

THE TRIASSIC/JURASSIC BOUNDARY IN THE ANDES OF ARGENTINA

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Abstract. The Arroyo Malo Formation at Alumbre Creek, on the northern bank of the Atuel River, west central Argentina, comprises a c. 300 m thick continuous marine succession across the Triassic-Jurassic System boundary, consisting of massive and laminated pelites indicative of a slope depositional environment. Late Triassic invertebrates, including ammonoids, nautiloids, bivalves, gastropods, brachiopods and corals are restricted to the lower 150 m. Beds between 125-135 m from the bottom yield *Choristoceras* cf. *marshi* Hauer, a species found in the Marshi/Crickmayi Zone of Europe and North America, together with loose fragments of *Psiloceras* cf. *pressum* Hillebrandt, coeval with the lower to middle part of the Hettangian Planorbis Zone. About 80 m higher are beds yielding *Psiloceras* cf. *rectocostatum* Hillebrandt, a species that gives name to an Andean biozone partially coeval with the Johnstoni and Plicatulum Subzones, upper Planorbis Zone. Other fossils recorded in the Rhaetian strata of this section are foraminifers, ostracods and plant remains identified as *Zuberia* cf. *zuberi* (Szaj.) Freng. and *Clathropteris* sp. The section was also sampled for conodonts and radiolarians, thus far with negative results. A palaeomagnetic study is underway.

Riassunto. La Formazione Arroyo Malo ad Alumbre creek, sulla sponda settentrionale del fiume Atuel, Argentina centro-occidentale, comprende una successione marina continua spessa circa 300 m attraverso il limite Triassico-Giurassico, ed è costituita da peliti massive e laminate indicative di un ambiente deposizionale di scarpata. Gli invertebrati del Triassico superiore, che includono ammonoidi, nautiloidi, bivalvi, gasteropodi, brachiopodi e coralli sono limitati ai primi 150 m. Gli strati fra i 125-135 m dalla base hanno dato *Choristoceras* cf. *marshi* Hauer, una specie trovata nella Zona a Marshi/Crickmayi di Europa e Nord America, insieme con frammenti sparsi di *Psiloceras* cf. *pressum* Hillebrandt, coeva con la parte mediana della Zona a Planorbis dell'Hettangiano. Circa 80 m più in alto ci sono strati contenenti *Psiloceras* cf. *rectocostatum* Hillebrandt, una specie che dà il nome ad una biozona andina parzialmente coeva con le Sottozone a Johnstoni e Plicatulum, Zona a Planorbis superiore. Altri fossili documentati negli strati del Retico di questa sezione sono foraminiferi, ostracodi e resti di piante identificati come *Zuberia* cf. *zuberi* (Szaj.) Freng. e *Clathropteris* sp.

thopteris sp. La sezione è stata anche campionata per quanto riguarda conodonti e radiolari, finora con risultati negativi. Uno studio paleomagnetico è in corso.

Introduction

Until quite recently all evidences indicated that in Argentina the Triassic was only represented by continental strata (Stipanovic 1983 and references therein). Previous records (Groeber 1924, 1929) of marine Triassic were based on some bivalves and brachiopods found in west-central Argentina, which were subsequently dated as Early Jurassic (Leanza 1948; Frenguelli 1948). Until 1986 the oldest recorded Mesozoic marine strata – dated as Sinemurian – were located on the northern bank of the Atuel River, within a succession studied by different authors since Bodenbender 1892 (see also Burckhardt 1900, 1903; Gerth 1925; Groeber 1947; Stipanovic 1969; Volkheimer 1970, 1978; Hillebrandt 1989). In other areas of west central Argentina the base of the marine Mesozoic was dated as late Early Pliensbachian.

In 1986 a field trip aimed at locating the oldest marine beds in the rio Atuel area, resulted in the first record of Hettangian ammonites for west-central Argentina (Riccardi et al. 1988, 1991). Furthermore, a succession c. 300 m thick below the oldest ammonites prompted Riccardi et al. (1988) to suggest the possible occurrence of marine Triassic in those 'unfossiliferous' beds. From these levels Ballent (1994) recorded some microfossils, and indicated its possible significance for future research on the Triassic-Jurassic boundary.

Undoubtedly Triassic marine invertebrates and plant

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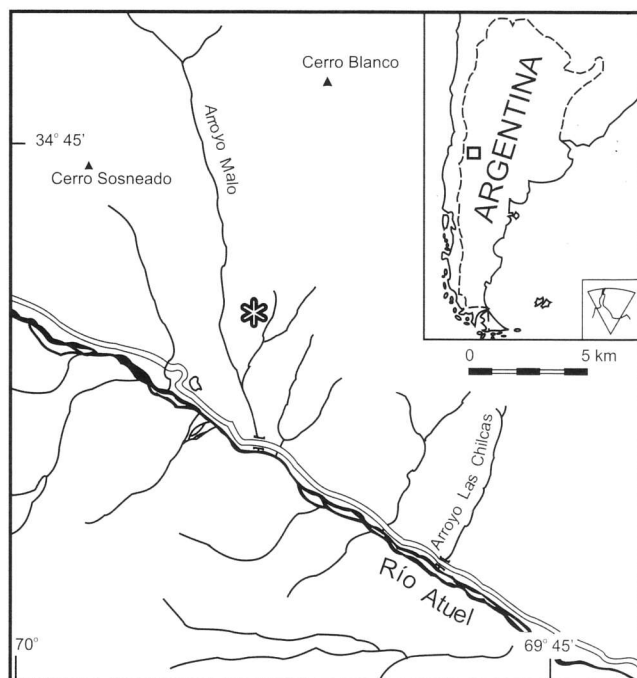


Fig. 1 - Location map.

remains were found in the same area during successive field trips carried out during 1994-1999 (Riccardi et al. 1997a-b; Riccardi & Iglesia Llanos 1999). Late Triassic invertebrates are restricted to the lower 150 m (Riccardi et al. 1997a-b, Damborenea & Manceñido 1998; Riccardi & Iglesia Llanos 1999).

As there are very few sections world-wide where the marine Triassic-Jurassic transition is exposed, the investigation of this new section could add significantly to the study and correlation of the system boundary. Therefore, it is currently being the subject of a multidisciplinary research project aimed at that end.

Stratigraphy

In the northern bank of the Atuel River the marine Triassic-Jurassic transition is exposed on the right bank of arroyo Alumbre, a small tributary of arroyo Malo, about 5 km north of its junction with the Atuel River (Fig. 1).

The section is exposed on the west limb of a north-south striking anticline. The lower part of the section consists of 286 m of massive and laminated pelites and turbidites with massive pebbly mudstones, intraformational breccias, clast supported conglomerates with normal gradation and cross-bedded sandstone lenses (Fig. 2). Synsedimentary folding and slump structures are quite common. The sedimentological features indicate a shallowing upwards sequence related to a continental slope fan delta.

Between 50 and 150 m there are several fossiliferous levels containing rather poorly preserved representatives of Triassic ammonoids, nautiloids, brachiopods, bivalves

and corals, as well as plant fragments. At 230 m the first Hettangian ammonites occur. This succession, included in the Arroyo Malo Formation, is conformably covered by 5-20 m thick cross bedded and imbricated polymictic conglomerates grading upwards into coarse massive sandstones, the El Freno Formation. Above follows, conformably, a coarsening-upward succession of c. 800 m of well-stratified pelites and sandstones, the El Cholo Formation, bearing Hettangian and Sinemurian ammonites.

Palaeontology

As mentioned, the Arroyo Malo Formation contains microfauna (foraminifers and ostracods), and in order of decreasing importance bivalves, gastropods, brachiopods, ammonoids, cnidarians and nautiloids (Fig. 3; complete list in Appendix). Samples studied for conodonts (G. L. Albanesi) and radiolarians (E. Carter) were reported as barren.

A report on the microfossils was given by Ballent (1994). She recorded the presence of poorly preserved, infilled and often broken, small foraminifera, consisting of coiled *Haplophragmoides*-like agglutinated tests and nodosariids. A few ostracods included healdiids such as *Ogmoconchella* and cytheraceans.

Bivalves are the most numerous and diverse group represented in the Triassic part of the Arroyo Malo Formation, with at least a dozen species belonging to almost as many families (see stratigraphic distribution in Fig. 2). Despite intensive sampling, the material is very scarce in the succession, and preservation is generally poor, though it differs according to lithology. The dark shales contain scattered complete (articulated or disarticulated) shells of relatively large specimens. The best specimens are preserved as external moulds in nodular local shell concentrations. These contain a very diverse fauna, but some size sorting appears to have taken place, since most shell pieces are less than 1 cm across. The few complete specimens are small-sized individuals of all species. The preservation of delicate ornamentation details, the presence of articulated bivalves, and the lack of abraded fragments indicate short transport, probably only minor local winnowing allowing size-selection.

No bivalves have been found in beds from the earliest Hettangian (Fig. 2). After the boundary beds, the first bivalves appear in beds with ammonites of the "*Waehneroceras-Schlotheimia*" Zone, separated by about 150 m of sediments from the last Triassic bivalve. The only bivalve species which appears both below and above the boundary is *Praechlamys* cf. *valoniensis* (Defrance) (Fig. 3t), which was found near the level with *Choristoceras* cf. *marshi* and extends to the Late Sinemurian "*Epophioceras* Zone" (Damborenea 2002a). This species has a similar stratigraphical distribution across the boundary in other parts of the world (McRoberts et al. 1997; Ivimey-Cook et al. 1999). All other bivalve species are restricted either

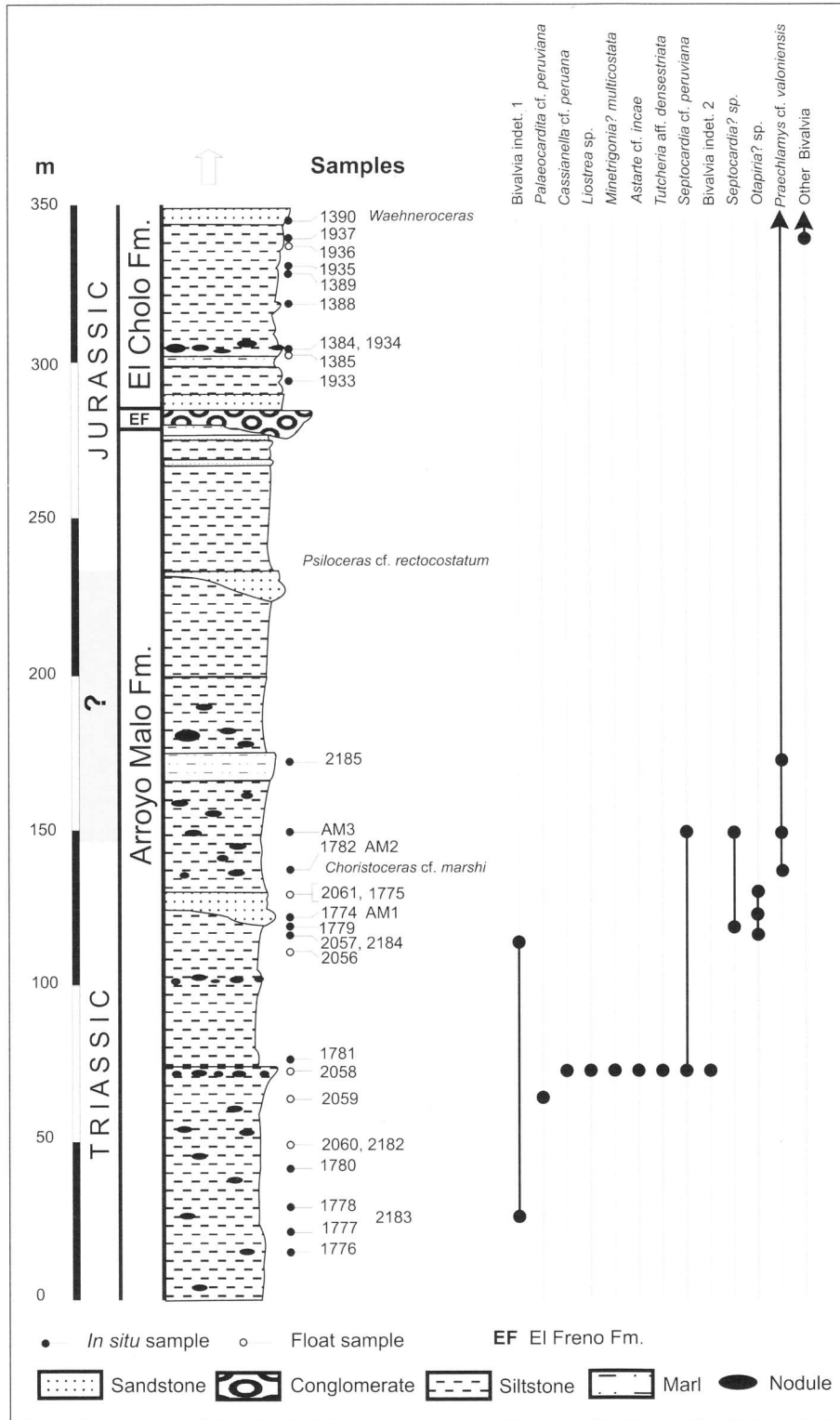


Fig. 2 - Stratigraphic section with location of samples (modified from Riccardi et al. 1997) and distribution of bivalve species. Stippled portion indicates the absence of biostratigraphically useful fossils, in which the Triassic-Jurassic boundary should be located.

to Triassic or Jurassic deposits. At the generic level *Cassianella*, *Minetrigonia*, *Palaocardita* and *Septocardia* do not extend after the Rhaetian worldwide. The earliest Jurassic bivalve faunas at Arroyo Malo contain instead *Palmoxytoma* cf. *cygnipes* (Young and Bird), *Camptonectes?* cf. *subulatus* (Münster), *Eopecten* cf. *velatus* (Goldfuss) and *Praechlamys valoniensis* (Defrance) (see Damborenea 2002; Fig. 3u), and also *Gryphaea* sp., undetermined oysters,

Plagiostoma? sp., *Pinna* sp., *Astartidae* gen. et sp. indet., and *Pleuromya* sp.

Ammonoids in the Triassic part of the section are quite rare and so far only part of a whorl and several external moulds have been found. They are referred to *Choristoceras* sp. (Fig. 3b) and *Choristoceras* cf. *marshi* Hauer (Fig. 3a), the latter indicative of the Marshi/Crickmayi Zone, Late Rhaetian. The first record of in situ Hettang-

ian ammonoids is from 80 m higher, where are present the first specimens comparable with material from Chile included by Hillebrandt (2000) in *Psiloceras* cf. *calliphylloides* Pompeckj and *Psiloceras rectocostatum* Hillebrandt, of the Rectocostatum Andean Zone, which is partially equivalent to the Johnstoni and Plicatulum Subzones, Planorbis Zone. Between the levels with *Choristoceras* cf. *marshi* and *P.* cf. *rectocostatum*, no other ammonoids have been found thus far. These levels should be equivalent to the lower part of the Planorbis Zone, i.e. Primocostatum and Tilmanni Zones of the Andean zonation. Significantly enough, loose material from the same levels where *Choristoceras* cf. *marshi* was found, is comparable with *Psiloceras erugatum* Buckman and *P. pressum* Hillebrandt, species indicative of the lower to middle part of the Planorbis Zone (see Bloos & Page 2000; Hillebrandt 2000). On top of the levels with *Psiloceras* cf. *rectocostatum* follows a fossiliferous succession with Early-Late Hettangian and Early Sinemurian ammonites (Riccardi et al. 1988, 1991).

Brachiopods are likewise rare, apparently absent from the key interval spanning the system boundary. Nevertheless, it is worth reporting a significant faunal change from the faunule bearing *Zugmayerella*? cf. *koermerei* Sandy (Riccardi et al. 1997a; Damborenea & Manceñido 1998; Riccardi et al. 2000b; Manceñido 2002; Fig. 3e-g) occurring about 30 m below the level with *Choristoceras* cf. *marshi*, and the next assemblage present circa 215 m above it, characterized by *Furcirhynchia* cf. *trechmanni* MacFarlan, 1992 (Manceñido 1994; Riccardi et al. 2000a-b; Manceñido, 2002; Fig. 3h-i).

Representatives of the spiriferinid genus *Zugmayerella* are widely distributed in Norian-Rhaetian deposits world-wide, and their alleged persistence in Early Jurassic beds is in need of further confirmatory evidence (Riccardi et al. 1997; Carter et al. 1994). The incoming of the rynchonellid genus *Furcirhynchia* in the Hettangian is a remarkable feature in such distant geographical areas as the Alps, New Zealand and the Andes (Manceñido 2000).

Palaeoecology and palaeobiogeography

Two main faunal types may be recognized from a general survey of Late Triassic bivalve faunas from South America. The geographical distribution of these as two "belts" roughly parallel to the palaeoshore, each along a wide latitudinal range, suggests a strong palaeoecological control. The Arroyo Malo bivalve fauna belongs to the "inner belt". It is similar to lower latitude faunas from the following areas of Chile and Perú: Domeyko (Hayami et al. 1977; Chong & Hillebrandt 1985), Junín-Cerro de Pasco (Jaworski 1922; Steinmann 1929; Cox 1949; Boit 1966; Maeda et al. 1983), Huairas (Jaworski 1922) and Acrotambo (Körner 1937). This "inner belt" spans nearly 30° in latitude. On the other hand, this fauna has no element in common with those from equiva-

lent present latitudes at Curepto and Los Molles (Chile) (Fuenzalida-Villegas 1937; Thiele-Cartagena 1967; Cecioni & Westermann 1968), which belong to the "outer belt". Goodwin (1997) analysed a similar case in the Northern Hemisphere: Norian faunas from Sonora (Mexico) are very close to those from Nevada and Oregon (USA) despite latitudinal differences in present day location. He proposed that the situation could be explained either suggesting important terrane displacements or as a consequence of independent response to similar environmental conditions. It is interesting to note that those Northern Hemisphere faunas (described among others by Newton 1986; Newton et al. 1987; Tamura & McRoberts 1993; Stanley et al. 1994; Stanley & González-León 1995; Damborenea & González-León 1998) are also very close to those from the South American "inner belt".

The Triassic bivalve fauna contains both shallow infaunal and epifaunal suspension feeders. *Cassianella* was probably a reclining suspension feeder (Fürsich & Wendt 1977; Laws 1982; Newton et al. 1987); *Liostrea* was a permanently cemented oyster; *Chlamys* and *Otapiria* were epibyssate shells; and *Minetrigonia*, "Astarte", *Palaeocardita*, *Septocardia* and *Tutcheria* were all shallow burrowers (Newton et al. 1987). They indicate a shallow subtidal, well-oxygenated environment of normal salinity.

Though most of the bivalve genera present at Arroyo Malo are cosmopolitan in distribution, at species level the fauna has clear east-Pacific affinities (from Oregon to Chile, references already mentioned), and is very different from contemporary Tethyan faunas (Damborenea 2002b). From the 12 Triassic bivalve species, 6 are comparable to species from Perú and Chile, one is cosmopolitan and the others were not determined at species level. With regard to brachiopods, the material assigned to *Zugmayerella* shows affinities with East Pacific and Maorian faunas, as pointed out by Manceñido (2002).

Magnetostratigraphy

Although magnetostratigraphic studies have been carried out in the Lower Jurassic of the area, the lowest levels studied are above the Triassic-Jurassic transition and well within the Hettangian. Samples from these levels carried a reversed polarity indicating that the beds assigned to the "Psiloceras Zone", and considered equivalent to the boundary between the Planorbis and Liasicus Standard Zones (Iglesia Llanos & Riccardi 2000), are at least equivalent to the uppermost Planorbis Zone and most probably to the Liasicus Zone, as indicated by Hillebrandt (2000), who placed the ammonite fauna in the Bayoensis Zone of the Andean zonation.

New magnetostratigraphic information is expected in the near future, as study of samples coming from levels where the Triassic-Jurassic transition is most probably located is in progress (by M.P. Iglesia Llanos).

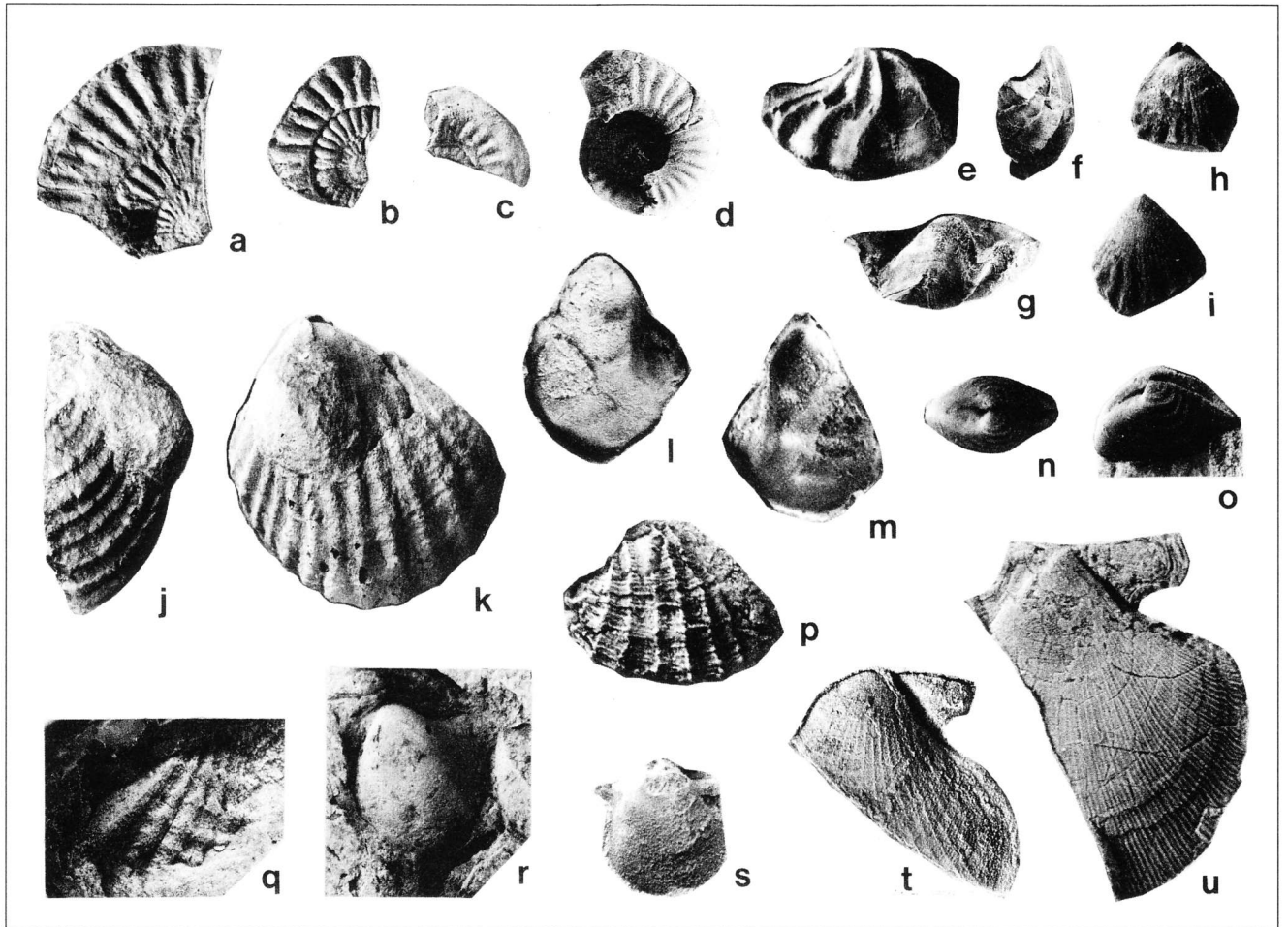


Fig. 3 - a) *Choristoceras* cf. *marshi* Hauer, MLP 28536, x1; b) *Choristoceras* sp., MLP 28537, x1; c) *Psiloceras* cf. *pressum* Hillebrandt, Hettangian, MLP 30823, x1; d) *Psiloceras* cf. *rectocostatum* Hillebrandt, Hettangian, MLP 30824, x1; e-g) *Zugmayerella?* sp. cf. *koernereri* Sandy, Rhaetian, MLP 27763, ventral, lateral and anterior views, x1; h-i) *Furcirhynchia* cf. *trechmanni* Mac Farlan, Hettangian, dorsal and ventral views, MLP 30826, x2; j-k) *Palaeocardita* cf. *peruviana* Cox, Rhaetian, left valve with an epizoic coral, MLP 27770, anterior and lateral views, x1; l-m) *Liostrrea* sp., Rhaetian, MLP 27766, right valve, internal mould and latex cast, x2; n-o) "*Astarte*" cf. *incae* Jaworski, Rhaetian, MLP 27767, latex cast, dorsal and left valve views, x3; p) *Septocardia?* sp., Rhaetian, left valve fragment, MLP 27762, x1.5; q) *Minetrigonia?* *multicostata* (Körner), Rhaetian, latex cast of right valve fragment, MLP 27765, x3; r-s) *Cassianella* cf. *peruana* Körner, Rhaetian, MLP 27766, internal moulds of two left valves, x3; t) *Praechlamys* cf. *valoniensis* (Defrance), Triassic/Jurassic boundary beds, right valve internal mould, MLP 30825, x2; u) *Praechlamys* cf. *valoniensis* (Defrance), Hettangian, right valve internal mould, MLP 25010-b, x2. All figured specimens are housed in the Invertebrate Palaeontology Department collection, La Plata Natural Sciences Museum (MLP).

The Triassic-Jurassic boundary

In the Arroyo Malo section levels with *Choristoceras* cf. *marshi* and *Psiloceras* cf. *rectocostatum* are separated by a c. 80 m thick succession, where thus far no ammonites have been found. As in the Andean zonation (Hillebrandt 2000) the *Psiloceras rectocostatum* Zone overlies the Primocostatum and Tilmanni Zones and these two zones are equivalent to the lowermost Jurassic, it is thus possible that most of the intervening unfossiliferous strata may belong in the Primocostatum and Tilmanni Zones as attested by loose fragments of *P.* cf. *pressum*, a species of the Primocostatum Zone. If this assumption is correct the Triassic-Jurassic boundary should be close to the levels where the *Choristoceras* specimens were found. It is expected that new fieldwork could yield evidence in support of this assumption.

Conclusions

The Arroyo Malo section is a new addition to the few marine sections depicting the Triassic-Jurassic boundary.

The boundary is located in an apparent lithologically continuous succession, where no evident hiatus exists. The record of ammonites appears to be rather poor, but the section is very well exposed and offers good prospects for finding more fossil material, especially within levels that probably represent the lowermost Hettangian. Further biostratigraphic studies are planned, both for macro and microfauna.

This research project, in progress, also includes a detailed sedimentological study by S. Lanés, which is near completion. A stable isotope study is also planned.

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Appendix

List of Late Triassic fossils from arroyo El Alumbre, Atuel river region, southern Mendoza.

Cephalopoda

Nautiloidea indet.

Choristoceras cf. *marshi* Hauer, 1865 (Fig. 3.a) (also figured in Riccardi and Iglesia Llanos 1999, p. 298-299, fig. 2a)

Choristoceras sp. (Fig. 3.b) (also figured in Riccardi and Iglesia Llanos 1999, fig. 2b)

Bivalvia

Cassianella cf. *peruana* Körner 1937 (Fig. 3r-s) (also figured in Riccardi et al. 1997a, fig. 3.4)

Otapiria? sp. (figured in Riccardi et al. 1997a, fig. 3.1)

Praeclamys cf. *valoniensis* (Defrance in Caumont, 1825) (Fig. 3t)

Limidae gen. et sp. indet.

Liostrea sp. (Fig. 3l-m)

Minetrigonia? *multicostata* (Körner, 1937) (Fig. 3q) (also figured in Riccardi et al., 1997a, fig. 3.5)

Astarte cf. *incae* Jaworski 1922 (Fig. 3n-o) (also figured in Riccardi et al. 1997a, fig. 3.7a-b).

Palaeocardita cf. *peruviana* Cox, 1949 (Fig. 3j-k) (also figured in Riccardi et al. 1997a, fig. 3.2a-b)

Tutcheria aff. *densestriata* (Körner, 1937)

Septocardia *peruviana*? (Cox, 1949) (also figured in Riccardi et al. 1997a, fig. 3.6)

Septocardia? sp. (Fig. 3p)

Bivalvia gen. et sp. indet. 1

Bivalvia gen. et sp. indet. 2

Gastropoda

cf. *Guidonia* ? sp.

Omphaloptycha cf. *jaworskii* Haas, 1953

Gastropoda gen. et sp. indet.

Brachiopoda

Zugmayerella? sp. cf. *koernerii* Sandy 1994 (Fig. 3e-g) (figured in Riccardi et al. 1997a, fig. 3.3a-c; Manceñido 2002, fig. 6.1b-d)

Foraminiferida (Ballent, 1994)

Haplobragmoides-like

Nodosariids

Ostracoda (Ballent, 1994)

Ogmoconchella sp.

Cytheraceans

Plants (Stipanovic in Riccardi et al. 1997a)

?*Zuberia* cf. *zuberi* (Szajnocha, 1889) Frenguelli, 1943 (figured in Riccardi et al. 1997a, fig. 3.8)

Clathropteris sp.