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The ichnogenus *Lapispira* from the Early Jurassic of Patagonia (Chubut, Argentina)

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Abstract
The ichnogenus *Lapispira* LANGE (originally recognized in the Hettangian of Germany) attained a wide geographic distribution, occurring mainly in Jurassic sediments. The ichnotaxon was recently re-described from Sinemurian-Pliensbachian deposits in southern Mendoza Province (Argentina), and is here newly reported from slightly younger (latest Pliensbachian) deposits of the Mulanguiñeu Formation of Chubut Province. According to recent revisions, the ichnogenus appears to have been mainly environmentally restricted to the shoreface and offshore-shoreface transition zone, being only exceptionally found in offshore tempestites. In Chubut *Lapispira bispiralis* LANGE is accompanied by an abundant euhaline fauna dominated by bivalves, several gastropods and rare ammonoids, and, similarly to what happens in the Neuquén Basin, it is commonly associated to *Rhizocorallium* isp.

Keywords
Lapispira, Early Jurassic, Patagonia, Chubut Province, Argentina.

Resumen
El ichnogénero *Lapispira* en el Jurásico temprano de Patagonia (Chubut, Argentina).- El icnogénero *Lapispira* LANGE, originalmente reconocido en el Hettangiano de Alemania, alcanzó una distribución geográfica muy amplia, mayormente en sedimentos jurásicos. Este icnotaxón fue recientemente redescripto en depósitos sinemuriano-pliensbachianos del sur de la Provincia de Mendoza (Argentina), y en este trabajo se registra en sedimentos algo más jóvenes (Pliensbachiano tardío) de la Formación Mulanguiñeu de la Provincia del Chubut. De acuerdo con revisiones recientes, el icnogénero parece haber estado principalmente restringido a ambientes de *shoreface* y la zona de transición *shoreface-offshore*, encontrándose sólo excepcionalmente en tempestitas de off-shore. En Chubut *Lapispira bispiralis* LANGE está asociada a una abundante fauna euhalina dominada por bivalvos, algunos gastrópodos y raros ammonoideos y, en forma similar a lo que sucede en Neuquén, está acompañado por *Rhizocorallium* isp.

Palabras clave
Lapispira, Jurásico temprano, Patagonia, Provincia del Chubut, Argentina.

INTRODUCTION

The peculiar ichnogenus *Lapispira* was first described by LANGE (1932) based on material from the Early Jurassic of northern Germany. This taxon remained poorly known and seldom recorded (HÄNTZSCHEL, 1962, 1975), but as a result of additional findings in Mendoza Province, Argentina (DAMBORENEA & MANCEÑIDO, 1994; LANÉS *et al*., 2004; LANÉS, 2005), the well-preserved and abundant material occurring in Sinemurian to Pliensbachian deposits at the Atuel valley, on the northern rim of the Neuquén Basin, allowed a detailed redescription to be made recently (LANÉS *et al*., 2008). Other records around the world were also mentioned in that paper, showing that the ichnogenus had a wider stratigraphic and geographic range than previously acknowledged. In south-western Mendoza it occurs in storm- and fair-weather sandstones deposited in the shoreface and offshore-shoreface transition zone (where it attains the largest sizes), only exceptionally appears also in very fine silty sandstones (offshore tempestites), thus its palaeoenvironmental significance and potential was also stressed.

The purpose of this brief paper is to report the new finding of the ichnogenus *Lapispira* in Early Jurassic deposits of Patagonia (i.e. over 1,000 km further south), and to discuss its palaeogeographic and palaeoenvironmental meaning. The new records of *Lapispira* are from west-central Chubut Province at Betancourt hills in the Río Genoa valley (Fig. 1a).

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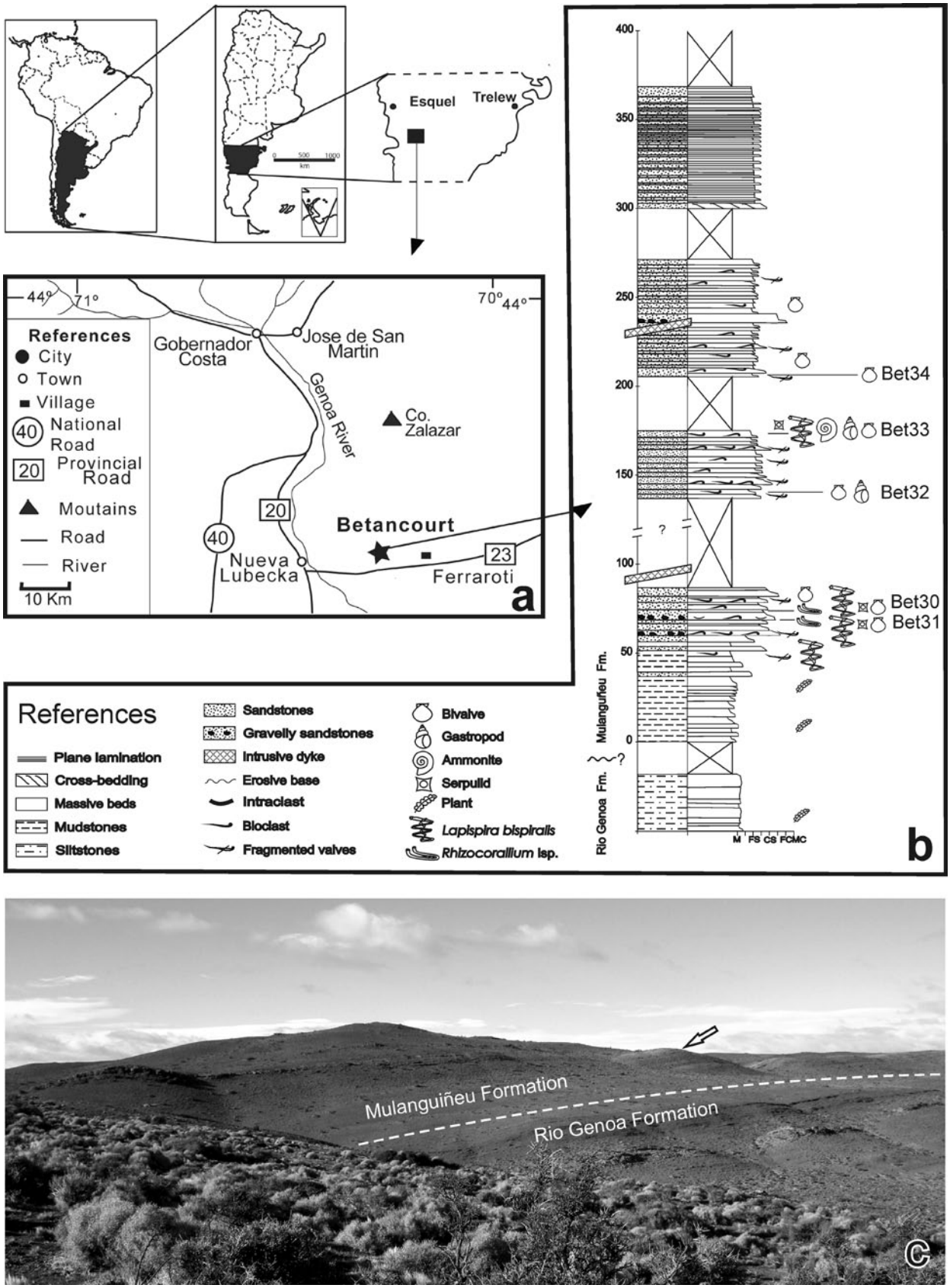


Fig. 1: **a,** Location map showing fossiliferous locality in Chubut Province, Argentina. **b,** Stratigraphic section at Betancourt locality showing the *Lapispira*-bearing beds. **c,** Lomas de Betancourt outcrops viewed from the north; dashed-line: pseudoconformity between the Early Permian Rio Genoa Fm. and the Early Jurassic Mulanguiñeu Fm.; arrow: lowermost levels with *Lapispira bispiralis* LANGE.

Geological setting

The marine Early Jurassic strata of west-central Patagonia are exposed along a north-northwest to south-southeast belt, and they unconformably overlie Late Palaeozoic marine deposits. The main outcrops are located in the Tecka and Tepuel hills in northwestern Chubut and near the Rio Genoa valley; other important fossiliferous sections are exposed in Pampa de Agnia region at Cerro Negro hill in central Chubut. The stratigraphic succession and nomenclature of the Early Jurassic sediments in the region have been referred to and discussed in several studies. The first references about Early Jurassic sediments in Chubut were made by KEIDEL (1917) and PIATNITZKY (1933). Afterwards, the sequence was described by PIATNITZKY (1936), FERUGLIO (1949) and SUERO (1952, 1953, 1958) among others (see RICCARDI & DAMBORENEA, 1993). The outcrops are widespread but rather poorly exposed and show frequent and sudden lateral facial changes which involve volcaniclastic and clastic sediments. This has considerably compounded the lithostratigraphic nomenclature, and has led to different geological interpretations about their history and relationships.

In the Río Genoa valley - Cerro Ferrarotti region (Fig. 1a) the Early Jurassic marine sediments are called Mulanguiñeu Formation (FERNÁNDEZ GARRASINO, 1977), and they overlie the Río Genoa Formation (Permian). The Mulanguiñeu Formation was earlier called "Serie con *Vola* y *Cardinia*" by SUERO (1952, 1958). According to CORTIÑAS (1984) the lower part of this unit is characterized by coarse-grained sandstones, with interbedded mudstones and scarce conglomerates; and the upper part, by mudstones, medium- to fine-grained sandstones and tuffs. He reported that marine invertebrate fossils occur in two main facies: sandstones/dark siltstones (with thick-shelled molluscs, brachiopods and corals, described by FERUGLIO, 1934 and WAHNISH, 1942), and tuffs (with abundant bivalves mostly undescribed, leaf remains and bioturbation traces), which were both interpreted as deposited in littoral to neritic environments. The Mulanguiñeu Formation exhibits important east-west lateral lithofacies changes, and so the successions exposed at different localities may vary considerably. Yet, the previous literature does not reveal any thorough microfacies analysis or detailed sedimentological palaeoenvironmental interpretation based upon the Early Jurassic sediments from the Genoa-Ferrarotti area, other than such broad references to a range of littoral to neritic marine settings.

The invertebrate faunas also show remarkable lateral changes in composition: the thick-shelled bivalves and gastropods accompanied by brachiopods and colonial corals are recorded near the base of the unit both at Nueva Lubecka and Cerro La Trampa localities to the west, and at Ferrarotti to the east, but seem to be absent in intermediate localities, such as Betancourt and Aguada Loca.

At Betancourt, the base of this unit and the contact with the underlying dark shales of the top of the Rio Genoa Formation are not clearly seen (Fig. 1c). The top of the Early Jurassic section is not exposed either, but the Mulanguiñeu Formation is more than 350 m thick at this locality. Several intrusive porphyritic dykes are locally present and complicate the logging of a continuous succession. At Betancourt the basal conglomerate and the *Cardinia* and *Weyla*-bearing facies are absent, and the section begins with about 50 m of unfossiliferous coarse-grained tuffaceous sandstones and gravelly sandstones, overlain by a thick succession (about 240 m) of fossiliferous, thin-bedded, very fine-grained tuffaceous sandstones and mudstones, occasionally interbedded with thin conglomerates, especially in the lower part of this interval (Fig. 1b). The section continues upwards with about 50 m of unfossiliferous, thick beds of cross-bedded, medium-grained, quartzites, alternating with fine-grained sandstones and mudstones, and it culminates with about 20 m of thin, planar laminated, sandstones.

MATERIAL AND DESCRIPTION

The material from Chubut is referable to *Lapispira bispiralis* LANGE, 1932, the type ichnospecies of the ichnogenus *Lapispira*, originally described from the Early Jurassic (Hettangian) of Germany.

At Betancourt *Lapispira bispiralis* was found in at least three intervals between 50 and 170 m from the base of the measured section (levels Bet31, Bet30 and Bet33), associated to a locally abundant but not diverse invertebrate fauna (see below). Most observations were made on the outcrops, but one collected specimen (MPEF-IC 540) is housed at the ichnological collection of the Museo Paleontológico Egidio Feruglio in Trelew, Chubut Province, Argentina.

Description and comparisons: The present material (Figs. 2a-e, g) consists of double helicoidal, concentrically arranged burrows, with coiling axes perpendicular to the bedding plane. Neither branches/bifurcations nor *spreite* were observed, and longitudinal sections are not clearly preserved. The tunnels are filled by fine-grained sandstone similar to the host sediments, but usually finer. The sediment infill shows that the scratches on the walls are roughly parallel to the tunnel longitudinal axis (Fig. 2g). It is interesting to note that the same scratch pattern is present in the *Rhizocorallium* isp. observed in the same beds (Fig. 2h), strongly suggesting that they were both built by similar shrimp-like crustaceans (cf. SEILACHER, 2007, p. 50-51).

Lapispira specimens from Chubut are strictly comparable to those from the Sinemurian-Pliensbachian beds of Mendoza, Argentina, described by LANÉS *et al.* (2008, figs. 5, 6, 7, 10, 11). They also agree with the Hettangian types from Germany (LANGE, 1932, pl. 16, figs. 1-2, pl. 17, figs. 3-6), and with Sinemurian material from Nevada, USA (LANÉS *et al*., 2008, figs. 13A-C).

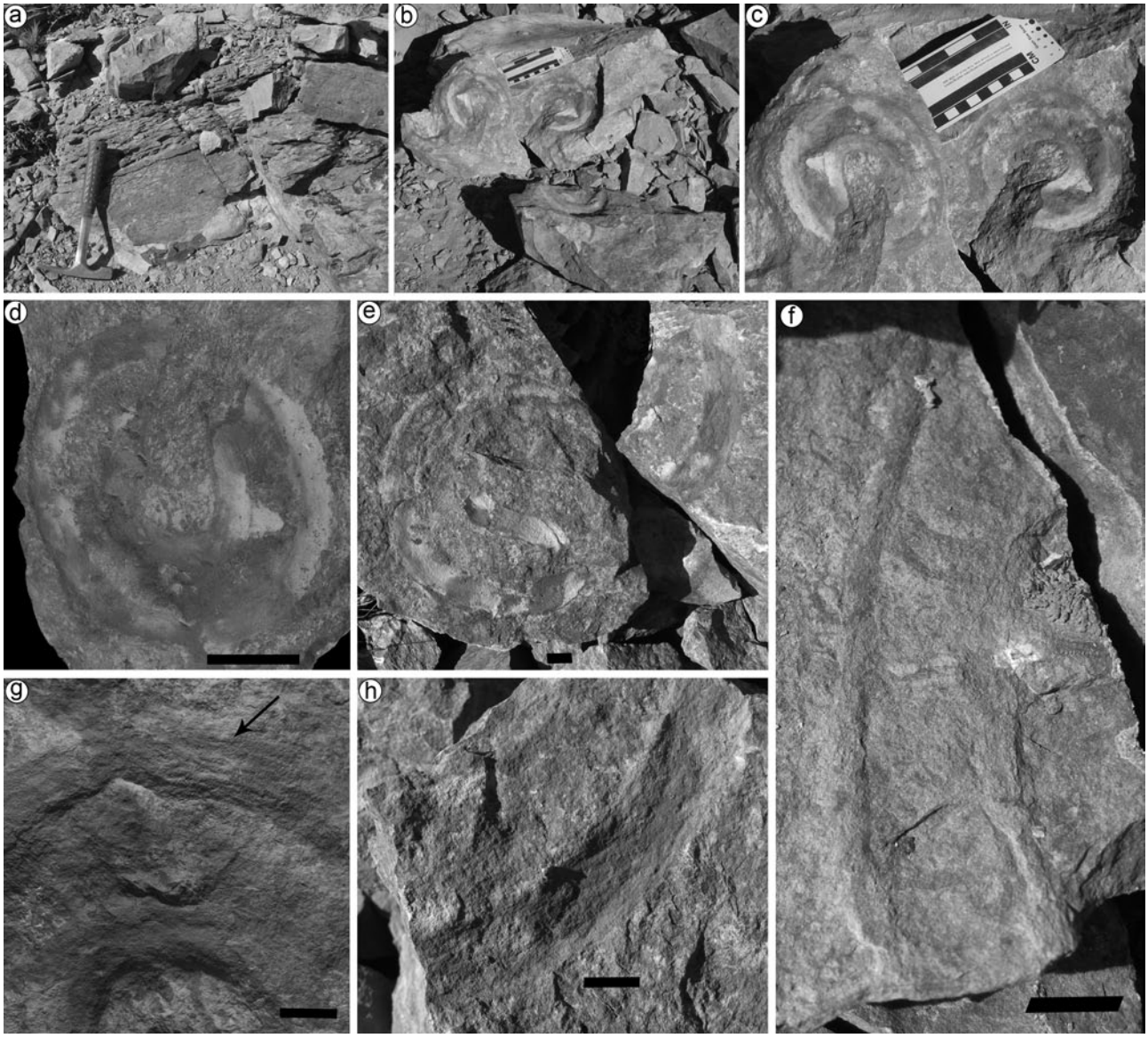


Fig. 2: **a,** General features of *Lapispira*-bearing bed. **a,** outcrop view. **b, c, e,** field photographs with close-up of specimens of *Lapispira bispiralis* LANGE. **d, g**, specimen MPEF-IC 540; **d,** top view, showing the two concentric rings; **g,** close view of scratch bioglyphs (arrowed). **f, h,** specimens of *Rhizocorallium* isp. associated with *Lapispira*, field photographs; notice in h the scratch bioglyphs similar to those on figure g. Figure a: geological hammer = 35 cm, Figures d-f, scale bars = 1 cm.

Dimensions: Measurements were taken following LANÉS *et al.* (2008, fig. 8). In general the specimens of Chubut are larger than those from Mendoza, hence fitting better with LANGE's original material from Germany (cf. LANÉS *et al*., 2008, fig. 9). The collected specimen has an external coil diameter of 125 mm, its internal coil diameter is 64 mm long, and the tunnel is 15.3 mm wide (Fig. 2d).

Density and associated trace fossils and body fossils: The field observations indicate that in this locality of the Jurassic Patagonian basin, the specimen density is lower than in the Neuquén Basin. In the Betancourt section *Lapispira bispiralis* was recorded in at least three of many fossiliferous levels (see Fig. 1b), but the highest density was observed at the lower levels (Bet31). In spite of such relative differences in trace density between the basins, *Lapispira* from Chubut is associated to *Rhizocorallium* isp. as in Mendoza (see LANÉS *et al.,* 2008). Other accompanying ichnofossils are referable to *Entobia* bioeroding into mollusc shells.

Lapispira bispiralis is associated to an abundant euhaline marine fauna dominated by bivalves, several gastropods, calcareous tubeworms and rare ammonoids (Figs 3-4). Bivalves include *Pholadomya* sp. (Figs. 3d-f), *Kolymonectes weaveri* DAMBORENEA (Figs.

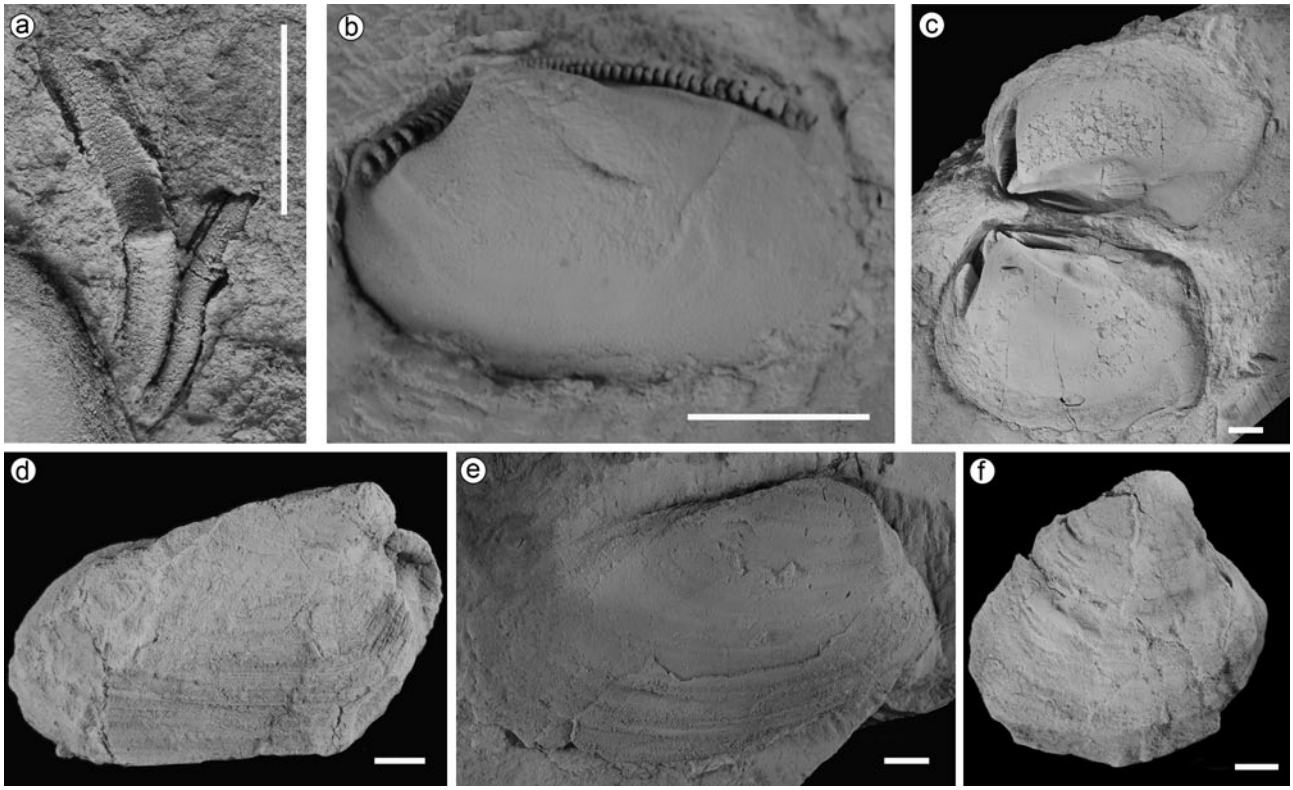


Fig. 3: Associated body fossils. **a,** Calcareous tubeworm, MPEF-IC 931. **b,** *Palaeoneilo*? sp., MPEF-PI 2939, internal mould. **c,** *Frenguelliella* sp., MPEF-PI 2940a, internal mould in butterfly position. **d-f,** *Pholadomya* sp.; **d,** MPEF-PI 2864f; **e,** MPEF-PI 4330; **f,** MPEF-PI 3137d. Scale bars = 5 mm.

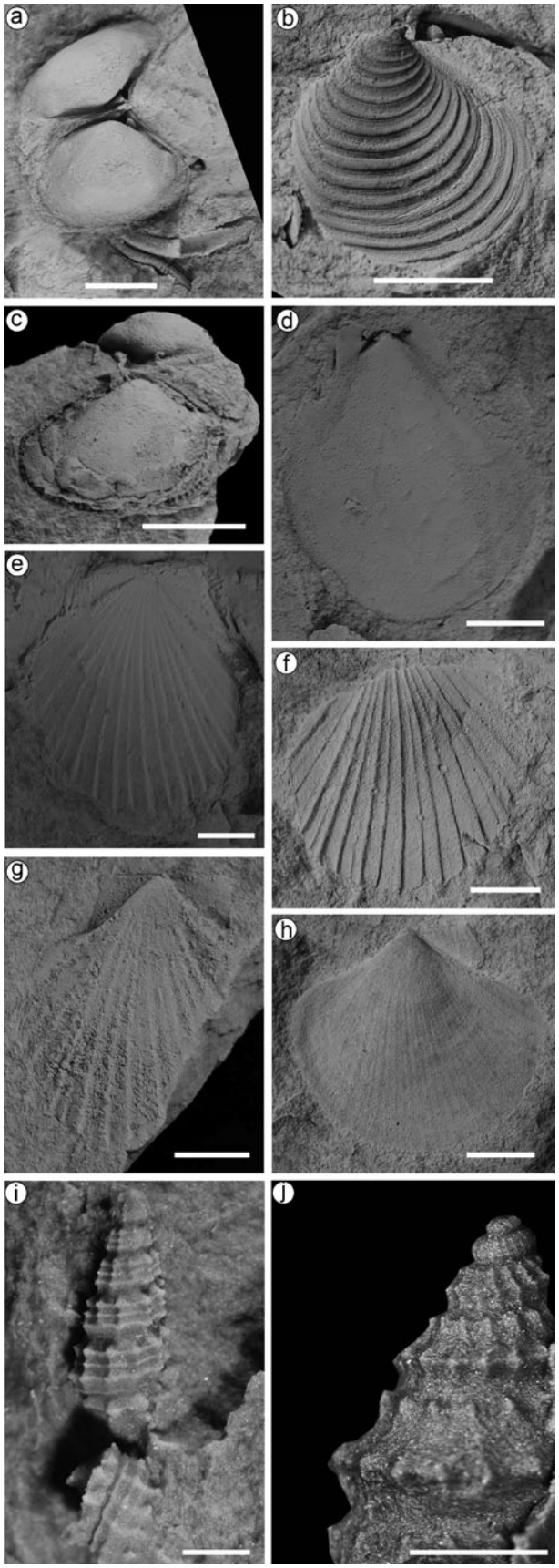
4e-h), *Entolium mapuche* DAMBORENEA (Fig. 4d), *Frenguelliella* sp. (Fig. 3c), *Gervillaria pallas* (LEANZA), *Palaeoneilo*? sp. (Fig. 3b) and frequent *Notoastarte*? sp. (Figs. 4a-c). Gastropods include *Cryptaulax damboreneae* FERRARI (Fig. 4i), *Procerithium nulloi* (FERRARI), *Pseudomelania feruglioi* FERRARI, *Calliotropis* sp. (Fig. 4j) and *Lewisiella?* sp. Ammonoids are represented by a few specimens, and *Canavaria* cf. *naxensis* (GEMM.) indicates a latest Pliensbachian age for these beds (*F. disciforme* Zone, see local zonation in RICCARDI, 2008a, b).

The distribution of this fauna is not equivalent in the three main levels where *Lapispira* is recorded. In Bet31, where *Lapispira* is more abundant, the dominant bivalve is *Pholadomya* sp., a deep infaunal form which is absent in other levels, whereas only one gastropod species is recorded (*Pseudomelania feruglioi* FERRARI) and epifaunal bivalves are represented by large *Gervillaria pallas* and *Entolium mapuche*. On the other hand, epifaunal bivalves, such as *Entolium* or *Gervillaria*, are absent in Bet33, but small gastropods are frequent instead, together with abundant shallow infaunal bivalves such as *Frenguelliella* sp., astartids and palaeotaxodonts. Tubeworms (Fig. 3a) are also common in *Lapispira*-bearing horizons. The lack of preserved epifauna together with the abundance of deep infaunal bivalves may reflect erosion by storm waves (capable of eroding the bed tops away, thus leaving only the deeper tiers, relative to fair-weather conditions), which is consistent with a shoreface setting and a significant degree of deposit amalgamation.

DISCUSSION

This ichnogenus has been regarded by LANÉS *et al*. (2008) as an elite trace fossil in the meaning of BROMLEY (1990). They also discussed possible interpretations of functional and behavioural nature; among the latter two alternative fabricational models were contrasted (LANÉS *et al*., 2008, figs. 12A and B): with and without construction of *spreite*, respectively. The material from Chubut described here does not shed any new light on this question as it lacks any evidence of *spreite*.

Since that redescription, *Lapispira* has been briefly considered in contributions of wider scope. SEILACHER (2007, p. 58, pl. 20) included it as a modification of the basic rhizocoralliid program, avowedly assuming the presence of *spreite* (i.e. reaffirming his earlier opinion, 1986, fig. 3-7h). In summarizing the taxonomy of helical trace-fossils, UCHMAN (2010) mentioned *Lapispira* among the vertical forms from the marine realm. BUATOIS & MÁNGANO (2011, p. 278) listed it among



several examples of ichnogenera reflecting colonization of shallow marine environments in the Mesozoic with the advent of members of the modern evolutionary fauna (*sensu* SEPKOSKI, 1981), such as malacostracan crustaceans.

Following GIBERT (2003), PAZOS (2009, p. 366) interpreted *Lapispira* as a Lazarus ichnotaxon. Even if applying such evolutionary concept (originally defined for body fossils) to ichnotaxa is deemed appropriate, it should be recalled that, strictly speaking, only GIBERT's diagram on the left of his fig. 3A (2003) would reflect a Lazarus taxon (*sensu* JABLONSKI, 1986), whereas the one on the right would rather represent an Elvis taxon (*sensu* ERWIN & DROSER, 1993). Therefore, it seems premature to risk such an interpretation for *Lapispira* on the basis of that evidence alone, since the possibility that similarity with extant forms may be homoplasious is indeed high (see below), qualifying them as an Elvis ichnotaxon is at least equally, if not more, likely.

Interesting results have emerged from studies of modern bioturbation on sea bottom sediments, box-cored and subjected to X-radiography analysis. In the South China Sea, on the western slope of the Philippines and east of Manila Trench, WETZEL (2008, table 1, figs. 3, 6B-C) documented spiral burrows in plant-debris-bearing brown mud of hyperpycnal origin resulting from strong monsoonal precipitation; they were interpreted as benthic recolonization after the 1991 Pinatubo ash fall, and were called cf. *Lapispira.* In the Eel Shelf area, off the mouth of Humboldt Bay, California, JACKSON (2011, table 2, figs. 11, 12, 13A-D) also recognized burrows with similar helical paths in siliciclastic mud disturbed by a major storm flood event (1995); such traces were referred to a new unnamed ichnospecies of *Lapispira*, frequently forming part of the fair-weather as well as the recovery suites and attributed to the activity of polychaete worms. In that connection, it should be noted that WETZEL prudently applied open nomenclature, deliberately placing "cf." in front of the ichnogenus name, whereas in JACKSON's Masters Thesis (2011) no qualifier is used. We can readily agree, that both such occurrences in present-day deposits probably represent the same ichnotaxon

Fig. 4: Associated body fossils. **a-c,** *Notoastarte*? sp.; **a,** MPEF-PI 2847, internal mould in butterfly position; **b,** MPEF-PI 3136, external mould; **c,** MPEF-PI 3168d, internal mould. **d,** ***Entolium mapuche*** DAMBORENEA, MPEF-PI 2946, internal mould. **e-h,** *Kolymonectes weaveri* DAMBORENEA; **e-f,** MPEF-PI 2956a-b, composite and external mould, left valves; **g,** MPEF-PI 2944a, left valve; **h,** MPEF-PI 2958, composite mould of right valve. **i**, *Cryptaulax damboreneae* FERRARI, MPEF-PI 4013. **j,** *Calliotropis* sp., MPEF-PI 4057. Scale bars: a-h = 5 mm; i-j = 2 mm.

(though not necessarily at ichnospecific level), yet, we are by no means convinced that they actually belong to *Lapispira*. They exhibit substantial differences in possessing a straight central shaft, lacking of any scratch bioglyphs, apart from having much smaller tunnel width (barely 1-2 mm) and overall burrow dimensions (external coil diameter less than 10 mm, spiral length less than 100 mm), thus implying a markedly different tracemaker in terms of animal group, penetration style, behavioural pattern, and even ecological requirements. We believe they should be better accommodated into another (new?) ichnogenus. Shoehorning those modern burrows into *Lapispira* requires a significant departure from the current diagnosis of the ichnogenus (and from LANGE´s original definition, for that matter). Even if so regarded, they would represent a unique subordinate ichnotaxon with singular constructional and tiering features, which would not undermine the (palaeo)environmental significance of *Lapispira bispiralis* (as discussed by LANÉS *et al*., 2008). On the other hand, certain European Miocene occurrences further reported (Austria: RUPP, 2008; Balearic Is.: GIBERT *et al*., 2011) appear more likely compatible with our results.

Concluding remarks

Concerning the palaeoenvironmental significance of *Lapispira,* on the northern rim of the Neuquén Basin it appears restricted to the shoreface and offshore-shoreface transition zone. It is abundant in storm- as well as in fair-weather sandstones (where it attains largest sizes), and occasionally occurs in very fine silty sandstones (offshore tempestites). All worldwide occurrences known so far clearly indicate that the forms strictly referable to this ichnogenus had a strong facies fidelity, which may constrain local occurrences to certain localities and particular levels in a sedimentary succession.

As a result of this study, within the overall marine littoral environment previously recognized in the Early Jurassic deposits from the Genoa-Ferrarotti area, the presence of *Lapispira* suggests a probable shoreface or offshore-shoreface transition zone for at least part of the Betancourt section, and extends its range in Argentina to more than 1,000 km further south and to somewhat younger (latest Pliensbachian) deposits.

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