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A JUVENILE *LARIOSAURUS* (REPTILIA, SAUROPTERYGIA) FROM THE KALKSCHIEFERZONE (UPPERMOST LADINIAN) NEAR VIGGIU' (VARESE, NORTHERN ITALY)

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Key-words: *Lariosaurus* (Reptilia, Sauropterygia), Kalkschieferzone (uppermost Ladinian), Systematic discussion.

Riassunto. Il ritrovamento di un esemplare giovanile appartenente al genere *Lariosaurus* Curioni nella località fossilifera di Cà del Frate (Viggiù, Varese), in un affioramento della Kalkschieferzone, consente un confronto con un altro esemplare dalle dimensioni pressochè identiche, raccolto nella località svizzera di Val Mara nella stessa formazione. Quest'ultimo esemplare fu considerato come una specie separata, *L. lavizzarii*, da Kuhn-Schnyder (1987), in quanto il rapporto tra la lunghezza dell' omero e la porzione precaudale della colonna vertrebrale dorsale indicava che lo stilopodio anteriore era molto meno sviluppato che in *L. balsami*. Secondo Kuhn Schnyder (1987) il rapporto tra la lunghezza del femore e quella della stessa porzione della colonna vertebrale sarebbe stato invece paragonabile a quello di altri esemplari di *L. balsami* di maggiori dimensioni, escludendo quindi la possibilità di crescita allometrica degli arti durante l' ontogenesi, per cui il rapporto omero/colonna vertebrale avrebbe avuto carattere diagnostico a livello specifico.

L'analisi diretta delle proporzioni degli elementi scheletrici di entrambi gli esemplari, evidenzia tuttavia un errore nel calcolo del rapporto femore/colonna vertebrale, testimoniando che anche il femore è relativamente meno sviluppato che negli esemplari più grandi. La diagnosi quindi non è del tutto corretta, in quanto la differenza tra stilopodio anteriore e posteriore è uguale a quella degli altri esemplari di *Lariosaurus* classificati come *L. balsami*.

Nella località di Cà del Frate era stato trovato precedentemente un esemplare di grandi dimensioni, con un omero relativamente più svilupppato rispetto a *L. balsami*, per cui era stato attribuito ad una nuova specie, *L. valceresii* Tintori & Renesto, 1990. L' esemplare giovanile recentemente scoperto non presenta questo carattere, ma tuttavia possiede lo stesso numero di vertebre dorsali di *L. valceresii*, inferiore a quello di *L. balsami*. Due ipotesi alternative sono possibili: i due esemplari di Cà del Frate e quello di Val Mara appartengono ad una stessa specie, distinta da *L. balsami* per la maggiore lunghezza relativa dell'omero, ma, a causa dell' incompleta ossificazione dell' osso questo carattere non può essere riscontrato negli individui giovani, oppure le differenze delle proporzioni relative di omero e femore sarebbero da attribuire a dimorfismo sessuale e non avrebbero quindi carattere diagnostico.

Abstract. The collection of a juvenile *Lariosaurus* specimen in the Kalkschieferzone of Cà del Frate (Viggiù, Varese, Northern Italy), allows the comparison with an other specimen of about the same size, collected from the same formation in the locality of Val Mara (Switzerland) and described as a new species: *L. lavizzarii* (Kuhn-Schnyder, 1987). The analysis of the size and proportions of both specimens testifies that the

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supposed difference of relative proportions between the anterior and posterior stylopodium with other known *Lariosaurus* specimens is due to an error in the calculation or in the plotting of the data, while allometric growth of both anterior and posterior stylopodium is confirmed. A large specimen was already collected from the same formation in the Italian locality of Cà del Frate, and it was ascribed to a separate species, *L. valceresii* Tintori & Renesto, 1990, on the basis of the relatively longer humerus with respect to *L. balsami*. This character, however, is not recognizable in the juvenile *Lariosaurus* specimen from the same locality. Two alternative conclusions are proposed: the small specimen belongs to the same species of the larger one, but the early growth stage obscures the main diagnostic character, or the different limb proportions in the large individual reflect sexual dimorphism rather than specific diversity.

Introduction.

Among the great variety of aquatic reptiles that lived in the Triassic seas, the "nothosaurs" were particularly abundant in the Middle Triassic of Europe. The body shape of the different "nothosaur" genera was rather similar, showing the same adaptations to aquatic life, mainly in the structure of the limbs and of the girdles (Carroll & Gaskill, 1985), but the size and limb proportions were variable.

Lariosaurus is a medium-sized "nothosaur" known mainly from the Triassic outcrops of the Perledo-Varenna Limestone (Lombardy, Northern Italy) (Balsamo Crivelli, 1839; Curioni, 1847; Mariani, 1924; Peyer, 1933, 1934 and Ticli, 1984), and from the Middle Triassic of Spain (Sanz, 1976, 1983), of the french Pyrenees (Mazin, 1985). All the *Lariosaurus* specimens collected from these localities were referred to the same species, *L. balsami* Curioni, while some specimens from the Gailtaler Alps of Austria (Zapfe & Konig, 1980) were recorded as *Lariosaurus* sp. or *Lariosaurus* cf. *balsami*.

Recently Kuhn-Schnyder (1987) described a new species, *L. lavizzarii* on the basis of a single specimen from the Kalkschieferzone type section at Val Mara, near Meride (Canton Ticino, Switzerland). This specimen (a juvenile) shows, according to Kuhn-Schnyder (1987), a more pointed outline of the skull and a relatively shorter anterior stylopodium than *L. balsami*. Tschanz (1989), in his paper on the probably primitive lariosaur *L. buzzii* Tschanz, from the Grenzbitumenzone of Monte San Giorgio (Switzerland) criticized *L. lavizzarii* as a valid taxon and considered the outline of the skull not diagnostic and the variation in the limb proportions as due to the early growth stage of the specimen. Rather strangely, however, the same author, retained *L. lavizzarii* in a recent joint paper (Bürgin et al., 1991, p. 984, tab. 4).

In his paper, Kuhn-Schnyder (1987) compared the length of different limb sections (Tab. 2) with that of the dorsal plus sacral portion of the vertebral column of some lariosaurs and pointed out that the humerus of the specimen from Val Mara was relatively shorter than those of other *L. balsami* specimens. The author considered the relatively shorter humerus as a diagnostic character rather than due to allometry because the ratio for the femur was approximately the same as in larger *L. balsami* specimens, thus being a great difference between the anterior and the posterior stylopodium.

Another *Lariosaurus* species, *L. valceresii* Tintori & Renesto, 1990, has been described on the basis of a large, well preserved specimen collected in the Kalkschiefer-

zone at the Italian locality of Cà del Frate (Tintori et al., 1985) near Varese (Northern Italy), in an outcrop that yielded also several fishes (Tintori & Renesto, 1983; Tintori et al., 1985). *L. valceresii* shows a relatively *longer* anterior stylopodium with respect to *L. balsami* (Tintori & Renesto, 1990).

Recently, a new specimen has been collected at the same locality that yielded the holotype of *L. valceresii*; this latter is a juvenile nearly identical in size to the holotype of *L. lavizzarii* (Tab. 1). A comparison of the proportions of both specimens from the Kalkschieferzone and of a juvenile specimen from Perledo-Varenna Limestone, belonging to *L. balsami* testifies that the difference in the relative length of the humerus with respect to the femur in *L. lavizzarii* reflects an error in the calculation or in the plotting of the data (Kuhn-Schnyder, 1987) related to the relative length of the femur; this latter is proportionally as shorter than in large specimens as the humerus is, owing to the different growth stage, as correctly argued by Tschanz (1989). No diagnostic characters can be found in juvenile lariosaurs to justify the erection of new species, this may be due to the incomplete ossification of the limb bones, but the possibility of sexual dimorphism in large individuals cannot be excluded.

Institutional acronyms.

The *Lariosaurus* specimens are identified in text, tables and figure captions with their catalogue number and the institutional acronyms of the museums in which they are stored: T-4288 PIMUZ (Palaeontologisches Institut und Museum der Universitaet, Zurich), the specimen from Val Mara, and 550 MCSNIO (Museo Civico di Scienze Naturali, Induno Olona), the newly discovered specimen.

Systematic palaeontology

The taxonomic assessment of most of the different "nothosaur" groups is still debated at any hierarchical level. Despite to their generalized morphology, the "nothosaurs" probably represent a paraphyletic assemblage (Sues, 1987; Rieppel, 1989; Tschanz 1989; Storrs, 1991) and the existing resemblances among different groups may be due to similarities rather to true synapomorphies. In the present work the taxonomic position of the genus *Lariosaurus* has been assessed according to the classification proposed by Tschanz (1989).

Class **Reptilia** Linnaeus, 1758
Order **Sauropterygia** Owen, 1860
Superfamily *Nothosauria* Seeley, 1882
Family *Lariosauridae* Lydekker, 1889
Genus *Lariosaurus* Curioni, 1847

Lariosaurus sp.

Pl. 1; Text-fig. 1-3

Material. One juvenile specimen registered as No. 550 of the catalogue of the Museo Civico di Scienze Naturali di Induno Olona (Varese, Italy).

Horizon and locality. The specimen was collected from the lower part of the Kalkschieferzone (Meride Limestone), uppermost Ladinian, at the locality of Cà del Frate (Viggiù, Varese, Italy).

Description.

Specimen 550 MCSNIO (Pl. 1) is exposed on its dorsal side. It is a nearly complete and associated skeleton, with the neck broken at the level of the 8th cervical vertebra. According to Sues (1987) and Tschanz (1989), the anatomy of this specimen clearly fits the diagnosis for the genus *Lariosaurus* (Tschanz, 1989) both in the skull morphology, and in the peculiarly flattened and distally enlarged ulna.

The skull. The skull (Fig. 1) was flattened during fossilization so that many bones are crushed and the occipital region is exposed. The anterior part of the skull is poorly preserved, particularly the right half. The premaxillae are wide and rounded anteriorly; their posterior process can be detected only on the left premaxilla. The left nasal is subtrapezoidal in shape, rather narrow, and it is partially overlapped by the dorsal portion of the maxilla. This bone is poorly preserved in its posterior portion

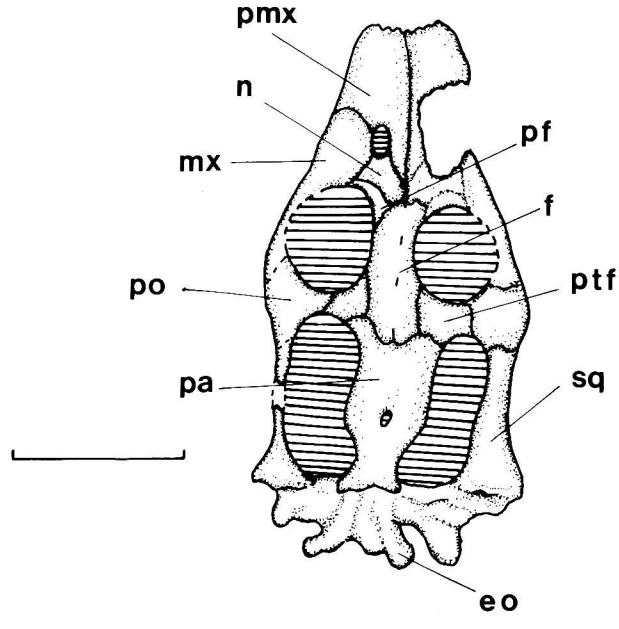

Fig. 1 - The skull of specimen 550 MCSNIO. Abbreviations: eo) exooccipital; f) frontal; mx) maxilla; n) nasal; pa) parietal; pf) prefrontal; pmx) premaxilla; po) postorbital; ptf) postfrontal; sq) squamosal. Scale bar equals 1 cm.

and the suture with the elongate postorbital is not visible. The posterior margin of the maxilla forms both the anterior and the ventral margin of the large, rounded orbit. At the level of the posterior end of the dorsal margin the maxilla meets the small semilunate prefrontal. Both the frontals and the parietals are narrow and elongate, and fused along the midline; the parietal is pierced by a discrete, round pineal foramen. At the posterior end of the ventral margin of the frontal, a small postfrontal can be detected. The parietal forms most of the dorsal margin of the temporal fenestra, which is well developed and longer than wide. The ventral border of the temporal fenestra is formed by the narrow anterior process of the squamosal: this bone widens posteriorly, where it distally meets the quadrate and the basioccipital, and the exooccipital proximally, which lateral flanges are well exposed in the specimen.

Axial skeleton. The vertebral column consists of 22-23 cervical, 20 dorsal, 5 sacral and up to 30 caudal vertebrae. As in other lariosaurs the neural spines are low and the neural arches are expanded, with small prezygapophyses somewhat upwardly directed and more wide and massive postzygapophyses. In dorsal view, the neural arches are subtriangular in the cervical region, and become trapezoidal in the dorsal region. The sacral vertebrae show the same size of the most posterior dorsal ones, but the caudal vertebrae decrease gradually in size and show more rounded postzygapophyses.

The ribs are pachyostotic in their proximal portion and taper distally. Cervical ribs are visible starting from the 15th cervical vertebra: they are rather narrow and nearly straight. Dorsal ribs are distinctly bent ventrally apart for the last two pairs, that are considerably shorter than the preceeding ones, forming a "lumbar" region. The sacral ribs are short and they taper abruptly towards the distal end. The first caudal ribs are somewhat longer and stouter than the sacral ones, becoming gradually smaller posteriorly. Traces of thin gastralia are visible among the anterior dorsal vertebrae.

Appendicular skeleton. Only the right half of the shoulder girdle is visible, owing to a lateral shift of the whole structure (Fig. 2). The clavicle is stout and wide, its outline is subtriangular, and its distal margin is thick and expanded, forming an anterolateral "corner" (Storrs, 1991). The narrow dorsal portion of the scapula is visible, overlapping the glenoid region. The rounded distal region is the only exposed portion of the coracoid. The humerus is a stout bone with a gently curved outline. Due to the early growth stage, it is not fully ossified, and the distal expansion with the entepicondylar foramen is not ossified. The radius is straight and rather stout, the ulna shows the flattened and expanded outline typical for the genus. A wide intermedium is the only ossified carpal element, it lies just at the distal end of the *spatium interosseum.* The metacarpals are long and rather stout. Only the more proximal phalanges of digit 2, 3, 4 are preserved.

A tiny, elliptical ilium is the only visible portion of the pelvic girdle (Fig. 3). The femur is straight and slender, it is directed at a right angle to the vertebral column. Tibia and fibula are well developed. The tibia is straight and shows an ex-

panded proximal head; the fibula is gently embayed and somewhat expanded distally. Astragalus and calcaneum are the only ossified tarsal bones; the metatarsals are nearly identical to the metacarpals, and only the more proximal phalanges of each digit of the pes are preserved.

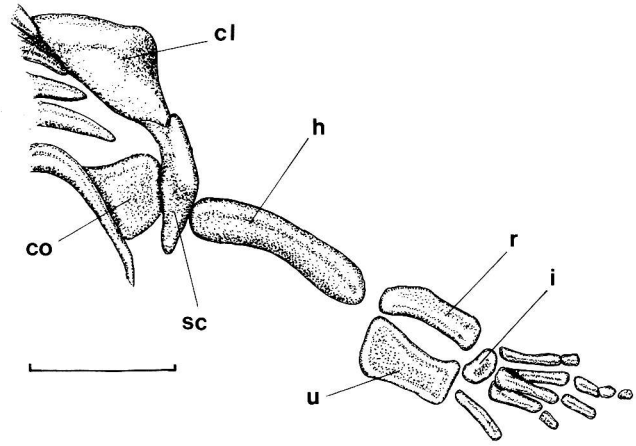

Fig. 2 - The right half of the shoulder girdle and the right anterior limb of specimen 550 MCSNIO, in dorsal view. Abbreviations: cl) clavicle; co) coracoid; h) humerus; i) intermedium; r) radius; sc) scapula; u) ulna. Scale bar equals 1 cm.

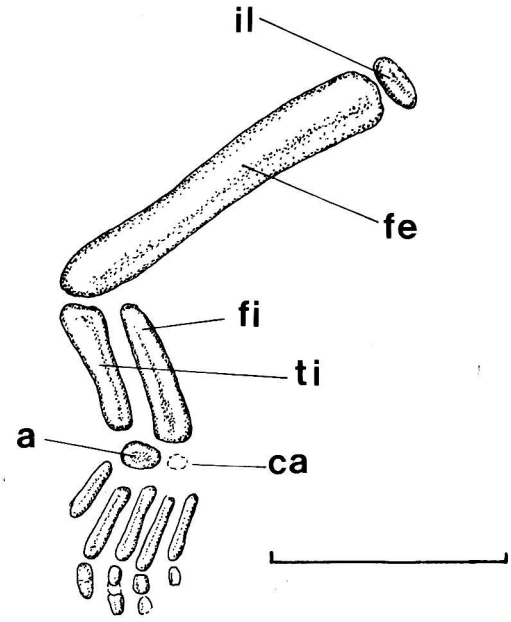

Fig. 3 - The left posterior limb of specimen 550 MCSNIO, in dorsal view. Abbreviations: a) astragalus; ca) calcaneum; fe) femur; fi) fibula; il) ilium; ti) tibia. Scale bar equals 1 cm.

Discussion.

Specimen T-4288 PIMUZ was thorougly described by Kuhn-Schnyder (1987) and no further description is needed here. It only has to be noted that, as specified in the discussion and in Tab. 1, the amount quoted by Kuhn Schnyder (1987) as "praesacrale Rumpfwirbellange", must be considered as "praecaudale". As already quoted in the introduction, T-4288 PIMUZ was considered a separate species, *L. lavizzarii* by Kuhn-Schnyder (1987), on the basis of the narrow outline of the skull and of the relatively shorter humerus (Kuhn-Schnyder 1987, p. 15). The skull outline of the Val Mara specimen, however, falls within the normal range of variability and thus cannot be considered a diagnostic character, as already suggested by Tschanz (1989).

Furthermore, it can be demonstrated that the difference in the relative length of the humerus with respect to the femur of T-4288 PIMUZ is approximately the same as in *Lariosaurus balsami* specimens. To demonstrate the presence of different ratios among limb sections between T-4288 PIMUZ and *L. balsami*, Kuhn-Schnyder published two tables (1987, p. 15); in the first one the author compared the humerus/femur ratio of different *Lariosaurus* specimens, but no significant data are obtained; in the second table (Kuhn-Schnyder, 1987, p. 15, here Tab. 2), the author compared the percentual ratios existing between the different limb sections and the "praesacrale Rumpfwirbellange" (actually the length of both the dorsal and sacral region, as can be pointed out from Tab. 1; from Peyer, 1933, 1934 and Tintori & Renesto, 1990). The algorythm was: length of the limb bone divided by the length of the (dorsal plus sacral) portion of the vertebral column x 100 (e. g. in the case of the humerus of the Frankfort specimen of *L. balsami* the ratio results: 21 : 95 x 100 = 22.1). The length relative to the femur of T-4288 PIMUZ resulted approximately the same as for larger *L. balsami* specimens, apparently excluding allometry during growth. For this reason the remarkably lower ratio for the humerus of T-4288 PIMUZ (nearly two times lower than in other specimens) was considered by Kuhn-Schnyder as a diagnostic character. However, the exact ratio for the femur of T-4288 PIMUZ is actually 21.6 and not 27.2 (to reach this value the femur should have been at least 22 mm long instead of 17.5). This implies that *both* the anterior and posterior stylopodia are relatively shorter in T-4288 PIMUZ, and their difference is approximately the same as in the *L. balsami* specimens. The comparison with other small specimens of *Lariosaurus* shows that they share the same pattern (Tab. 3), and the presence of allometry is confirmed. As a consequence the diagnosis for *Lariosaurus lavizzarii* is not valid.

The taxonomic assignment of 550 MCSNIO rises problems; only one other *Lariosaurus* specimen has been discovered so far in the same locality. This specimen is large and has a relatively higher humerus/femur ratio (0.95) than *L. balsami* (0.80) (Tintori & Renesto, 1990, here Tab. 4 and Fig. 5) and was ascribed to a different species *L. valceresii* (Tintori & Renesto, 1990). Morphological differences are also present in the humeri of *L. balsami* and *L. valceresii* (Fig. 4). The humerus of *L. balsami* (Fig. 4 A) is rather pachyostotic, and its cross section changes very little along the

Specimen	T-4288 PIMUZ	550 MCSNIO
Length of:		
Skull (snout-occipital condyle)	37	31
Vertebral column (dorsal)	68	65
Vertebral column (sacral)	13	12
Humerus	13.5 - 13	13 - 13
Radius	7 - 7.5	6.5 - 7
Ulna	7 - 7	7 - 7
Third metacarpal	4 - 4	4
Femur	17.5	16 - 16
Tibia	7.5 - 7	6 - 6.5
Third metatarsal	5 - 4.5	5 - 5

Tab. 1 - Measurements (in mm) taken on T-4288 PIMUZ and 550 MCSNIO.

	T-4288 PIMUZ	Munich	Frankfort
Humerus	100:17.0	100:20.3	100:22.1
Femur	100:27.2	100:25.8	100:27.4
Radius	100:10.6	100:10.6	100: 9.4
Ulna	100:11.6	100:11.6	100:12.6

Tab. 2 - Percent ratios between the presacral (or precaudal) dorsal portion of the vertebral column and different limb sections in some *Lariosaurus* specimens as published by Kuhn-Schnyder (1987).

	T-4288 PIMUZ	Munich	Frankfort
Humerus	100:16.6	100:20.3	100:22.1
Femur	100:21.6	100:25.8	100:27.4

Tab. 3 - The values for the humerus and femur of the same specimens of Tab. 2, with the correct value for the femur of T-4288 PIMUZ.

shaft. The bone is distinctly bent posteriorly in the middle and no distinct processes can be detected in the distal portion. The humerus of *L. valceresii* (Fig. 4 B), on the other hand, is comparatively more slender, the shaft is straighter, the distal portion is distinctly enlarged and flattened compared to the proximal one, the entepicondylar foramen is placed more distally to the long axis of the bone, and finally a distinct supinator process is present. These differences were ascribed by Tintori & Renesto (1990) to improved swimming ability of *L. valceresii* with respect to *L. balsami*.

The juvenile specimens 550 MCSNIO and T-4288 PIMUZ, however, does not share these characters. This may lead to different conclusions. It is possible that the specimens from the Kalkschieferzone do belong to a separate species from *L. balsami*,

but in the juveniles, being the humerus not completely ossified, the diagnostic characters cannot be detected. An alternative hypothesis is that the differences in proportions and morphology of the anterior limb among the large lariosaur specimens (Fig. 4, 5) are due to sexual dimorphism rather than to specific diversity, as suggested by Sander (1989) for *Neusticosaurus*. In some *Neusticosaurus* species, the juveniles and some adult specimens show a lower humerus/femur ratio with respect to other conspecific individuals along with a different shape of the bone; these differences were interpreted by Sander (1989) as indicators of sexual dimorphism and related to differ-

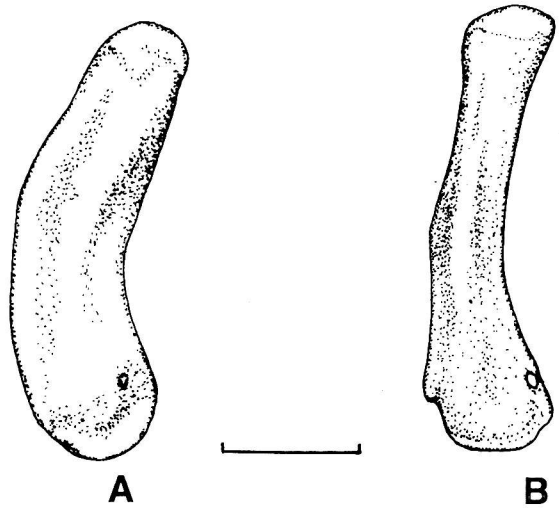

Fig. 4 - Morphological comparison of different lariosaur humeri. A) *L. balsami*, Munich specimen (after Peyer, 1933); B) *L.valceresii*, holotype (after Tintori & Renesto, 1990). Scale bar equals 2 cm.

Specimens	A	B	C	D	E	F	G	H	I
Humerus	16.2	16.6	17	22.1	24.6	20.2	21.6	23.5	20.8
Femur	19	21.6	20.5	27.4	26.9	24.9	26.1	24.4	25.8
Difference	2.8	5	3.5	5.3	2.3	4.7	4.5	1.9	5
(D+S)VC	77	81	83	95	126	142	235	251	302

Tab. 4 - In the first two lines the same ratios (recorded as percentual) for the humerus and femur of Tab. 2 and 3 are listed for many *Lariosaurus* specimens, along with the difference (Diff.) between that for the humerus and for the femur. With (D+S)VC is recorded the length of the dorsal plus sacral portions of the vertebral column. The different *Lariosaurus* specimens are indicated as follows: A) 550 MCSNIO; B) T-4288 PIMUZ; C) *L. balsami*, spec. L 662 (Ticli, 1984); D) *L. balsami*, Frankfort specimen (Peyer, 1933); E) *L.valceresii*, specimen M 505 from Estada (Sanz, 1976; Tintori & Renesto, 1990); F) *L. balsami*, spec. L 202 (Ticli, 1984) ; G) *L. balsami*, spec. Curioni VI (Peyer, 1933); H) *L. valceresii*, holotype (Tintori & Renesto, 1990); I) *L. balsami*, Munich specimen (Peyer, 1933). Data based on personal observations for T-4288 PIMUZ, 550 MCSNIU, L 662, L 202 and for *L. valceresii* holotype. Other data are from Peyer (1933, 1934) and Sanz (1976).

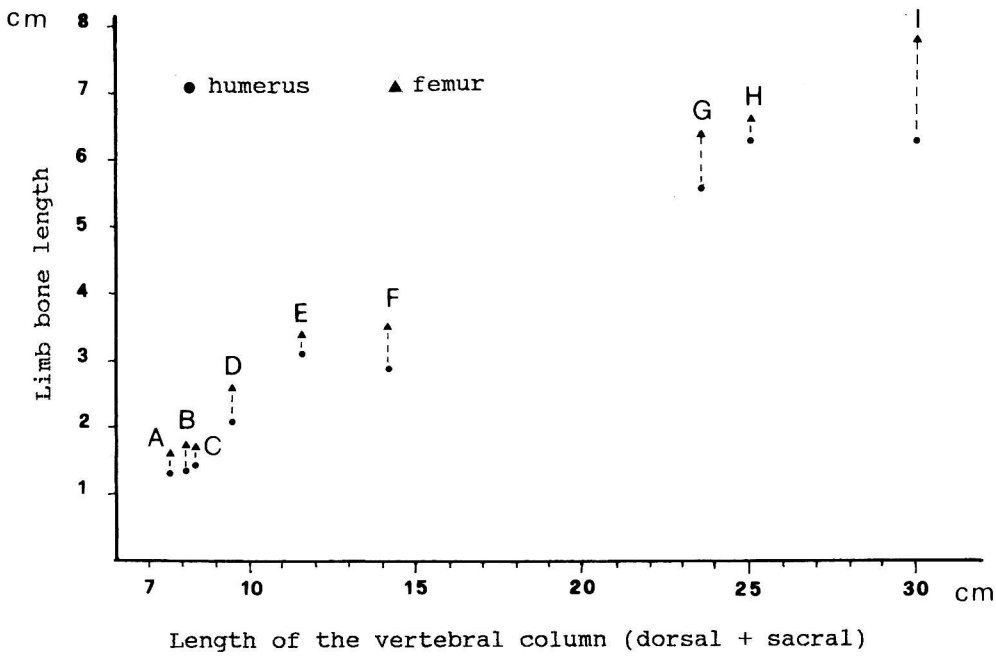

Fig. 5 - Diagram of humerus (circles) and femur (triangles) length of different *Lariosaurus* specimens, plotted against growth stage. On the vertical axis, limb bone length is shown; on the horizontal axis, the length of the dorsal plus sacral portion of the vertebral column is recorded. Specimens are labelled as in Tab. 4.

ent swimming abilities. In the first case *L. lavizzarii* has priority, even if the diagnosis is not valid and the holotype is a juvenile one, and *L. valceresii* should be invalidated. If the differences in limb proportions are due to sexual dimorphism, *L. lavizzarii* (= *L. valceresii*) should actually be the other sex of *L. balsami*, which then would be the only valid lariosaur species (along with *L. buzzii* Tschanz, which Kuhn-Schnyder, 1990, transferred to a different genus, *Silvestrosaurus*). Unfortunately, there are not as many *Lariosaurus* specimens as there are for *Neusticosaurus*, which renders difficult any comparison. It is rather strange however that all the adult specimens from Perledo-Varenna Limestone should belong to the same sex and that those of the other sex should have been found in the Kalkschieferzone and in the Triassic of Spain (Tintori & Renesto, 1990). In addition, it has to be noted (even if it is not a conclusive evidence) that the number of dorsal vertebrae of 550 MCSNIO, of the holotype of *L. valceresii* (Tintori & Renesto, 1990) and of the Spanish specimen (Sanz, 1976), is lower than that of *L. balsami* specimens (20 instead of 22).

Sanz (1983) described other nine *Lariosaurus* specimens from the Ladinian of Montral-Alcovar (Tarragona, Spain), which yielded the specimen (Sanz, 1976) ascribed to *L.valceresii* (Tintori & Renesto, 1990). Unfortunately, they are fossilized as natural casts and some are incomplete. Only four specimens are complete enough to allow

comparisons (Sanz, 1983, p. 211, tab. 6); three, however, are very small juveniles with the same proportion of other small lariosaurs (humerus/femur ratio ranging from 0.69 to 0.74), and only one (reported by Sanz, 1983 as Solenhofen specimen) is somewhat longer than the specimen described by Sanz (1976). Apparently its humerus is slightly *longer* than the femur (humerus/femur ratio = 1.01) and this fits well the diagnosis for *L. valceresii*. Kuhn-Schnyder (1987, p. 18), however, doubts that the inclusion of this specimen within the genus *Lariosaurus* was correct. At present there are only slight evidences for the assignement of the specimens from the Kalkschieferzone and from Montral Alcovar to a separate species, thus it is advisable to leave the question open, since only future finds will allow more reliable decisions.

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PLATE 1

Lariosaurus sp. Specimen 550 MCSNIO from the Kalkschieferzone of Cà del Frate exposed in dorsal view. Scale bar equals 2 cm.