Vertebrate Fossils from the Northalpine Raibl Beds, western Northern Calcareous Alps, Tyrol (Austria)

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KEYWORDS

Northern Calcareous Alps
Northalpine Raibl Beds
vertebrate fossils
facies

Abstract

Vertebrate fossils such as fish teeth derived from Actinopterygii (*Saurichthys* morphotype, *Colobodus?*, indeterminate) and lateral teeth of *Paleobates* (small sharks) as well as reptile fragments ascribed to Eusauropterygia? and Prolacertiformes are reported from the Northalpine Raibl Beds of the Karwendel and Mieming mountain ranges of the western Northern Calcareous Alps (Tyrol, Austria). The vertebrate fossils occur in oncolite and coquina beds that are intercalated in dark shales. We interpret these intercalated beds as high-energy sediments deposited during storm events (tempestites) in an inner shelf environment. The Raibl vertebrate fossils documented here add another well-established record of characteristic fish and tetrapod taxa that lived in the Middle-Late Triassic seaways that covered Western Europe.

Aus den Nordalpinen Raibler Schichten des Karwendels und der Mieminger Kette in den westlichen Nördlichen Kalkalpen (Tirol, Österreich) werden Vertebratenreste wie Fischzähne von Actinopetrygiern (*Saurichthys* Morphotyp, *Colobodus*?, unbestimmbare Fischzähne) und laterale Zähne von *Paleobates* (kleine Haie) sowie Reptilienfragmente von Eusauropterygiern? und Prolacertiformes beschrieben. Die Vertebratenreste wurden in Onkolithen und Schillagen gefunden, die in dunkle Tonschiefer eingeschaltet sind. Wir interpretieren diese Lagen als hochenergetische Sedimente (Tempestite), entstanden durch Sturmereignisse in einem inneren Schelfbereich. Die in dieser Arbeit dokumentierten Vertebratenreste der Raibler Schichten sind ein weiterer Nachweis typischer Fisch- und Tetrapodentaxa, die in den Meeren der Mittel- und Obertrias in Westeuropa lebten.

1. Introduction

The “Northalpine Raibl Beds” (Nordalpine Raibler Schichten; Stratigraphische Tabelle von Österreich, Piller et al., 2004), which are exposed in the western part of the Northern Calcareous Alps, disconformably overlie the Wettersteinkalk/dolomite (Wetterstein Formation) or Arlbergschichten (Arlberg Beds) and are conformably overlain by the Hauptdolomite. The Northalpine Raibl Beds are dated as Carnian (Julian-Tuvalian) based on bivalves, ammonites, and smaller foraminifers (Tollmann, 1976).

The lower boundary of the Northalpine Raibl Beds is sharp and marks one of the most prominent events within the Triassic succession of the western Tethys (“Raibl Event”). Thus, carbonate sedimentation on the Wetterstein platform ended abruptly and platform carbonates are sharply overlain by fine-grained siliciclastic sediments of the basal Raibl Beds. Locally, the surface of the Wetterstein Formation is karstified. A thin layer enriched in pyrite and Fe-hydroxides occurs at the boundary, indicating subaerial exposure prior to sedimentation of the basal Raibl Beds (Brandner, 1978; Brandner & Poleschinski, 1986). The Raibl Beds in the western part of the Northern Calcareous Alps are up to 500 m thick, and in the Karwendel mountain range they are up to about 300 m thick and composed of alternating siliciclastic, carbonate and evaporitic sediments (Jerz, 1966; Schuler, 1968; Harsch, 1970; Schulz, 1970; Krainer, 1985; Brandner & Poleschinski, 1986; summary in Tollmann, 1976).

The Raibl Beds are divided into a lower part (Untere Abteilung = “Carditaschichten”), composed of (see Jerz, 1966; Tollmann, 1976):

a) Untere Schiefertonserie (lower shale series; horizon 1a),
b) Untere Karbonatgesteinsserie (lower carbonate series; horizon 1b), and
c) Mittlere Schiefertonserie (middle shale series; horizon 1c); and an upper part (Obere Abteilung = „Torer Schichten“) composed of
d) Mittlere Karbonatgesteinsserie (middle carbonate series; horizon 2a),
e) Obere Schiefertonserie (upper shale series; horizon 2b) and
f) Obere Karbonatgesteinsserie (upper carbonarte series; horizon 2c).

The succession is entirely marine; a rich invertebrate macrofauna is known from the siliciclastic horizons (listed in Wöhrmann, 1889, 1893; Bittner, 1890; Klebelsberg, 1935). The lowermost horizon (lower shale series, horizon 1a) is characterized by the occurrence of the bivalve *Palaeocardita crenata guembeli* (Pichler), and the upper shale series (horizon 2b) contains the bivalve *Alectryonia montiscaprilis* (Klipstein) amongst others.

Vertebrate fossils have not previously been described from the Northalpine Raibl Beds, but are known from the Southalpine Raibl Group (Koken, 1913).

The aim of the paper is to provide a description of vertebrate fossils, to describe the depositional environment and to discuss the paleobiogeographic implications.

2. Material and Location

The studied samples are from different localities of the Karwendel and Mieming mountain ranges in the western part of the Northern Calcareous Alps (Tyrol, Austria) (Fig. 1):

Samples RS 1, 8 and 9 are from horizon 1 a (lower shale series), loose rock samples from Judenbach near Mieming

Sample RS 2 is from horizon 1 c (middle shale series) at Kalvarienberg near Zirl, Karwendel

Sample RS 3 is from horizon 1 c (middle shale series), loose rock sample from Helfertal (Gleirschtal), Karwendel

Sample RS 4 is from horizon 2 b (upper shale series) at Kalvarienberg near Zirl, Karwendel

Sample RS 5 is from horizon 1 a (lower shale series) near Haller Salzberg, Karwendel

Samples RS 6 and 7 are from horizon 1a (lower shale series) at Kohlergraben, Hinterautal, Karwendel

Sample P 3347: Oncolite, Raibl Beds, Mötz (unknown horizon)

Sample P 3744: Coquina bed, Raibl Beds, Mieming (unknown horizon)

Sample P 3770/38: Fossiliferous limestone (rudstone with oncoids), Raibl Beds, Mieming (unknown horizon)

Sample P 3770/40: Fossiliferous limestone (rudstone), Raibl Beds, Mieming (unknown horizon)

Sample P 6626: Fossiliferous limestone, Raibl Beds, Obermieming (unknown horizon)

Samples RS 1 – 9 are in the private collection of M.S., and samples P are from the collection of the Institute of Geology and Paleontology, University of Innsbruck.

3. Facies

In the Karwendel and Mieming mountain ranges the Raibl Beds are a cyclic succession up to about 300 m thick composed of alternating siliciclastic and carbonate intervals (Fig. 2). Siliciclastic intervals are composed of dark gray shale and siltstone with intercalated beds of fine-grained sandstone and different types of limestone, including coquina, oncolite, and oolite. Siliciclastic intervals are interpreted as subtidal deposits. Intercalated sandstone beds, coquina beds and oolitic limestone beds indicate deposition under high-energy conditions and most probably represent storm layers (details in Harsch, 1970; Jerz, 1965, 1966; Schuler, 1968; Schulz, 1970).

Carbonate intervals are composed of shallow-marine platform carbonates, dominated by low-energy “pelleted mud facies” with intercalated moderate- to high-energy deposits such as oolithic grainstones, peloidal grainstones and oncolites (see details in Krainer, 1985).

The vertebrate fossils are derived from thin fossiliferous limestone beds that are intercalated in shale (lower, middle and upper shale series). The limestone beds are composed of the following microfacies types:

a) Oncolite (samples RS 1, 8, 9) from the lower shale series (horizon 1 a): gray, 6 cm thick, containing abundant bivalves. The microfacies is oncolitic floatstone containing oncoids up to 1.5 cm in diameter, bivalve shell fragments, echinoderms and rare gastropods floating in the matrix (Fig. 3A, B). The oncolite is nonlaminated, poorly sorted and slightly recrystallized. The matrix is siltstone to fine-grained sandstone (mostly 0.1 – 0.2 mm) containing peloids, small carbonate lithoclasts, angular quartz grains, a few glauconite grains and small bioclasts such as echinoderms, ostracods, punctate brachiopods, and very rare smaller foraminifers. Locally the matrix is composed of micrite.

Most oncoids are cyanoids or porostromate oncoids composed of *Girvanella* (*Sphaerocodium borenmanni*) and en-

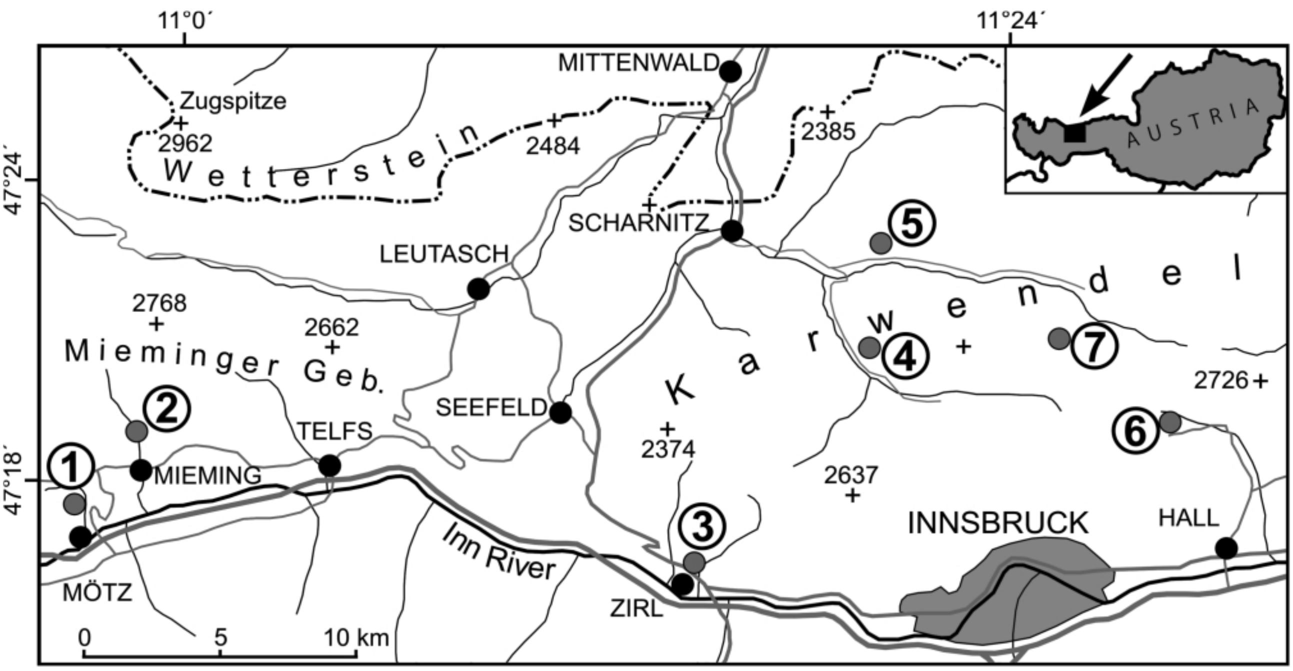


Figure 1: Geographic map showing locations of the studied samples in the Karwendel and Mieming mountain ranges: 1 Mötz, 2 Judenbach near Mieming, 3 Kalvarienberg near Zirl, 4 Helfertal, 5 Kohlergraben, 6 Haller Salzberg, 7 Großer Gschnierkopf (section Fig. 2).

crusting foraminifers. Most of the larger oncoids are of type R (composed of randomly arranged hemispheroidal layers), smaller oncoids are of type C (concentrically stacked spheroid layers), and a subordinate number are of type L (lobate growth forms; Flügel, 2004, Fig. 4.15 A). The laminae are composed of micrite only (type 1), of micrite with sparitic patches (type 2) and commonly of micrite alternating with layers of encrusting organisms (type 4 of Flügel, 2004, Fig. 4.15 B).

b) Thin coquina bed (sampleRS 2) from the middle shale series (horizon 1c), 4 cm thick, containing abundant bivalves (Fig. 3C). The microfacies is bivalve packstone composed of densely packed bivalve shell fragments up to 2 cm long (mostly 3 – 10 mm). The bivalve shell fragments are recrystallized, display thin micritic envelopes and are commonly aligned parallel to the bedding plane. Echinoderm fragments and worm tubes, rare small gastropods and punctate brachiopods are subordinate. The matrix is calcisiltite containing a few peloids.

c) A thin limestone bed (sample RS 3) from the middle shale series (horizon 1c) is identified as peloidal grainstone to floatstone, fine-grained, laminated and moderately sorted (Fig. 3H). Grain-size is mostly 0.05 – 0.2 mm. Predominant grain types are peloids and smaller foraminifers that are partly pyritized. Subordinate are ostracods and other bioclasts. The peloidal grainstone overlies bioturbated peloidal wackestone and grades into mudstone.

The floatstone layer is 1 cm thick and consists of peloidal grainstone matrix in which abundant shell fragments float. The matrix contains abundant peloids and smaller foraminifers, a few ostracods and other bioclasts. The grains are cemented by calcite. The larger fossils floating in the matrix are mostly bivalve shell fragments (up to 15 mm), subordinate small gastropods, echinoderms (3 – 10 mm), rare ammonites and small punctate brachiopod shells.

The sample contains the following foraminifers: *Ammodiscus* sp. (Fig. 4A), *Glomospira* sp. (Fig. 4B), *Glomospirella ammodiscoides* (Rauser-Chernousova, 1938) (Fig. 4C), *Glomospirella* sp. (Fig. 4D, E), *Trochammina alpina* Kristan-Tollmann, 1964 (Fig. 4F), *?Endotriadella*, *Aulotortus pragsoides* (Oberhauser, 1964) (Fig. 4G), *Agathammina austroalpina* Kristan-Tollmann & Tollmann, 1964 (Fig. 4H, I), *Gsollbergella spiroloculiformis* (Oraveczné-Scheffer, 1968) (Fig. 4L), *Variostoma exile* Kristan-Tollmann, 1960 (Fig. 4J), *Dentalina* sp., *Nodosaria* sp. and *Pseudonodosaria* sp. (Fig. 4K).

Abundant occurrences of small representatives of the genera *Glomospira*, *Glomospirella* and *Agathammina* were observed in the Raibl Beds near shale horizons and within limestones intercalated in shales. In the lower part of the Raibl Beds the abundant occurrence of *Variostoma exile* is known from a locality in the Karwendel Mountains (W. Resch, written. comm.). Lagenids of the Superfamily Robuloidacea (sensu Loeblich & Tappan 1988) are rare and represented by the morphotypes *Dentalina* and *Nodosaria* besides *Austrocolomia* cf. *marschalli* (W. Resch, written comm.).

d) Fossiliferous limestone bed, gray, 5 cm thick (sample RS 4) from the upper shale series (horizon 2b), composed of floatstone to rudstone containing abundant bivalve shell fragments up to 15 mm long, subordinate echinoderm fragments up to 3 mm, small punctate brachiopod shell frag-

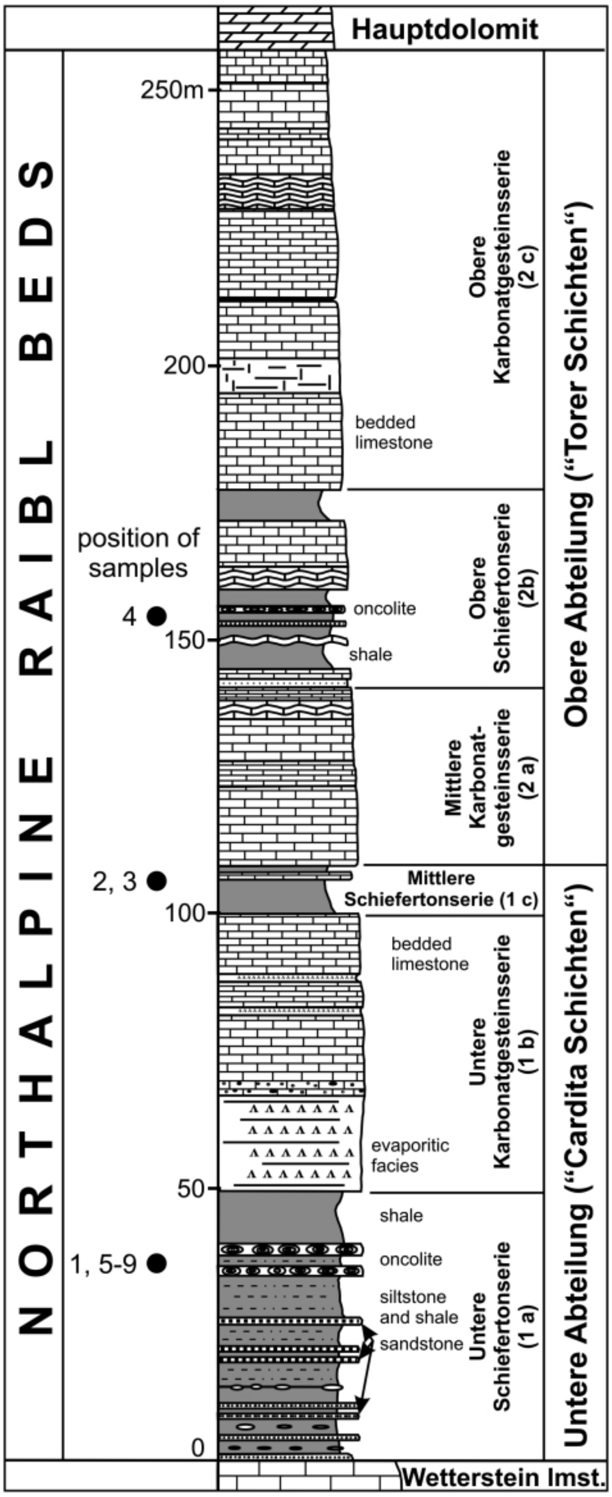
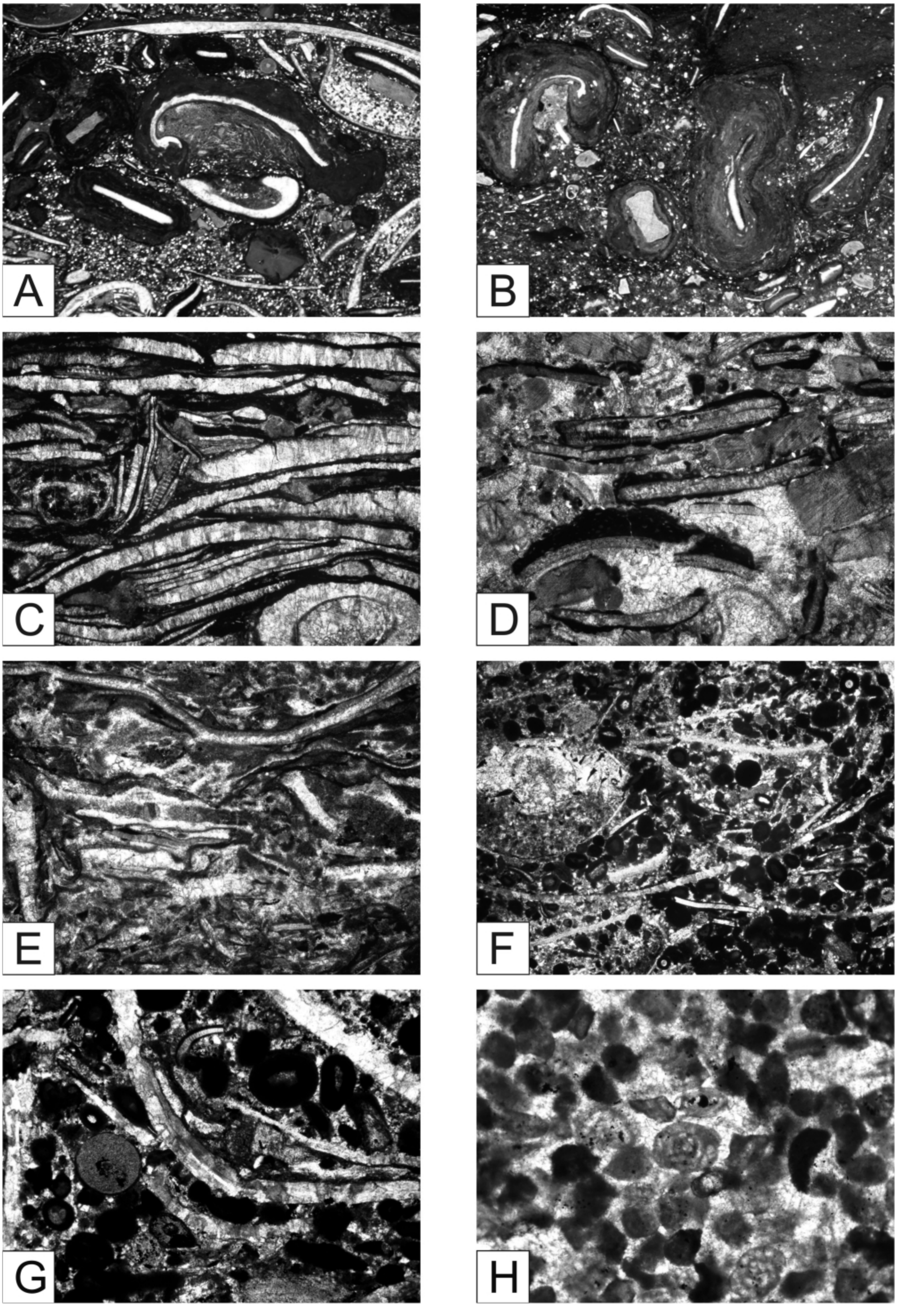


Figure 2: Measured stratigraphic section of the Northalpine Raibl Beds in the Karwendel mountain range at Großer Gschnierkopf (redrawn from Krainer, 1985). Black dots indicate position of samples 1 – 9 within the section. Location of section is shown in Fig. 1.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ments, ostracods, rare smaller foraminfers and phosphatic fossil fragments (?fish remains). Locally the bioclasts are densely packed, and the bioclasts float in matrix. Locally the rock is slightly washed and contains many peloids between the bioclasts. The rock is nonlaminated and poorly sorted, and the fossils are strongly fragmented. Larger shell fragments are oriented parallel to the bedding plane (Fig. 3D, E).

e) Fossiliferous limestone bed (sample 5) from the lower shale series (horizon 1a), brownish-gray, 4 cm thick. The microfacies is indistinctly laminated rudstone, poorly sorted and poorly washed, composed of abundant fragmented bivalve shells. The shell fragments are up to 10 mm long and partly aligned parallel to the bedding plane. Common are crinoid fragments up to 3 mm. In the lower part oncoids up to 7 mm in diameter occur. Punctate brachiopod shell fragments, ostracods, echinoid spines and smaller foraminfers are rare. The matrix is sandy and composed of abundant pyritized ooids (mostly 0.2 – 0.3 mm), peloids, and small, angular quartz grains (Fig. 3F, G).

f) Fossiliferous limestone bed (sample RS 7) from the lower shale series (horizon 1a), gray, containing abundant crinoids and also ammonites (*Carnites floridus*, *Joannites cymbiformis*); 5 cm thick. The microfacies is indistinctly laminated and poorly sorted rudstone composed of abundant bivalve shell fragments up to 15 mm long and crinoids, some ostracods and a few foraminifers. Many shell fragments and rare crinoids are encrusted by "*Sphaerocodium*" forming "coated grains" and rarely small oncoids. The rock is moderately washed; pore space is partly cemented by calcite and partly filled with silty matrix containing small peloids, quartz grains and rare glauconite grains.

4. Facies interpretation

Flügel (2004) interpreted the oncolites to have been deposited in a deeper subtidal lagoon with reduced sedimentation.

We recognized an upward shallowing trend within the siliciclastic horizons. Oncolite beds, which are commonly associated with oolite, and intercalated coquina and rudstone beds indicate deposition in a high-energy environment. Coquina and rudstone beds were most probably deposited during storm events ("tempestites"). Oncolites associated with oolite indicate deposition in a high-energy shallow shelf environment behind oolite shoals. Thin limestone beds of peloidal grainstone may represent distal storm layers. Sedimentation rates of tempestites (storm layers), coarse (sandy) terrigenous beds and oncolites associated with ooids were significantly higher than those of oncolites and fine-grained siliciclastic sediments which accumulated in a deeper, subtidal lagoon environment. The foraminiferal assemblage is poor in Involutinina and lacks *Tolypammina*. Echinoderm fragments are also rare. Lagenids and *Variostoma exile* are also rare, small, and preserved as broken fragments indicating some transport. Despite the presence of unchambered Textulariina and low-diversity Miliolina the foraminifers indicate normal saline conditions of an inner shelf environment.

The foraminiferal assemblage indicates a Carnian age.

Figure 3: Thin section photographs of microfacies types of limestone beds from the Northalpine Raibl Beds which are intercalated in shale and contain vertebrate fossils (plane light). A, B: Oncolite (oncolitic floatstone) with oncoids up to 15 mm, bivalve shell fragments, echinoderms, rare gastropods floating in silty matrix containing peloids, small carbonate lithoclasts and angular quartz grains. A = sample RS 8, width is 20 mm; B = sample RS 9, width is 13 mm. C: Bivalve packstone (coquina) composed of densely packed, recrystallized bivalve fragments, subordinate echinoderms, rare gastropods and punctate brachiopods. Sample RS 2, width is 6.3 mm. D: Slightly washed, poorly sorted and strongly fragmented rudstone composed of recrystallized bivalve shells and echinoderms (crinoids), rare ostracods and smaller foraminifers. Sample RS 7, width is 6.3 mm. E: Rudstone containing abundant bivalve shell fragments, subordinate echinoderm fragments, punctate brachiopods, ostracods and rare smaller foraminifers. Sample RS 4, width is 6.3 mm. F: Poorly sorted and poorly washed rudstone with many bivalve shells, echinoderms and abundant pyritized ooids (black), peloids and small angular quartz grains. Sample RS 5, width is 6.3mm. G: Detail of F, width is 3.2 mm. H: Peloidal grainstone containing abundant peloids and smaller foraminifers, rare ostracods and other small bioclasts. Sample RS 3, width is 1.2 mm.

5. Vertebrate Paleontology

Vertebrate fossils from the Northalpine Raibl Beds pertain to sharks, bony fishes and marine and marginal marine reptiles.

5.1 *Palaeobates* sp.

Two hybodont shark teeth have long and narrow crowns that are covered by a reticulate ornamentation of coarse ridges (Fig. 5G, H). The crown surfaces are nearly flat and non-cuspidate. The elongate crown is slightly arched lingually, and there is a median groove that runs along the length of the crown. Crown lengths and widths are 11 and 4.8 mm.

These teeth are unquestionably recognizable as lateral teeth of *Palaeobates*, a common Middle-Late Triassic shark in the Tethyan realm (e.g., Stensio, 1921; Seilacher, 1943, 1991; Cappetta, 1987; Hagdorn & Reif, 1988; Hagdorn, 1990; Duffin, 1998, 1999; Delsate & Duffin, 1999; Diedrich, 2009). J. Kriwet (written commun., 2011) has suggested that they may belong to the species *P. angustissimus*. However, the absence of root anatomy makes it impossible to assign them with certainty to a species, so we identify them as *Palaeobates* sp.

5.2 Actinopterygii

Kner (1866) and Griffith (1959) described the actinopterygian fish *Saurichthys* from the Raibl Beds. Three teeth (Fig. 5A, B, D) are conical, with bluntly pointed tips and smooth enamel at and near the tips. The crown bases are strongly plicated, with an ornamentation of coarse, anastomosing ridges at their bases. Two of these teeth (Fig. 5B, D) well fit the "*Saurichthys* morphotype" of actinopterygian tooth, and one (Fig. 5B) can be assigned to *Birgeria* (e.g., Savage & Large, 1966; Rieppel, 1985; Storrs, 1994; Delsate & Duffin, 1999; Duffin, 1999). This kind of tooth is present in *Saurichthys* and *Severnichthys*, so a more precise identification is not possible. The third tooth (Fig. 5A) belongs to an actinopterygian but is not distinctive enough

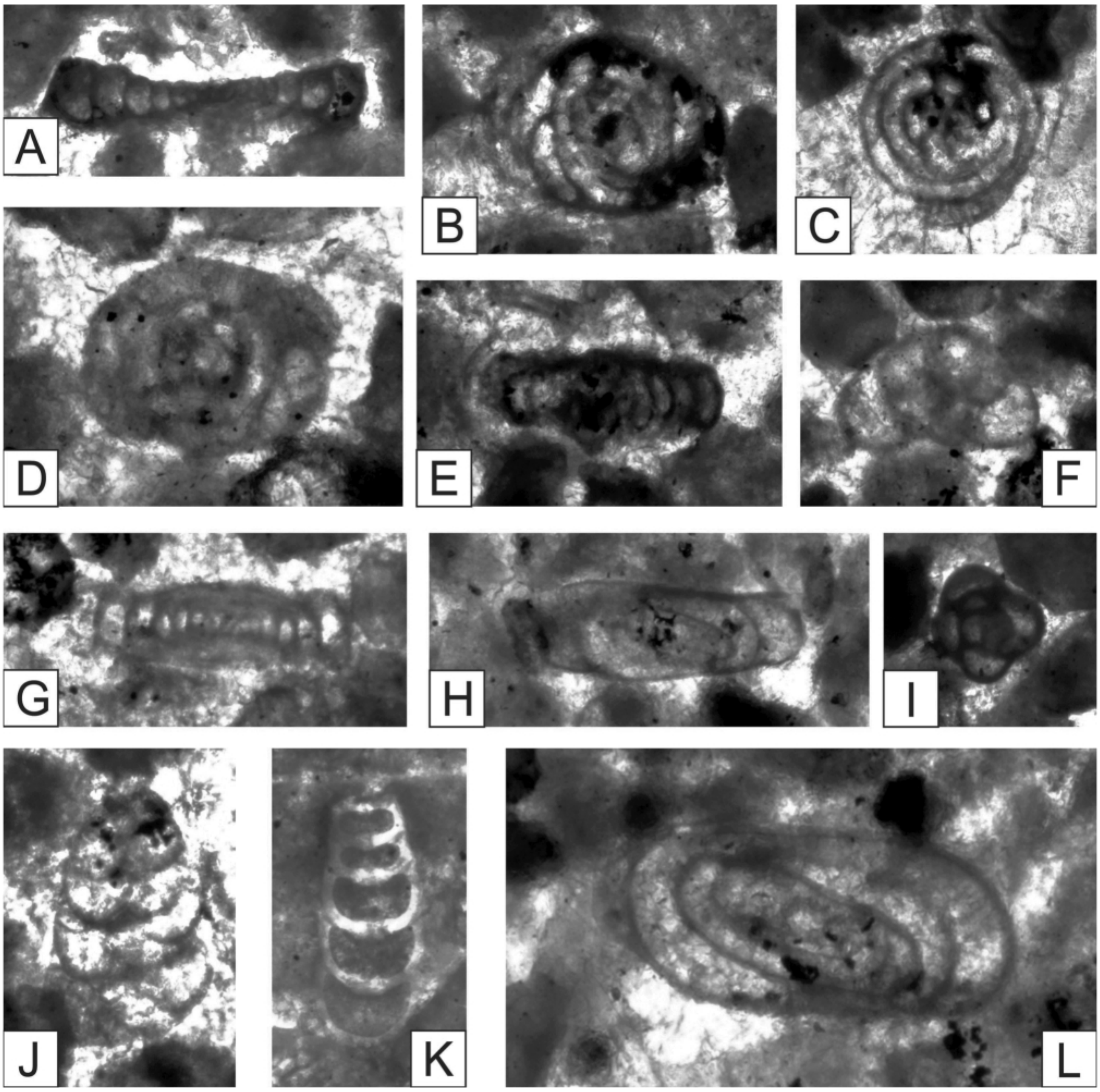


Figure 4: Smaller foraminifers from the Raibl Beds. A *Ammodiscus* sp.; B *Glomospira* sp.; C *Glomospirella ammodiscoides* (Rauser-Chernousova, 1938); D *Glomospirella* sp., axial section; E *Glomospirella* sp. equatorial section; F *Trochammina alpina* Kristan-Tollmann, 1964; G *Aulotortus pragsoides* (Oberhauser, 1964); H *Agathammina austroalpina* Kristan-Tollmann & Tollmann, 1964, longitudinal section; I *Agathammina austroalpina*, transverse section; J *Variostoma exile* Kristan-Tollmann, 1960; K *Austrocolomia* cf. *marschalli* Oberhauser, 1960; L *Gsollbergella spiroloculiformis* (Oraveczné-Scheffer, 1968).

to be more precisely identified.

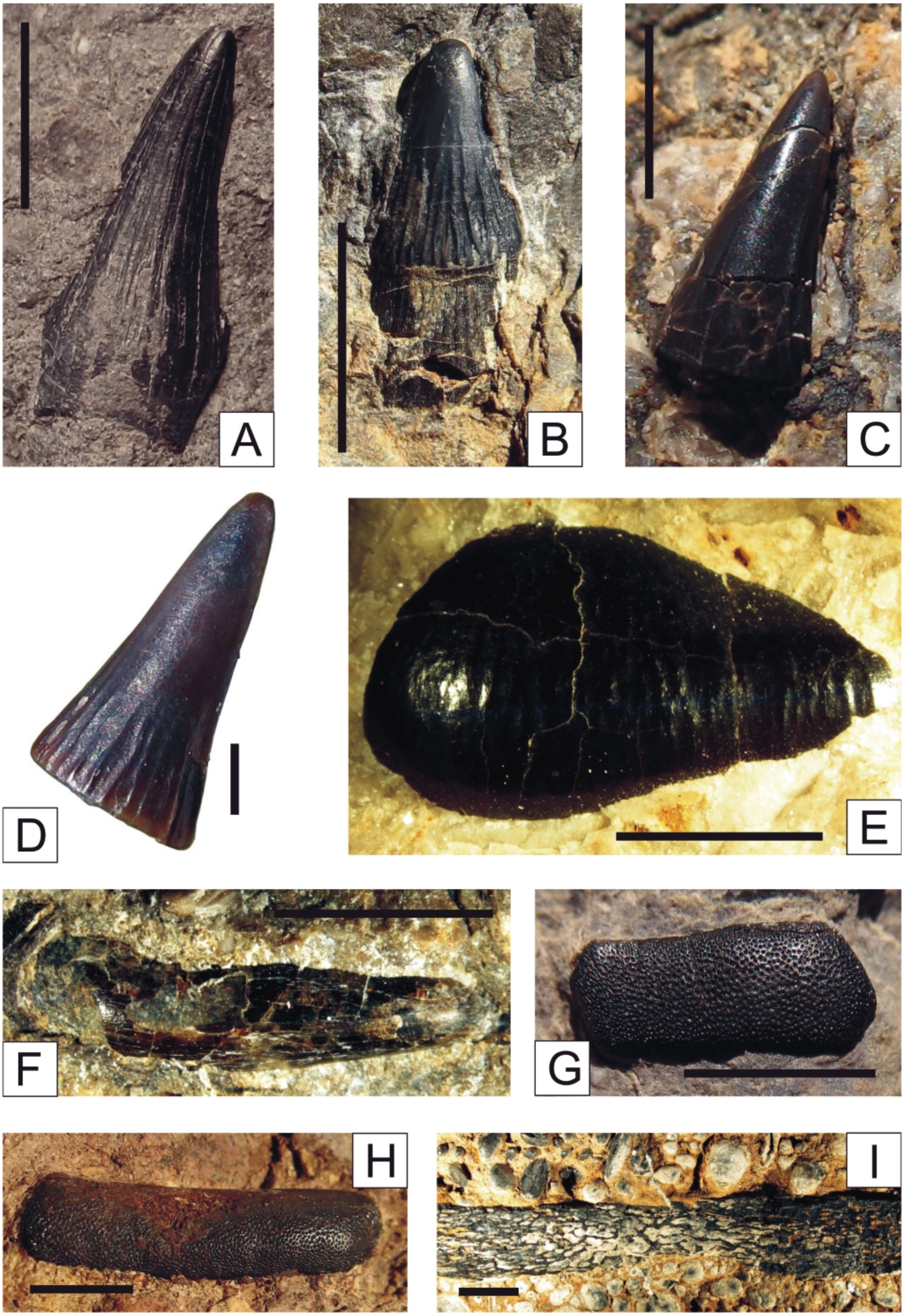
5.3 *Colobodus*?

P-3744-2 is a small tooth with a round, hemispherical crown that is oval in occlusal view (Fig. 5E). The lower part of the crown base is ornamented with regularly-spaced ridges. The tooth somewhat resembles a "molariform" tooth of a pycnodontiform fish (cf. Cuny et al., 1995, fig. 3), but it more resembles a tooth of *Colobodus* (cf. Stolley, 1920; Guttormsen, 1937; Bürgin, 1995; Plesker, 1995), to which it more likely belongs. This isolated tooth, however, does not provide sufficient morphology to make a certain genus-level assignment.

5.4 Eusauropterygian?

Specimen 6626.2 is a nearly cylindrical tooth with a blunt tip that is 10 mm long and 2 mm wide (Fig. 5F). The tooth crown is slightly recurved near the crown base and has a nearly cir-

Figure 5: Vertebrate fossils from the Northalpine Raibl Beds. A, Indeterminate actinopterygian tooth (sample 1, collection of M.S.). B, D Teeth of *Saurichthys* morphotype (B sample 2, coll. of M.S.; D sample 3, coll. of M.S.). C Tooth of a ?prolacertiform (sample 6, coll. of M.S.). E *Colobodus*? tooth (sample P 3744). F Eusauroptyerygian tooth (sample P 6626). G-H *Palaeobates* teeth (G sample 7, coll. of M.S.; H sample 10, coll. of M.S.). I Unidentified bone fragment (sample P 3347). Scale bar is 5 mm, for D 1 mm.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cular cross section. No carinae or distinct fluting are visible across the crown, and the crown surface has numerous, faint and discontinuous striae between what appear to be thin longitudinal ridges. The ridges are regularly spaced.

Tooth "2" is similar to tooth 6626.2 in ornamentation though it is relatively more conical—its crown tip converges to a pointed tip. This tooth is 11 mm long and has a diameter near the crown base of 3.2 mm.

Similar teeth are well known from Triassic nothosaurs and plesiosaurs (together, eusauropterygians) (e.g., Rieppel & Wild, 1996; Dalla Vecchia & Avanzini, 2002). Indeed, other than its smaller size, these teeth well resemble teeth identified as Eusauropterygia by Dalla Vecchia & Avanzini (2002). As they noted, such teeth are not diagnostic of a lower level taxon, though the Carnian age of the Raibl teeth probably precludes a plesiosaur, as their oldest records are late Norian.

5.5 Prolacertiformes

Tooth 6 has a conical crown with distinct carinae but nearly smooth enamel and a blunt, slightly convex root base. It converges to a pointed tip and is very slightly recurved. The crown is 10 mm long and has a maximum diameter of 2 mm (Fig. 5C).

The lack of any serrations on the carina precludes any of the archosaur tooth morphotypes of Heckert (2004). The lack of longitudinal ridges on the crown also excludes Eusauropterygia from consideration. The closest resemblance we can determine is to anterior teeth of the prolacertiform *Tanystropheus*, especially to anterior teeth of *T. meridensis* from the Ladinian of Switzerland (Wild, 1973, 1980). The possibility that this tooth comes from another prolacertiform—similar teeth are found in other genera---cannot be excluded, so we tentatively identify tooth 6 as Prolacertiformes. The shape of the root base and slightly recurved crown with a carnina suggest this tooth is more likely tetrapod than fish.

The Raibl Beds also contain large bone fragments (up to several cm long), which could not be identified. These bone fragments occur mainly in oncolite and coquina beds (Fig. 5I).

6. Discussion/Conclusion

Koken (1913) discovered a metoposaurid amphibian skull (*Metopias santae crucis* n.sp.) in August 1906 in coarse, conglomeratic sandstone within the "Schichten von Heiligkreuz" near the church of Heiligkreuz in the Gadertal/Val Badia, Dolomites (Northern Italy). This skull is now assigned to the Metoposauridae as a nomen dubium by Hunt (1993).

According to Koken (1913), this sandstone contains thin coal lenses and plant remains and locally grades into sandy marls. The sandstone is overlain by marl with two intercalated limestone beds, the upper bed containing *Ostrea montis caprilis* and amber.

This facies belongs to the Dibona Sandstone Member of the Heiligkreuz Formation of the Southalpine Raibl Group, which is dated as late Julian (upper part of the *austriacum* Zone and lowermost part of the *dilleri* Zone) (Breda et al., 2009).

The vertebrate fossils from marine strata of the Northalpine Raibl Beds documented here are a characteristic sample of Middle-Late Triassic marine vertebrates from Western Europe. The polyacrodontid elasmobranch *Palaeobates*, *Saurichthys*-morphotype actinopterygians and colobodontids are fishes known from many Triassic localities in Europe. Eusauropterygians (nothosaurs and/or plesiosaurs) are characteristic Triassic marine tetrapods, known especially well from the Muschelkalk facies of the Germanic basin. Prolacertiforms were Triassic tetrapods that lived in a marginal marine setting, so their fossils often occur in marine beds (Wild, 1973). The Raibl fossils of these taxa documented here thus add another well-established record of characteristic fish and tetrapod taxa that lived in the Middle-Late Triassic seaways that covered Western Europe.

Acknowledgments

We thank Felix Heller (Innsbruck) for the preparation of thin sections and Werner Resch (Innsbruck) for determination of the smaller foraminifers. The paper has benefited from constructive reviews and suggestions by Richard Lein and Jürgen Kriwet. Special thanks are due to Werner Resch for his valuable discussion and important suggestions.

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Received: 10 January 2011
Accepted: 13 March 2011

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