglericonus* n. sp. in the lowermost Sevatian in Slovakia (Channel et al., 2003, fig. A3. 35) suggests that the genus has a range throughout the Rhaetian.

A single element of *Misikella posthernsteini* was recovered from section INC in association with radiolarians indicative of 2b-c: this is the first record of the species from the *Proparvicingla moniliformis* Zone in North America. In Tethys, *M. posthernsteini* appears concurrently with the ammonoid *Cochloceras* in the Steinbergkogel section in Austria (Krystyn and Kuerschner, 2005); this datum is favored for definition of the Norian-Rhaetian boundary (e.g. Carter, 1993; Kozur, 1999). In North America, the first appearance datum (FAD) of *E. mosheri* seems to represent a proxy for the base Rhaetian in the absence of *Misikella posthernsteini*, which appears later. This is evidently the case both in Nevada (Orchard et al., 2007) and in Baja. In Nevada, as in the two *Misikella posthernsteini* localities in British Columbia allochthonous terranes (QCI and Tyaughton Creek), the species is restricted to the lowermost Triassic *Crickmayi* Zone sensu Tozer (1994). In both QCI and Nevada, *M. posthernsteini* occurs with *tozeri* Zone radiolarians. In comparison with known North American occurrences, this suggests that the present Baja collection may be of Crickmayi Zone age. However, in comparison with Tethys, *Misikella posthernsteini* might be expected throughout the entire lower sandstone member and its absence may result from the general sparseness of the Baja faunas. Hence, it is difficult
to delineate a posthernsteini Zone. The other conodonts from the sandstone member do not resolve this issue because all of them have been shown to range in both the early and late Rhaetian.

**RADIOLARIAN BIOSTRATIGRAPHY**

The study of Rhaetian radiolarians has developed mainly since the finding of complete faunal successions in the Sandilands Formation of Queen Charlotte Islands (Carter et al., 1989; Carter, 1990). Many new species were described and Unitary Associations (UA) zonation was developed based on independent dating by conodonts and rare ammonoids (Carter, 1993) (Fig. 3). In turn, this detailed zonation now provides a framework for determining conodont ranges in the San Hipólito Formation of Baja California Sur.

The Baja radiolarian fauna is sparse in limestone beds assigned to the *Betraccium deweveri* Zone. However, micrite nodules from the overlying sandstone member have yielded common, variably preserved faunas from the *Proparvincula moniliformis* Zone (Assemblages 1 + 2a-d), and abundant, well-preserved faunas in higher beds assigned to the *Globolaxtorum tozeri* Zone (Assemblage 3). Some differences have been noted in the range of certain species, e.g. *Nabolella trispinosa* (Carter), which seems to range higher in Baja. These differences plus the rarity of the zonal indicator *Proparvincula moniliformis* have contributed to a less precise age assignment for assemblages of the *P. moniliformis* Zone. *Globolaxtorum tozeri* faunas are distinctive, however, and compare very closely with those in Queen Charlotte Islands.

The Baja fauna is dominated by species of *Canoptum, Citriduma, Fontinella, Globolaxtorum, Haecckelicyrtium, Laxtorum, Livarella, Nabolella (=Squinabolella), Paronaela, Paratraniooastrum, Serilla (= Risella, see Carter, in press), and Tipperella*. Many of these species are cosmopolitan in distribution with occurrence in Oregon (Yeh, 1989), Nevada (Orchard et al., 2007), Philippines (Yeh, 1992; Yeh and Cheng, 1996), Japan (Yao, 1982, Yoshida, 1986; Sugiyama, 1997; Carter and Hori, 2005), China (Yang and Mizutani, 1991; Yeh and Yang, 2007), New Zealand (Spörli and Aita, 1988), Italy (Amodeo, 1999, Reggiani et al., 2005), Austria (Kozur and Mostler, 1981; Kozur, 1984), Turkey (Tekin, 1999, 2002), and Russia (Bragin, 1991).

In comparison with Queen Charlotte Islands, Baja faunas show clear differences in the composition of assemblages. As with *Proparvincula moniliformis*, the genera *Canutus*, *Eptingium*, *Ferresium*, and the pantanelliids *Betraccium, Cantalum* and *Pantanellium* are also relatively rare in Baja whereas they are abundant in QCI. In contrast, a number of species described from more low latitude localities are common in Baja, but are rare to absent in QCI. These include: *Deflandrecyrtium carterae* and *Haeckelicyrtium takemurai* described from the Philippines (Yeh and Cheng, 1996); *Deflandrecyrtium ithacanthum* and *Haeckelicyrtium breviora* described by Sugiyama (1997) and *Livarella longus* Yoshida from Japan; *Syringiusa rhetaica* from Austria (Kozur and Mostler, 1981); and *Tricornicyrtium dikmetasensis* and the genus *Parvicrachiale* described from Turkey (Tekin, 1999). The affinity between the Baja faunas and those of more Tethyan regions (particularly Philippines, Japan, and Turkey) implies a more southerly and westerly position of the Vizcaíno Sur terrane during the Late Triassic–Early Jurassic.

**SUMMARY**

Late Triassic faunas found in the San Hipólito Formation demonstrate that the limestone member is late Norian in age based on conodonts of the *bidentata* Zone and on sparse radiolarian fauna of the *Betraccium deweveri* Zone. The breccia member represents re-working of the upper Norian limestone, but radiolarians suggest that the breccia may include basal Rhaetian strata. Hence, the exact position of the Norian–Rhaetian boundary is undetermined. Collections from the sandstone member are Rhaetian in age, but neither the conodonts nor the radiolarians indicate the latest Rhaetian is present in the collections recovered.
Conodont faunas from the sandstone member include species of *Epigondolella* that are well known in the Rhaetian of North America, accompanied by elements that are not. Rather, the Baja species of *Misikella*, *Oncodella*, and *Zieglericonus* characterize low latitude Eurasian Tethys. Contemporaneous strata in the accreted terranes of British Columbia (Queen Charlotte Islands, Tyaughton Creek) are dominated by *Epigondolella mosheri*, with very rare occurrences of *Oncodella* and *Misikella*. In cratonic North America, *Misikella posthernsteini* and *Zieglericonus rhaeticus* are known only from the latest Rhaetian of Nevada where they occur, as with *M. posthernsteini* in QCI, only above beds with *Epigondolella* and in association with Crickmayi Zone ammonoids. Hence, the Baja conodont faunas appear to be intermediate between those of eastern Panthalasssa and Tethys, which may reflect an intermediate biogeographic provenance.

The radiolarians from the sandstone member compare closely with those from the Rhaetian *Proparvicingula moniliformis* Zone (lower to middle Rhaetian) and *Globolaxtorum tozeri* Zone (upper Rhaetian) in the Sandilands Formation of Queen Charlotte Islands, British Columbia (Carter, 1993), but minor variation is recognized in the range of a few species. Furthermore, the faunas are also accompanied by forms that characterize low latitude regions of Tethys (i.e. Philippines, central Japan, and Turkey) but are unknown in Queen Charlotte Islands. The recent discovery of both *Misikella* and *Zieglericonus* in New York Canyon, Nevada, and their absence in cratonic successions further north, suggests that these taxa preferred low latitude environments but it does not necessarily imply a distal westerly origin (Orchard et al., 2007). Rather, they appear as late Rhaetian immigrants into an *Epigondolella* dominated biofacies. The Baja faunas are closer to those of Tethys where *Misikella* and its associates became dominant in the early Rhaetian.

### TAXONOMIC NOTES

**Bajadontus** Orchard gen. nov.

**Etymology:** From a combination of its geographic origin and tooth-like function

**Diagnosis:** As for the only known species.

*Bajadontus unicornis* Orchard sp. nov.

(Fig. 7. 29-33)
Holotype: GSC 120359, Fig. 7. 29, 30.
Etymology: Referring to the large terminal cusp.
Type stratum: Bed IND-Y, ~70 m below the top of the upper Norian limestone member, San Hipolito Formation
Type locality: GSC loc. C-173415. Section IND, Punta San Hipólito on the Vizcaino Peninsula of Baja California Sur.
Material: About 20 specimens.

Diagnosis: The segminate P4 element has a posterior cusp that is about three times as large as the other denticles, of which there are up to 7; these slightly decrease in size and elevation to the anterior. The cusp is posteriorly inclined and has a concave posterior margin. The lower surface is deeply excavated, asymmetrically flared with a slight posterolateral expansion beneath the cusp, and strongly tapered to the anterior. The lateral margins of the element lack any flange development.

Remarks: This new conodont resembles small elements of *Norigondolella steinbergensis* (e.g. Fig. 7. 6), from which it may well have developed, but they differ in lacking a platform and in having a more deeply excavated and flared basal cavity. The latter feature is shared by Rhaetian taxa like *Misikella* and *Zieglericonus*, but any relationship with those hinges on a comparison of the multielement apparatuses of the new taxon, which is unknown.

**Epigondolella spp.**
(Fig. 8)
Remarks: Several different *Epigondolella* species are thought to occur in the San Hipolito Formation, although none are common. This makes it difficult to assess intraspecific variation, which has not been established for several species of late Norian and Rhaetian age. Broadly
contemporaneous or overlapping species include _E. bidentata_, _E. slovakensis_ Kozur, and _E. zapfei_ Kozur from Europe, and _E. carinata_, _E. englandi_, _E. humboldtensis_ Meek, and _E. mosheri_ (several morphotypes) from North America. There is an urgent need to delineate these taxa taxonomically and thereby demonstrate their stratigraphic utility.

Elements here included in _E. mosheri_ sensu lato lack the very long posterior platforms of specimens from the Amoenum Zone of Nevada and Queen Charlotte Islands but they are distinctly longer and narrower than the stratigraphically older specimens of _E. bidentata_. They also commonly have an accessory anterior denticle on one platform margin and thus resemble _E. zapfei_ from the _bidentata_ Zone in Europe. However, this variation is denticulation is also shown by _E. mosheri_ and other populations elsewhere (e.g., Orchard 1983, 1994), so for now they are kept united. Broader, more ornate specimens are referred to _E. carinata_ and _E. englandi._

**Norigondolella sp. A**
(7.34, 35)

**Remarks:** The platform of the large P1 specimen has irregular and nodose lateral margins, particularly anteriorly. The large posterior cusp lies within a lobe defined by marginal indentations and is surrounded by a broad platform brim. The single specimen may be a gerontic element of _Norigondolella steinbergensis._

**Parvigondolella sp. A**
(7.15, 16, 23-26)

**Parvigondolella sp. A** – Orchard, Carter, Lucas & Taylor, pl. 1, fig. 20.

**Remarks:** This species resembles small growth stages of _E. ex. gr. bidentata_ but it lacks a platform and lateral nodes. The carinal denticles are of uniform size but decrease in height to the posterior, where the cusp is not well differentiated. The basal edge is straight. This species differs from the holotype of _Paragondolella andrusovii_ Kozur and Mock in lacking a large cusp and downturned posterior process, but some elements assigned to the latter species are similar. A similar specimen was previously reported from near the base of the Nun Mine Member of the Gabbs Formation (Orchard et al., 2007).

**Parvigondolella sp. B**
(Fig. 7.17)

2007 _Parvigondolella sp. B_ – Orchard, Carter, Lucas & Taylor, pl. 1, fig. 21

**Remarks:** These elements have a well differentiated cusp, and a short downturned posterior process carrying one or two denticles; it lacks both platform and nodes. The basal cavity is elongate and expanded beneath the short posterior process. A specimen was also reported from the lower Nun Mine Member of the Gabbs Formation in Nevada (Orchard et al., 2007). This species resembles the holotype of _Paragondolella andrusovii_ with its large cusp and downturned posterior process, but the anterior and posterior parts of the blade are not well differentiated.

**Parvigondolella sp. C**
(Fig. 7.27, 28)


**Remarks:** This element is similar to small growth stages of _E. ex. gr. bidentata_ but it lacks lateral denticles. Rather, it has narrow lateral flanges that extend along both sides of the posterior part of the element. Similar but longer elements occur in the uppermost Nun Mine Member of the Gabbs Formation (Orchard et al., 2007), and in the Sandilands Formation of QCI.

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APPENDIX

Information on each of the sampled sections is provided below.

IND (FIG. 4)

This 80 m section is in the limestone member, collected in 1996. Three conodont collections consist largely of *Epigondolella* and *Norigondolella* species, but one the most diverse of those recovered from the unit. *Bajadontus unicornis* gen. et sp. nov. occurs immediately above radiolarians of the *B. deweveri* Zone.

COA (FIG. 4)

This ~140 m section, collected in 1996, begins at the base of the lithologically variable limestone member, which rests on the chert unit and includes monotids at its base. Three conodont collections with *Epigondolella* and *Norigondolella* species were recovered.

INA (FIG. 5)

This section is 150 m thick, begins at the base of the limestone member, and goes through ~50 m of the breccia member. Collected in 1996, conodonts recovered from five beds in the limestone member and from a clast within the breccia are taxonomically comparable. Samples from about the middle and from the top of the limestone member contain *B. deweveri* Zone radiolarians. A questionable radiolarian assemblage 1 fauna occurs within the breccia sample, which is an important indication that formation of the breccia was an early Rhaetian event. *Monotis* sp. cf. *M. subcircularis* occurs both at the top of the limestone and in clasts from the breccia.

COB, COD (FIG. 5)

This section was sampled twice, in 1982 (COD) and 1996 (COB). The COD section extends up to 140 m from the base of the sandstone member. It is part of the complete section, BPW82-alpha-BPW82-60, collected up to ~776 m from the top of the limestone member through the sandstone member in 1982. Later, the COB section (the lowest 45 m) was resampled beginning at the base of the sandstone member. Conodont data come from seven samples in the lower ~90 m, from an eighth sample near the top of the underlying breccia member, and from a sample higher in the section that may be repeated by a fault. Radiolarians represent both the *moniliformis* and *tozeri* zones, and suggest that the base of 2b is no higher than ~10 m above the base of the member.

COC (FIG. 6)

Collected in 1996, this ~84 m thick section produced the most abundant Rhaetian conodont and radiolarian faunas. The basal ~15 m is transitional from the underlying breccia, but otherwise it is all in the sandstone unit. Six conodont collections and 12 radiolarian faunas include several radiolarian assemblages, including a defined boundary between the *moniliformis* and *tozeri* zones at ~78 m.

INB, INC (FIG. 6)

This section was sampled twice, in 1982 (INC) and 1996 (INB). The INC section extends to 80 m from the base of the sandstone member and is part of the complete section, BPW82-4-BPW82-34, of 180 m, collected from the top of the breccia member through the sandstone member. Later the INB section (the basal ~75 m of the sandstone member) was resampled. This section is unique in providing a fossil age at the base of the sandstone member; both radiolarians and conodonts show it to be Rhaetian, but the radioarians indicate that it is not basal Rhaetian. Twelve conodont collections and 14 diagnostic radiolarian collections spanning both *moniliformis* and *tozeri* zones were recovered.