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ABSTRACT—A new upper Bajocian ammonite assemblage containing the morphoceratids *Dimorphinites dimorphus* (d'Orbigny) and *Vigoriceras defrancei* (d'Orbigny) is reported from the circum-Pacific area. These ammonites were found at the top of the Torcazas Formation, in the Quebrada San Pedro area, Precordillera of northern Chile. Taphonomic, systematic, and paleobiogeographic data confirm these dimorphs were part of indigenous populations within the Tarapaca Basin, belonging to the same demic biospecies: *Dimorphinites defrancei* (d'Orbigny). The West Tethyan and East-Pacific distribution of *D. defrancei* corroborates the availability of the migratory seaway, the so-called Hispanic Corridor, between the western Tethys and the eastern Pacific Ocean during the upper Bajocian Parkinsoni Zone. The discovery of this upper Bajocian *Dimorphinites* assemblage provides a new biochronostratigraphic horizon in the Tarapaca Basin and an interoceanic correlation point for the latest Bajocian.

INTRODUCTION

SEVERAL AMMONITE assemblages containing morphoceratids have been discovered in the Quebrada San Pedro area, northern Chile, Region de Antofagasta, Comuna Sierra Gorda, approximately 40 km ESE of Sierra Gorda town and 75 km south of Calama city (Fig. 1). These assemblages were collected from three localities (12P, 13P and 14P) along an isolated outcrop that is exposed for 600 m. The outcrop is located 1 km north of the composite section described as Quebrada San Pedro and 10 km south of the classic localities of the Caracoles Mining District previously studied by numerous authors (Gottsche, 1878; Steinmann, 1881; Möricke, 1894; Westermann, 1967, 1981; Hillebrandt, 1970, 1973, 1977, 2001; Westermann and Riccardi, 1979, 1980; Jensen and Quinzio, 1979, 1981; Gröschke and Hillebrandt, 1985, 1994; Hillebrandt et al., 1986; Gröschke et al., 1988; Riccardi et al., 1990a, 1990b; Riccardi and Westermann, 1991a,1991b; Fernandez-Lopez et al., 1994; Fernandez-Lopez and Chong Diaz, 2010)

This paper provides a systematic description of the morphoceratids from Quebrada San Pedro (Antofagasta, Chile), which includes two available European morphospecies *Dimorphinites dimorphus* (d'Orbigny, 1846) [M=macroconch] and *Vigoriceras defrancei* (d'Orbigny, 1845) [m=microconch], now regarded as dimorphs of *Dimorphinites defrancei* (d'Orbigny, 1845) [M + m] new combination. The specimens found in Chile provide important taphonomic, systematic, paleobiogeographic and biochronological information, and they have important paleogeographic and geochronologic implications.

GEOLOGICAL SETTING

The localities yielding the morphoceratids described in this paper occur in Jurassic strata that extend along the western edge of the Domeyko Range (S 23°30′–27°, Fig. 1). These deposits were originally part of the marine, back-arc Tarapaca Basin (S 12°–29°; Mordojovich, 1981; Westermann and Riccardi, 1985; Mpodozis and Ramos, 1989; Carlotto et al., 2005; Vicente, 2005, 2006; Parent, 2006) or Domeyko Basin (Flint et al., 1993; Ardill et al., 1998; Hillebrandt et al., 2000).

In the Caracoles and Quebrada San Pedro areas, a succession of Jurassic, fossiliferous deposits belonging to the Caracoles Group unconformably overlies Triassic volcanic and metamorphic rocks (Harrington, 1961; Garcia, 1967; Montaño, 1976; Ardill et al., 1998; Marinovic and Garcia, 1999). The lowest marine deposits of this group are brown, calcareous sandstones and fine-grained conglomerates belonging to the Coronado Formation (Fig. 2). This unit is overlain by shallow-marine, yellow and brown shales with intercalations of limestones and calcareous sandstones of the Torcazas Formation. These are in turn overlain by offshore, yellow and green shales with intercalations of limestones of the Mina Chica Formation. The Coronado, Torcazas and Mina Chica formations span the Bajocian through the Bathonian and display maximum thicknesses of 40, 100 and 75 m, respectively.

Lithostratigraphically, the new morphoceratid assemblages were collected from the top of the Torcazas Formation, below the Mina Chica Formation, in Quebrada San Pedro area. The sequence of the Torcazas Formation at this location consists of 10–15 m of gray and yellow silty limestones, wackestones to packstones and marls that are very fossiliferous in the upper part and are the source of several successive ammonite assemblages. The limestone beds vary in thickness from 15 to 40 cm, and they extend laterally several tens of meters. Most of the beds contain abundant resedimented and silicified macrofossils and display sharp and irregular bases, as well as normal grading of bioclasts, suggesting that carbonate inputs were affected by traction currents and scouring. The most abundant macrofossils are costate brachiopods, bivalves, ammonites, belemnites and gastropods. Isolated and fragmentary bones of decimetric or centimetric size are locally common. The most abundant ammonites are *Megasphaeroceras* Imlay, 1961 [M + m] spp.

At the uppermost beds of the Torcazas Formation, in this outcrop, Stephanoceratidae, Perisphinctidae and Oppeliidae are scarce, but *Cadomites* Munier-Chalmas, 1892 [M]-*Polyplectites* Mascke, 1907 [m], *Vermisphinctes* Buckman, 1920 [m]-*Prorsisphinctes* Buckman, 1921 [M] and *Oxycerites* Rollier, 1909 [M]-*Paroecotraustes* Spath, 1928 [m] are well represented. Morphoceratidae, Lissoceratidae and Strigoceratidae are very scarce, respectively represented by *Dimorphinites* Buckman, 1923 [M]-*Vigoriceras* Rioult, 1994 [m], *Lissoceras* Bayle, 1879 [M]-*Microlissoceras* Sturani, 1971 [m]

FIGURE *1*—Geographic location of the Caracoles and Quebrada San Pedro Bajocian and Bathonian marine deposits.

and *Strigoceras* Quenstedt, 1886 [M]. Besides Ammonitina, Phylloceratina and Lytoceratina are extremely scarce. Among the morphoceratids of this stratigraphic interval, macroconchs of *Dimorphinites dimorphus* (d'Orbigny) and microconchs of *Vigoriceras defrancei* (d'Orbigny) have been identified and are described below.

TAPHONOMIC ANALYSIS OF THE MORPHOCERATID AMMONITES

The morphoceratids described and figured in this paper (Figs. 3–5) were collected by one of the authors (F.-L.) from the uppermost limestone beds of the Torcazas Formation during several field seasons, between 2006 and 2010.

The total number of morphoceratids found is nine (five macroconchs and four microconchs). Most of these specimens are preserved as calcareous internal molds of unflattened ammonites. They are filled with relatively homogeneous mudstones to wackestones in the outer preserved whorls, whereas the inner whorls are partially filled with macrocrystalline calcite. They are resedimented elements (displaced on the sea-bottom before their burial), showing structural continuity between the sedimentary infill and the enclosing sedimentary rock, without evidence of reelaboration (exhumation and displacement on the sea-bottom before their final burial; cf. Fernandez-Lopez, 2007). Fragmentary shells, lacking peristomal borders, are dominant, generally without traces of rounding, encrustation, or bioerosion. Shells bearing signs of intrathalamous encrusting by organisms (cf. Tintant, 1984), such as serpulids, bryozoans, oysters and crinoids, are absent. Body chambers without apical sedimentary infilling, internal molds with a local infill channel on the ventral region, or siliciclastic pseudomorphosis of the shells are absent, too. Phragmocones with incomplete sedimentary infilling (i.e., hollow ammonites) and calcitic internal molds of phragmocones with recrystallized septa represent the dominant mode of preservation. No signs of biostratinomic or synsedimentary dissolution of the aragonitic remains have been recognized. Aragonitic shells were dissolved during later diagenesis. Empty ammonite camera, with incomplete sedimentary infilling and moldic porosity resulting from the dissolution of walls and septa were partially filled by spar cement giving rise to calcitic pseudomorphs of shells during late diagenesis.

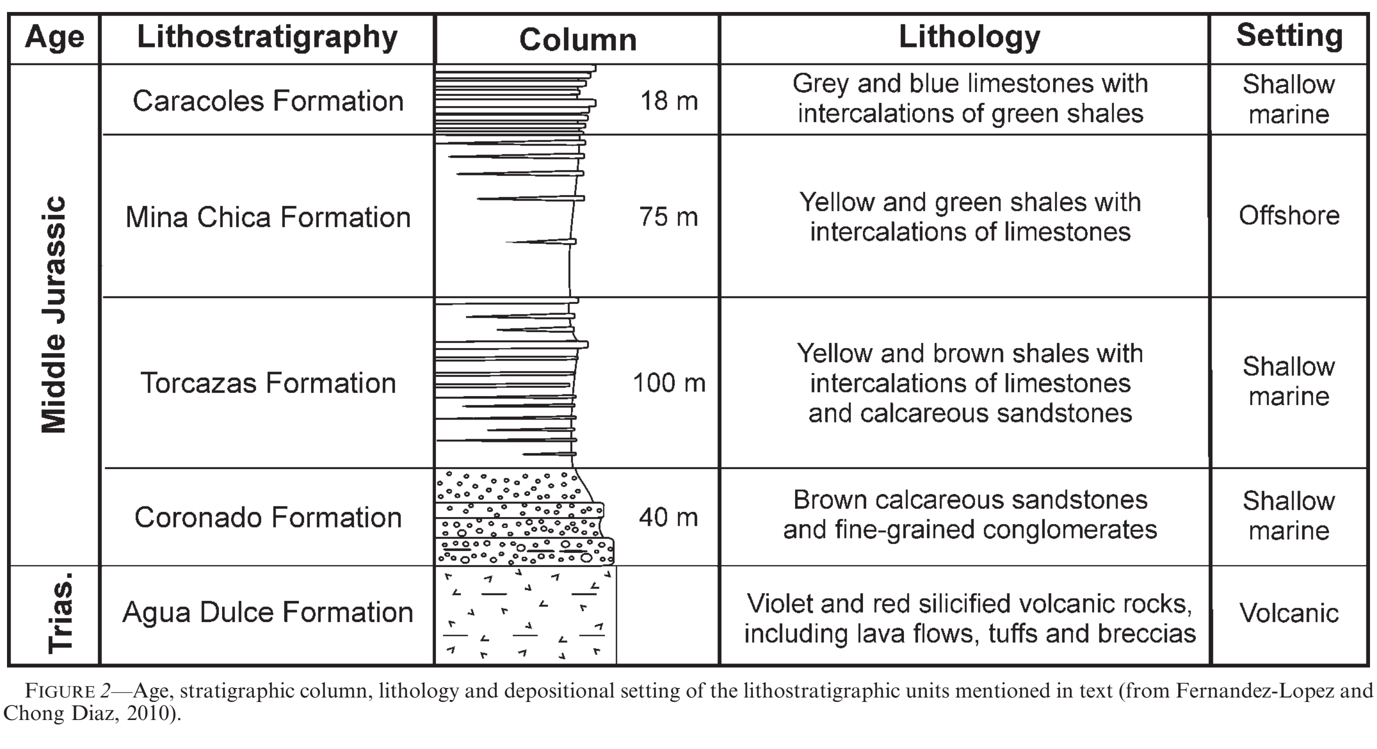

FIGURE *2*—Age, stratigraphic column, lithology and depositional setting of the lithostratigraphic units mentioned in text (from Fernandez-Lopez and Chong Diaz, 2010).

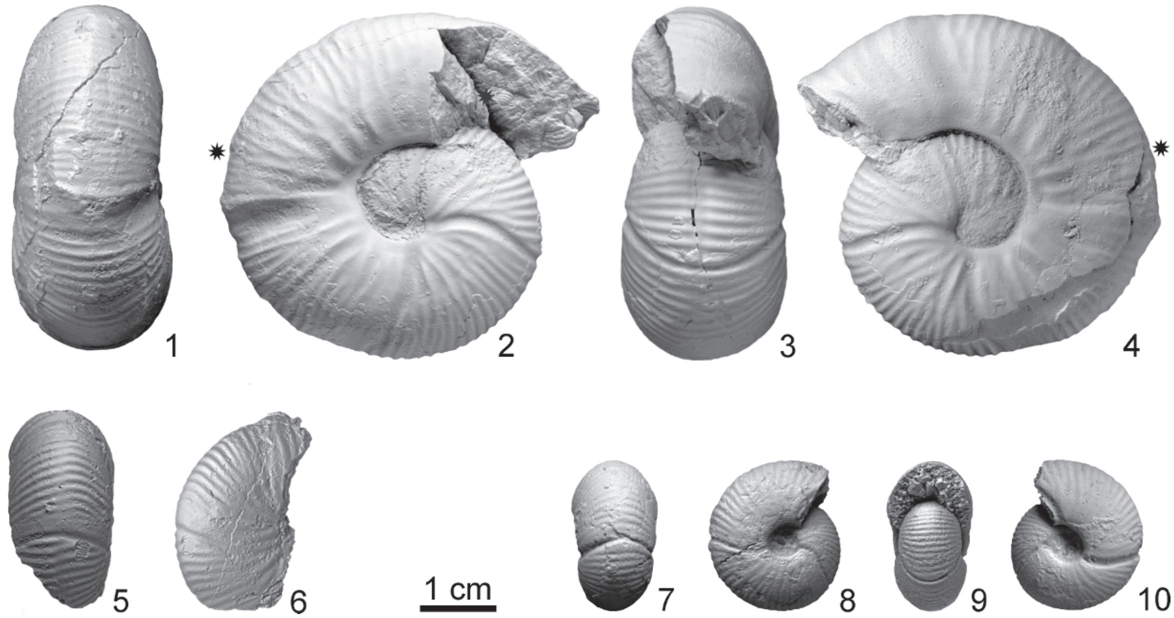

FIGURE 3—*Dimorphinites dimorphus* (d'Orbigny) [macroconch] from Quebrada San Pedro (Antofagasta, Chile). Black asterisk marks the last septum of the phragmocone. The specimens were whitened with magnesium oxide prior to photography. *1–4,* 13P84/4, ventral, left side, oral and right side views of complete specimen of pre-adult, showing peristome simple, sedimentary internal mold of outer whorls mostly without shell; *5, 6,* 13P84/9, ventral and left side views of incomplete specimen of pre-adult, with part of the bodychamber, internal mold of fragmentary bodychamber, without shell, inner whorls not preserved; *7–10,* 12P84/4, ventral, left side, oral and right side views of incomplete specimen, with septate whorls, internal mold of fragmentary phragmocone, with recrystallized inner whorls without shell.

These taphonomic observations are indicative of both a high rate of sediment accumulation and a low rate of sedimentation during biostratinomic processes, due to tractive bottom-currents and sedimentary starvation in relatively deep-water environments, according to the model of Fernandez-Lopez (1997, 2000, 2007, 2008).

These morphoceratid internal molds do not exceed 50 mm in diameter (mean size = 25.1 mm). Most of them represent pre-adult individuals, lacking evidence of juveniles. Both macroconchs and microconchs are represented by populations dominated by pre-adults (taphonic-populations of type-2 in Fernandez-Lopez, 1995; Fernandez-Lopez et al., 1999), suggesting autochthonous production of shells by indigenous populations of the marine basin (Fernandez-Lopez and Melendez, 1996). If the accumulation of shells had been produced by immigrants, or resulted from necroplanktic drift of shells from more open marine or exotic oceanic areas, it would probably be dominated by adults (taphonomic-populations of type-3 in Fernandez-Lopez, 1995; Fernandez-Lopez et al., 1999) and, in the case of drifted shells, the specimens would bear signs of intrathalamous encrusting by organisms (cf. Tintant, 1984; Callomon, 1985; Fernandez-Lopez and Melendez, 1996).

FIGURE 4—Septal suture of *Dimorphinites dimorphus* (d'Orbigny) [M], specimen 13P84/4 (cf. Figure *3.1–3.4*) showing ontogenetic simplification at 70° of the last septum and 155° from the peristome. L=lateral lobe, U_2=second umbilical lobe.

SYSTEMATIC PALEONTOLOGY

Order AMMONITIDA Zittel, 1884
Superfamily ?PERISPHINCTOIDEA Steinmann, 1890
Family MORPHOCERATIDAE Hyatt, 1900

The family Morphoceratidae is known in West Tethys, from the late Bajocian to the late Bathonian. In Europe, it is a common component of assemblages of the lower Bathonian Zigzag Zone (Mangold, 1970, 1997; Westermann, 1993; Galacz, 1995, 1999; Dietze et al., 1997, 2002). This family is known in the Andes from the lower Bathonian to upper Bathonian as a relatively scarce component of certain ammonite assemblages (Westermann and Hillebrandt, 1995; Riccardi and Westermann, 1999).

Morphoceratids comprise sphaerocone and planulate forms, with constrictions and irregular bundling or furcation of the ribs, and most have a smooth ventral band or sulcus. Septal sutures are relatively simple, with an unretracted suspensive lobe (cf. Arkell et al., 1957).

Evidence of sexual dimorphism in morphoceratids, with minute, evolute microconchs bearing lateral lappets, and larger, involute macroconchs with a contracted bodychamber and a simple peristome, has been proposed by diverse authors. In particular, the following taxonomic groups are regarded as dimorphs: *Morphoceras* Douville, 1881 [M]-*Ebrayiceras* Buckman, 1920 [m], *Polysphinctites* Buckman, 1922 [m]-*Asphinctites* Buckman, 1924 [M], *Dimorphinites* Buckman, 1923 [M]-*Vigoriceras* Rioult, 1994a [m], *Berbericeras* Roman, 1933 [M]-*Microberbericeras* Geczy and Galacz, 1998 [m] and *Pseudodimorphinites* Seyed-Emami (in Seyed-Emami et al., 1989) [M]-"*Polysphinctites*" [m].

Morphoceratids have most commonly been classified with the perisphinctaceans, due to the presence of distinct constrictions (Arkell, 1955; Westermann, 1956, 1958a; Mangold, 1970, 1997; Galacz, 1980, 2008; Donovan et al., 1981; Westermann and Callomon, 1988; Seyed-Emami et al., 1989;

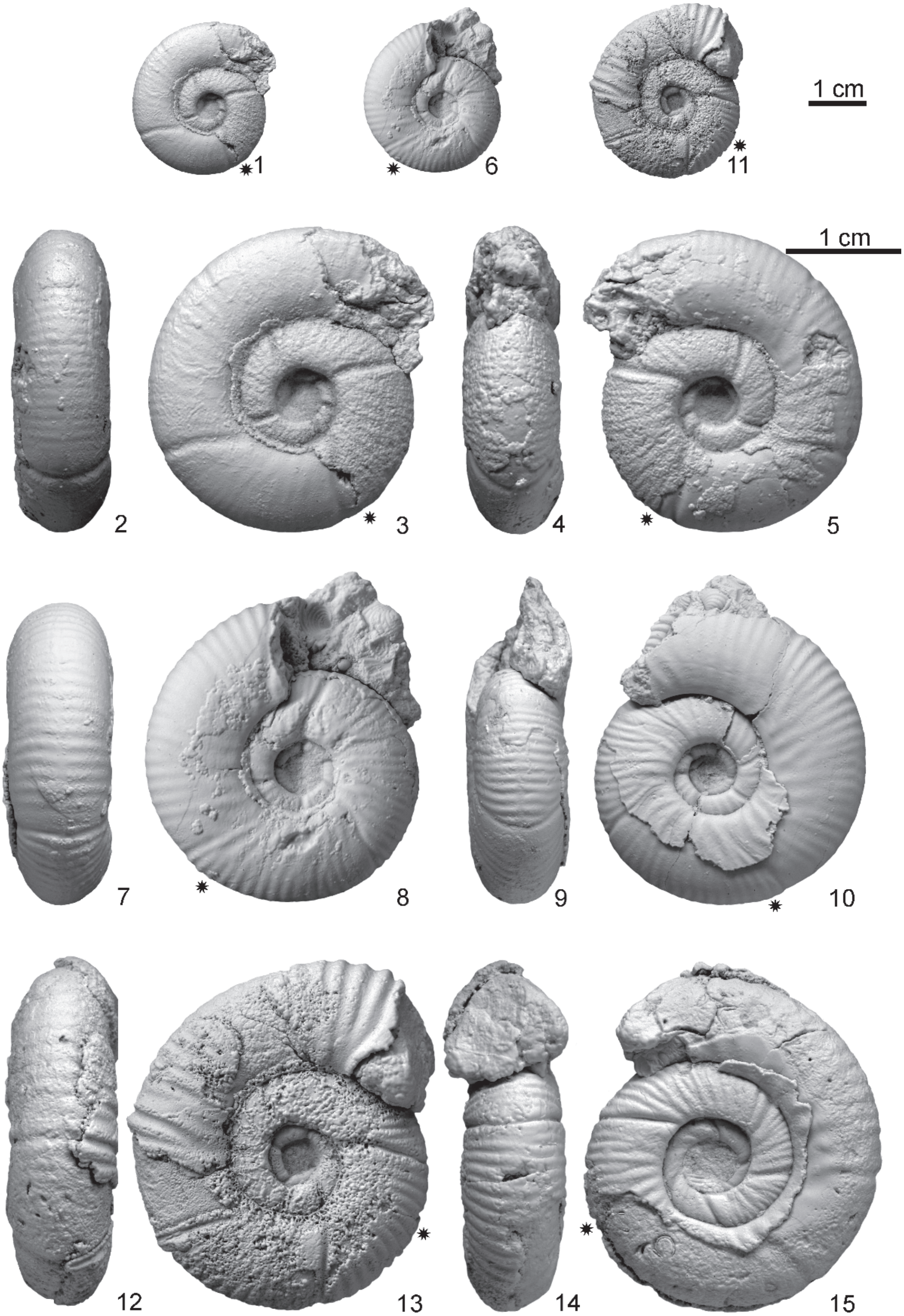

FIGURE 5—*Vigoriceras defrancei* (d'Orbigny) [microconch] from Quebrada San Pedro (Antofagasta, Chile). Black asterisk marks the last septum of the phragmocone. The specimens were whitened with magnesium oxide prior to photography. Internal molds of bodychambers mostly without shell. Phragmocones with recrystallized calcitic whorls and mostly with calcitic pseudomorphic shell. *1–5,* 13P84/7, nearly complete pre-adult specimen, with phragmocone and most of the bodychamber, without peristome; *6–10,* 13P84/6, incomplete specimen of pre-adult, with phragmocone and most of the bodychamber, last portion of the bodychamber and peristome are missing; *11–15,* 14P82/2, nearly complete specimen showing partial impression of peristome with lappets (at the right side).

TABLE 1—Measurements and abbreviations of the morphoceratid specimens from Quebrada San Pedro. Stratigraphic information is indicated by locality number, section letter and stratigraphic level: sections 12P, 13P and 14P; stratigraphic levels 82 and 84; /N=number of specimen. [M] and [m] indicate macroconch and microconch. Measurements (in mm) include maximum shell diameter at which the following measurements were made (D), whorl-height (H), whorl-height/diameter ratio (H/D), whorl-width (W), whorl-width/diameter ratio (W/D), umbilical diameter (U), umbilicus/diameter ratio (U/D), whorl-width/whorl-height ratio (W/H), primary ribs per half whorl (Ni/2), secondary ribs per half whorl (Ne/2), secondary ribs/primary ribs ratio (i) and number of constrictions per whorl (C).

Specimens		D	H	H/D	W	W/D	U	U/D	W/H	Ni/2	Ne/2	i	C
13P84/4	[M]	44.0	16.6	0.37	16.2	0.37	11.0	0.25	0.97	11	47	4.3	4
		35.7	16.2	0.45	20.6	0.58	2.0	0.06	1.27	11	36	3.3	—
12P84/4	[M]	18.5	7.5	0.40	10.3	0.56	4.2	0.23	1.37	—	23	—	3
		14.0	6.7	0.48	8.9	0.64	2.7	0.19	1.32	—	25	—	—
14P82/2	[m]	30.0	9.0	0.30	8.9	0.30	14.7	0.49	0.98	16	30	1.9	4
		22.5	7.7	0.34	8.6	0.38	9.1	0.40	1.11	—	—	—	4
13P84/8	[m]	25.0	9.3	0.37	9.0	0.36	8.4	0.34	0.96	—	—	—	5
		19.0	8.7	0.46	9.3	0.49	5.4	0.28	1.06	—	—	—	—
13P84/6	[m]	26.0	9.2	0.35	8.9	0.34	9.3	0.36	0.97	13	32	2.5	6
		20.0	8.1	0.40	8.7	0.43	5.9	0.30	1.07	12	33	2.8	4
13P84/7	[m]	26.0	8.5	0.33	8.2	0.31	11.0	0.42	0.96	—	37	—	4
		20.0	7.6	0.38	8.0	0.40	6.0	0.30	1.05	—	—	—	—

Besnosov and Mikhailova, 1991; Page, 1993; Rioult, 1994a, 1994b, 1994c; Geczy and Galacz, 1998; Riccardi and Westermann, 1999). However, studies of the septal suture have shown the presence of a dorsal Un lobe in the morphoceratids, which is characteristic of the Stephanocerataceae (Schindewolf, 1957, 1965; Westermann, 1958b; Hahn, 1970; Kullmann and Wiedmann, 1970; Tintant and Mouterde, 1981; Sandoval, 1983; Schlegelmilch, 1985; O'Dogherty et al., 2006). On the other hand, a possible sphaeroceratinid ancestor from the late Bajocian in Indonesia (Westermann, 1993) and transitional Tethyan forms from the stephanoceratid genus *Orthogarantiana* Bentz, 1928, or from a perisphinctid genus such as *Leptosphinctes* Buckman, 1920, or *Prorsisphinctes* Buckman, 1921, have been mentioned by Sandoval (1983) and Sturani (1964b, 1971) respectively.

Genus DIMORPHINITES Buckman, 1923

Type species.—"*Ammonites dimorphus*" d'Orbigny (1846, p. 410, pl. 141, figs. 1, 2, 5–8) by original designation (Buckman, 1923, pl. 377). This species is now regarded as a junior synonym of "*Ammonites defrancei*" (d'Orbigny, 1845), described and interpreted below.

Diagnosis.—Sphaeroconic shells, from small (~10 mm) to medium-size (~80 mm), with involute inner and intermediate whorls. Umbilicus from moderately narrow or occluded to wide. Venter rounded without smooth ventral band or groove. Aperture simple. Irregular bundling or furcation of the ribs, that pass over the venter rectiradiately or with a gentle forward inclination. Constrictions from the innermost whorls to the adult peristome. Sutures relatively simple, with suspensive lobe not retracted.

Occurrence.—*Dimorphinites* is known from Europe, northern Africa and southern Transcaucasus: England (Buckman, 1923; Donovan et al., 1981), France (d'Orbigny, 1845; Rioult, 1994a, 1994b, 1994c), Algeria (Roman, 1930), northern Italy (Sturani, 1964a, 1964b; Clari et al., 1984), Sicily (Wendt, 1964; Pavia et al., 2002; Galacz, 2008), Alps (Krystyn, 1972), Hungary (Galacz, 1980), Betic Basin (Sandoval, 1983, 1990; Sandoval et al., 2001; O'Dogherty et al., 2006), Iberian Basin (Fernandez-Lopez, 1985), Transcaucasus (Rostovtsev, 1985), Atlas (Enay et al., 1987), Carpathian (Wierzbowski et al., 1999; Schlögl et al., 2005), Tunisia (Soussi et al., 2000), Portugal (Fernandez-Lopez et al., 2006, 2009a) and Germany (Dietze and Bernt, 2009).

In the Tethyan areas, the *Dimorphinites* seems to be restricted to the uppermost Bajocian Parkinsoni Zone. Nevertheless, possible ancestral members of this taxonomic group could be represented in the upper Bajocian Garantiana or Niortense zones of Venetian Prealps (Sturani, 1971) and Betic Basin (Sandoval, 1983). This genus also could be represented in the lower Bathonian Zigzag Zone of Sicily (Wendt, 1964; Pavia et al., 2002).

Discussion.—*Dimorphinites* has been regarded as macroconchiate with simple peristome, and dimorphic microconchs with lappets currently included in the (sub)genus *Vigoriceras* (Douville, 1881; Glangeaud, 1897; Makowski, 1963; Mangold, 1970, 1997; Galacz, 1980; Sandoval, 1983, 1990; Rioult, 1994a, 1994b, 1994c; Dietze et al., 2002; Dietze and Bernt, 2009).

At least three nominal species of the genus *Dimorphinites* are available from Tethyan areas: 1) *D. dimorphus* (d'Orbigny, 1846, p. 410, pl. 141, figs. 1, 2, 5–8; lectotype designated by Rostovtsev, 1985 and Rioult, 1994b) from the "Oolite ferrugineuse of Bayeux" Formation, middle part of the Parkinsoni Zone (Densicosta-Subzone) of Bayeux or Port-en-Bessin (Calvados, France); 2) *D. compressus* Galacz (1980, p. 102, pl. 23, figs. 4, 6) from the upper part of the Parkinsoni Zone, of Gyenespuszta, Northern Bakony (Hungary); and 3) *D. centriglobus* Rioult (1994c, p. 131, pl. 50, fig. 8) from the middle part of the Parkinsoni Zone (Densicosta Subzone; cf. fig. 6) of Sainte-Honorine-des-Pertes (Calvados, France).

Dimorphinites differs from *Morphoceras* Douville (1881, p. 242; type species: "*Ammonites polymorphus*" d'Orbigny, 1846; renamed "*M. multiforme*" Arkell, 1951) by the absence of smooth ventral band. Other macroconchiate morphoceratids, such as *Asphinctites* Buckman (1924; type species: *A. recinctus* Buckman, 1924, TA-5, pl. 484), *Berbericeras* Roman (1933, p. 67; type species: *B. sekikense* Roman, 1933, pl. 2, fig. 15) and *Pseudodimorphinites* Seyed-Emami (in Seyed-Emami et al., 1989, type species: "*Morphoceras pingue*" Grossouvre, 1919, p. 391, pl. 14, fig.7), are similar to *Dimorphinites* based on the lack of a ventral groove, but they show wider umbilicus and more evolute inner whorls. "*Dimorphinites nodifer*" Wendt (1964, pl. 21, fig. 5) may belong to the genus *Berbericeras*, as suggested by Dietze et al. (2002).

DIMORPHINITES DIMORPHUS (d'Orbigny, 1846) [M]
Figures 3, 4, Table 1

Ammonites dimorphus d'ORBIGNY, 1845, p. 410, pl. 141, figs. 1, 2 (lectotype), 5–8.

Dimorphinites dimorphus d'Orbigny sp. BUCKMAN, 1923, pl. 377, figs. 1–3.

Morphoceras dimorphum d'Orbigny. ROMAN, 1930, p. 17, pl. 7, figs. 1, 2.

Dimorphinites dimorphus (d'Orbigny). STURANI, 1964b, p. 26, pl. 3, figs. 3, 4, text-fig. 22; KRYSTYN, 1972, p. 262, pl. 8, fig. 4; ROSTOVTSEV, 1985, p. 162, pl. 44, figs. 7–10; SANDOVAL, 1990, p. 161, pl. 4, fig. 5; RIOULT, 1994b, p.130, pl. 50, fig. 7; PAVIA et al., 2002, p. 47, fig. 26 (right); DIETZE AND BERNT, 2009, p. 6, figs. 1a–e, h–k.

Dimorphinites (Dimorphinites) dimorphus (d'Orbigny). GALACZ, 1980, p. 100, pl. 23, figs. 1–3, 5; SANDOVAL, 1983, p. 330, pl. 27, figs. 1, 2; WIERZBOWSKI et al., 1999, p. 48, figs. 17 (4, 5), 18 (1); SCHLÖGL et al., 2005, p. 344, pl. 13, fig. 2; GALACZ, 2008, p. 62, pl. 2, figs. 11, 12.

Description.—Inner and intermediate whorls are sphaeroconic, with nearly occluded umbilicus, convex flanks and venter. The coiling becomes evolute, with contracted bodychamber and flattened whorl-sides, at the last whorl of the phragmocone. The aperture is constricted, with simple peristome. Ribbing is blunt, irregular and dense, without smooth ventral band or groove, and weaker in the outer whorl. Constrictions, three to four per whorl, are narrow and deep commencing in the innermost whorls. In the largest specimen that shows umbilical egression, the bodychamber encompasses 125° (Fig. 3.1–3.4). All the specimens display recrystallized septa, although locally preserved. Sutures are relatively simple, with suspensive lobe not retracted (Fig. 4).

Material.—A relatively well-preserved (13P84/4), two incomplete (13P84/9, 12P84/4), and two fragmentary and crushed specimens (12P84/5-6), from 10 to 50 mm in diameter. The largest specimen (Fig. 3.1–3.4) show remains of the last two septa, lacking evidence of sutural crowding, at 125° of the peristome in the left side. The smallest specimen (Fig. 3.7–3.10) is completely septate.

Occurrence.—*Dimorphinites dimorphus* is the most common and widely distributed species of the genus, characterizing the middle part of the Bajocian Parkinsoni Zone from: England (Truellei Subzone cf. fig. 6; Buckman, 1923; Dietze and Bernt, 2009), France (Densicosta Subzone; Rioult, 1994b) and Venetian Prealps (Sturani, 1964a, 1964b). Certain problems of these chronostratigraphic assignments, however, are due to the diverse criteria of subzonation applied in the European basins within condensed assemblages (cf. Pavia, 1994, 2000). On the basis of the presence of *Parkinsonia rarecostata* (Buckman) in the same assemblages, the range of *D. dimorphus* have been extended into the lower part of the Parkinsoni Zone at least in Morocco (Enay et al., 1987), England (Page, 1993) and Germany (Ditze and Bernt, 2009). Moreover, this species has been mentioned in the upper part of the Parkinsoni Zone (Bomfordi Subzone) in the Venetian Prealps (Italy, Sturani, 1971), type area (France, Pavia and Martire, 2010) and Monte Kumeta (Sicily, Galacz, 2008). The species characterizes a Dimorphus Biohorizon (or subzone) in the uppermost Parkinsoni Zone of diverse Mediterranean basins (Galacz, 1980; Sandoval, 1983, 1990; Ouahhabi, 1994; Wierzbowski et al., 1999; O'Dogherty et al., 2006). It is known also with condensed assemblages at the Bajocian/Bathonian transition in Sicily (Wendt, 1964; Pavia et al., 2002).

Discussion.—The largest macroconch of Quebrada San Pedro (Fig. 3.1–3.4) belongs to a pre-adult individual. It shows possible signs of maturity, such as umbilical egression, flattening of the bodychamber, variocostation and simplification of the septal sutures (Fig. 4). Crowding of the last sutures and collared aperture, however, are missing and the bodychamber is extremely short. Within Tethyan *Dimorphinites*, the variability in adult size and bodychamber is extreme too, surpassing values of 80 mm and 360° respectively. Therefore, *Dimorphinites* developed umbilical egression during the late pre-adult growth period, before maturity and cessation of growth, while the bodychamber length initially decreased and subsequently increased.

Dimorphinites compressus Galacz is distinguished from *D. dimorphus* by its less inflated morphology. *Dimorphinites centriglobus* Rioult displays a sphaeroconic phragmocone and a planulate bodychamber more pronunced. Smaller, adult *Dimorphinites* have been figured by Wendt (1964, p. 133, pl. 21, fig. 3) and Pavia et al. (2002, p. 48, fig. 26, bottom left).

Genus VIGORICERAS Rioult, 1994

Type species.—"*Ammonites defrancii*" d'Orbigny (1845, p. 239, pl. 129, figs. 7, 8) by original designation (Rioult, 1994a, p. 115).

Diagnosis.—Planulate shells, small-size (15–35 mm), with moderately evolute whorls. Umbilicus moderately narrow to wide. Venter rounded, without smooth ventral band or groove. Aperture with lateral spatulate lappets. Irregular bundling or furcation of the ribs, that pass over the venter rectiradiately or with a gentle forward inclination. Constrictions from the innermost whorls. Sutures relatively simple, with suspensive lobe not retracted.

Occurrence.—The (sub)genus *Vigoriceras is* known from several localities of Europe: France (d'Orbigny, 1845; Rioult, 1994a), England (Buckman, 1924) and Hungary (Galacz, 1980). These records are late Bajocian in age, exactly Parkinsoni Zone. However, microconchs of this taxonomic group could be represented in the Bajocian Garantiana or Niortense zones of Venetian Prealps (Sturani, 1971) and in the lower Bathonian Zigzag Zone of Sicily (Wendt, 1964; Pavia et al., 2002) and Iberian Range (Fernandez-Lopez, 1985).

Discussion.—At present, two nominal species of the genus *Vigoriceras* are available from the Western Tethys: 1) *V. defrancei* (d'Orbigny, 1845, p. 239, pl. 129, figs. 7, 8), from the "Oolite ferrugineuse of Bayeux" Formation, middle part of the Parkinsoni Zone (Densicosta Subzone) of Saint-Vigor (Calvados, France) and the type species of the genus; and 2) *V. dimorphoides* (Parona, 1896, p. 21, pl. 2, fig. 8; figured by Sturani, 1971, pl. 14, fig. 19) from the Monte Meletta assemblage (Niortense Zone, Venetian Prealps) but showing diverse sedimentary infill than other fossils from the same assemblage (according to Sturani, 1971, p. 175).

Vigoriceras differs from *Ebrayiceras* Buckman (1920, p. 23; type species: *E. ocellatum* Buckman, 1920, TA-3, pl. 173) by the absence of smooth ventral band. Other microconchiate morphoceratids, such as *Polysphinctites* Buckman (1922; type species: *P. polysphinctus* Buckman, 1922, TA-4, pl. 322), *Microberbericeras* Geczy and Galacz (1998; type species: "*Berbericeras (Microberbericeras) kopeki*" Geczy and Galacz, p. 499, pl. 2, figs. 17, 18) and the dimorphic counterpart of *Pseudodimorphinites* are similar to *Vigoriceras,* lacking of ventral groove, but they show wider umbilicus, more evolute inner whorls and more discoidal shell.

VIGORICERAS DEFRANCEI (d'Orbigny, 1845) [m]
Figure 5, Table 1

Ammonites Defrancii d'ORBIGNY, 1845, p. 389, pl. 129, figs. 7, 8.

Ammonites Defrancei d'Orbigny. GLANGEAUD, 1897, p. 100, pl. 3, figs. 1–3.

Dimorphinites defrancii d'Orbigny sp. BUCKMAN, 1924, pl. 510.

Dimorphinites (unnamed subg.) *defrancii* (d'Orbigny). GALACZ, 1980, p. 103, pl. 22, fig. 3.

Dimorphinites (*Vigoriceras*) *defrancii* (d'Orbigny). RIOULT, 1994a, p. 115, pl. 50, figs. 5 (holotype) and 6.

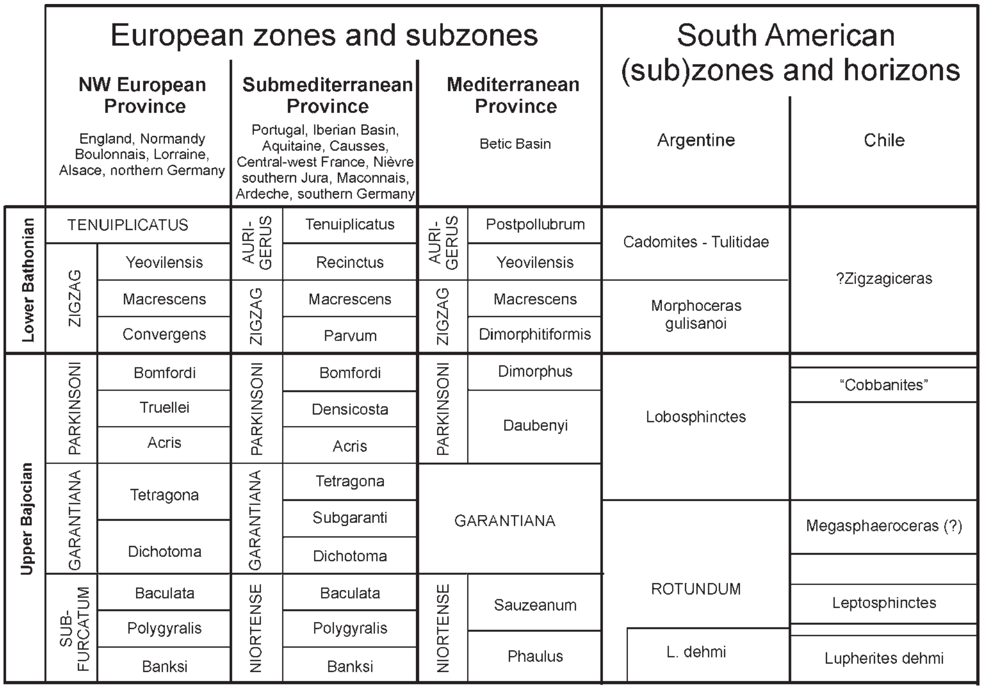

FIGURE 6—Standard zonation for the upper Bajocian and lower Bathonian, showing correlation of European zones and subzones with South America zones, subzones and horizons (cf. Rioult et al., 1997; Mangold and Rioult, 1997; Hillebrandt, 2001; Callomon, 2003; O'Dogherty et al., 2006; Riccardi, 2008; Fernandez-Lopez et al., 2009b).

Vigoriceras defrancei (d'Orbigny) [m]. PAVIA et al., 2002, p. 47, figs. 26 (top left);

Vigoriceras defrancii (d'Orbigny). DIETZE AND BERNT, 2009, p. 6, figs. 1f, g.

Description.—Planulate, with moderately evolute whorls. Whorl-section ovally shaped. Umbilicus moderately narrow to wide. Venter rounded, without smooth ventral band or groove. Aperture with lateral lappets. The ribbing is blunt, irregular and dense, weaker in the adult outer whorls. The constrictions, four to six per whorl, with forward inclination, are narrow and deep. Bodychamber ranges between 190 and 280°. The septa are commonly recrystallized. Sutures relatively simple, with suspensive lobe not retracted.

Material.—Three relatively well-preserved (13P84/7, 13P84/6, 14P82/2) and a fragmentary specimen (13P84/8), from 20 to 30 mm in diameter. All these specimens preserve phragmocone and bodychamber, but only one displays septal approximation (Fig. 5.6–5.10).

Occurrence.—*Vigoriceras defrancei* has been recorded in the middle part of the Bajocian Parkinsoni Zone from: England (Buckman, 1923; Dietze and Bernt, 2009), France (Rioult, 1994a) and northern Italy (Sturani, 1964a, 1964b). It has also been mentioned at the lower part of the Bajocian Parkinsoni Zone in Hungary (Galacz, 1980), in the upper part of the Parkinsoni Zone in Normandy (Pavia and Martire, 2010) and within condensed assemblages at the Bajocian/Bathonian transition in the Iberian Range (Fernandez-Lopez, 1985).

Discussion.—Only one of the four specimens from Quebrada San Pedro (Fig. 5.6–5.10) shows crowding and simplification of the last septal sutures, but associated with the shortest bodychamber. Most of these specimens, therefore, belong to pre-adult individuals.

Vigoriceras dimorphoides (Parona) display smaller size, with more globose shape and more involute coiling. Jaworski (1926, p. 262, pl. 2, fig. 4) determined an Argentine specimen as *Morphoceras* n. sp. cf. *M. defrancei* (d'Orbigny), from the Aalenian/Bajocian transition beds of Cerro Tricolor (Argentine). However, this specimen differs of the Morphoceratidae by the strong retraction of the oblique umbilical lobes and the more complex septal suture. It was proposed as holotype of a new species of Perisphinctidae: *Praeleptosphinctes jaworskii* Westermann (1956, p. 268; Westermann and Riccardi, 1982, p. 39, text-fig. 7a–e).

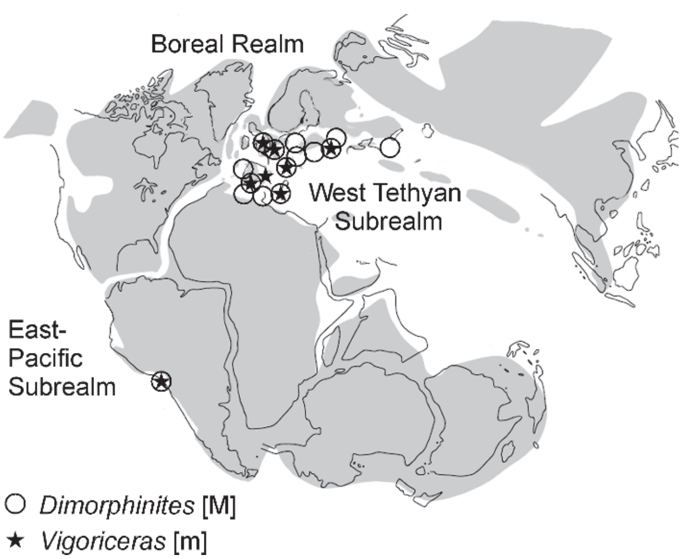

FIGURE 7—Principal paleobiogeographic units during Bajocian/Bathonian transition, with location of *Dimorphinites* (asterisk) and *Vigoriceras* (circle) occurrences (paleogeography based on Moyne and Neige, 2007; Fernandez-Lopez et al., 2009b).

SYSTEMATIC, PALEOBIOGEOGRAPHIC AND BIOCHRONOSTRATIGRAPHIC INTERPRETATION

Most ammonite species of the late Bajocian and early Bathonian from South America are endemic to the Andean

Province, or subprovinces, and the Eastern Pacific Subrealm (Westermann and Riccardi, 1980; Westermann, 1981, 1993, 2000, 2001; Riccardi et al., 1990a, 1990b, 1992, 1994; Riccardi and Westermann, 1991a, 1991b, 1999; Hillebrandt et al., 1992a, 1992b; Fernandez-Lopez et al., 1994, 2009b; Gröschke and Hillebrandt, 1993, 1994; Hillebrandt, 2001; Gröschke, 1996; Page, 2008; Riccardi, 2008). Upper Bajocian and lower Bathonian biozones and chronozones are, therefore, commonly defined by the regional, stratigraphic range of Pacific taxa (Fig. 6). The Andean Province was characterized by Eurycephalitinae, *Megasphaeroceras* being the most common member of the late Bajocian ammonite assemblages. Nevertheless, these eurycephalitins are associated with diverse taxa of West Tethyan affinity belonging to the families Stephanoceratidae (*Cadomites* [M]-*Polyplectites* [m], *Strenoceras* Hyatt, 1900 [m], *Orthogarantiana*? [M]), Spiroceratidae (*Spiroceras* Quenstedt, 1858), Perisphinctidae (*Leptosphinctes* Buckman, 1929 [M], *Prorsisphinctes* Buckman, 1921 [M], *Lobosphinctes* Buckman, 1923 [M]) and Lissoceratidae (*Lissoceras* Bayle, 1879 [M]).

In the Tarapaca Basin, the latest Bajocian *Dimorphinites defrancei* (d'Orbigny) [M + m] is represented by indigenous populations indistinguishable from its Tethyan counterparts, as far as can be seen from the scarce material. This species ranged throughout the Northwest European, Sub-Mediterranean and Mediterranean provinces of the West Tethyan Subrealm, the north-eastern Tethyan border and, according to this new record in the north Chile, the southeastern Pacific areas of the East-Pacific Subrealm (Fig. 7). Since *Dimorphinites defrancei* (d'Orbigny) [M + m] has only been known from the upper Bajocian Parkinsoni Zone in the western and north-eastern Tethyan border, this standard zone is now extended to the SE Pacific. Some associated taxa, such as *Vermisphinctes* [m]-*Prorsisphinctes* [M], *Strigoceras* [M] and *Oxycerites* [M] - *Paroecotraustes* [m] also indicate the uppermost Bajocian age and Tethyan affinities. Judging from work in progress, a fragmentary specimen of *Strigoceras* from the Dimorphinites assemblage of Quebrada San Pedro belongs to the species *S. truellei* (d'Orbigny) and corresponds also to the Bajocian Parkinsoni Zone.

The West Tethyan and East-Pacific distribution of *Dimorphinites defrancei* (d'Orbigny) [M + m] lend further credence to the presence of a marine connection between the western Tethys and the eastern Pacific Ocean, the hypothesized Hispanic Corridor (cf. Smith, 1983; Cantú-Chapa, 2001; Iturralde-Vinent, 2006). Moreover, the Mediterranean origin of the Morphoceratidae becomes uncertain, as the possibility exists of an origin along the southeastern Pacific margin.

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