FIRST REPORT OF CLARAIA (BIVALVIA) IN THE SERVINO FORMATION (LOWER TRIASSIC) OF THE WESTERN OROBIC ALPS, ITALY

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Riassunto. Viene per la prima volta segnalata la presenza di un orizzonte a Claraia nel Servino della Valsassina (Alpi Orobie occidentali), situato a circa 8 m dalla base formazionale. Gli esemplari presentano un'ampia variabilità morfologica che interessa principalmente l'ornamentazione. Questo ha portato a distinguere in vari morfogruppi riferibili alle seguenti morfospetie: C. cf. aurita (Hauer, 1850), C. cf. bittneri Ichikawa, 1958, C. teiad/a (Leonardi, 1929), C. intermedia (Bittner, 1901), C. radialis (Leonardi, 1929) e C. cf. clarai (Emrich, 1844). Applicando il concetto di specie-popolazione, la maggior parte degli esemplari è riconducibile a C. intermedia mentre i rimanenti, per la conservazione non ottimale, vengono classificati in nomenclatura aperta (C. cf. aurita).

L'orizzonte a Claraia delle Alpi Orobie viene correlato ai livelli di transizione tra le subzone a C. clarai e C. aurita della Fm. di Werfen (Membro di Siusi) delle Dolomiti, dove le coeve popolazioni a Claraia registrano, parimenti a quella investigata, un'ampia variabilità intraspescifico. Significativa è la presenza, in questi livelli a C. intermedia, di esemplari a prevalente scultura radiale riferibili a C. radiatiis (Gruppo C. stachel). L'orizzonte a Claraia, che documenta nel Servino delle Alpi Orobie il primo evento trasgressivo triassico contenente fossili marini significativi dal punto di vista cronosтратigrafico, è riferibile ad un'età posta tra il Griesbachiano finale e il Dieneriano inferiore.

Abstract. A fossiliferous horizon containing Claraia is reported for the first time 8 m above the base of the Servino Fm. in the western Orobie Alps (Lecco, Lombardy). The specimens have a broad morphological variability which mostly concerns the sculpture, and thus several morphospecies can be recognized (C. cf. aurita (Hauer, 1850), C. cf. bittneri Ichikawa, 1958, C. teiad/a (Leonardi, 1929), C. intermedia (Bittner, 1901), C. radialis (Leonardi, 1929), C. cf. clarai (Emrich, 1844)). These taxa have mostly been classified into C. intermedia by applying a species-population concept.

The Claraia horizon of the Orobie Alps can be correlated with the transitional layers between the C. clarai and C. aurita subzones of the Werfen Fm. (Siusi Member) in the Dolomites. Thus, in this area, the first Triassic marine transgression with age-diagnostic fossils of the Servino Fm. may have an age ranging from the latest Griesbachian to the early Dienerian.

Introduction.

The cosmopolitan genus Claraia is an important tool from both a stratigraphical and a paleogeographical point of view for the Early Triassic (Nakazawa, 1977; Yin, 1985). In particular, it has a great chronological value for marine successions lacking ammonoids, as it occurs in the Western Tethys. Claraia is very abundant in the eastern Southern Alps (east of the Adige valley), where discoveries have been made since the first half of the last century (Dolomites, Carnia, Valsugana, Recoaro; Fig. 1). Here Claraia occurs in the lower members (Mazzin and Siusi) of the Werfen Fm. (Broglio Lorig et al., 1983). To the west of the Adige valley quotations are so far rare, with the last and uncommon discoveries being in the Servino Fm. of the Giudicarie area (Lepsius, 1878; Fig. 1). The Dolomites were submerged beneath a shallow sea while the sedimentary environment passed westward to mud-flat conditions (Assereto et al., 1973).

The Servino Fm. (Brocchi, 1908; Assereto & Casoni, 1965) represents the Lower Triassic in Lombardy. It rests paraconformably on the Permian Verrucano Lombardo continental red beds. A regional westward encroachment onto Permian highlands (Assereto at al., 1973) suggests the occurrence of a hiatus at the forma-}

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Stratigraphic setting and sedimentary environment of the *Claraia* beds in the western Orobie Alps.

The fossil locality is located in the Cignoletta valley, a stream channel on the northern slope of the Grigna Group near the small town of Primaluna (Valsassina, Lecco; Fig. 1). In the Cignoletta valley a complete section of the southern limb of the Orobie Anticline and the overlying Northern Grigna thrust sheet is exposed (Fig. 2). In the lower part (750 m a.s.l.) biotite paragneisses of Hercynian age ("Gneiss minuti a biotite" Auct.) are tectonically overlain by the Upper Permian continental red beds of the Verrucano Lombardo (13+17 m-thick).

The Servino Fm. rests paraconformably on the Verrucano Lombardo. The lithostratigraphy adopted here for the Servino Fm. in the western Orobie Alps is based on that proposed by Scinnach et al. (1996), who recognize three different intervals from the top of the Verrucano Lombardo: Prato Solaro Member, middle part of the Servino Fm. and upper part of the Servino Fm. In the Cignoletta valley, the Prato Solaro Member is 0.7 m-thick (Fig. 2). It is represented by texturally mature quartzose conglomerates and sandstones largely deposited in fan-delta setting, the thickness of which ranges from less than 1 m to 50 m in the western Orobie Alps.

The middle part of the Servino Fm., 62 m thick, consists of mature, fine-grained quartzarenites and medium- to coarse-grained sublitharenites with abundant interstitial ferroan dolomite in 5 to 40 cm-thick beds. Grey, micaceous calcareous siltstones in 1 to 5 cm-thick beds and thin veils of black organic-rich to deep red mudrocks are intercalated. This interval was deposited in a high-energy coastal setting influenced by both tides and waves. *Claraia* beds are found in this interval about 8 m above the base of the formation. These bivalves occur in two distinct levels (Fig. 2) which belong to a horizon, 45 cm-thick, of medium- to coarse-grained sandstones with current ripples passing upwards to medium-scale cross- and trough-lamination; the topmost festooned layer displays parting lineation at the base and winnowed granules at the top. A high-energy upper shoreface environment is thus indicated for the *Claraia* beds.

The upper part of the Servino Fm. consists of yellow dolostones and greenish to deep red siltstones, and is over 50 m-thick in this section with faults at the top.
Material and Taphonomy.

The collection consists of about sixty specimens represented by disarticulated left and right valves (Tab. 1). All studied material is deposited at the Museum di Paleontologia dell’Università di Milano with the numbers MPUM 8002-8066. The specimens mostly come from the lower level (A). In the upper level (B) only a few specimens have been collected (no. 54, 55, MPUM 8017, 8018). The fossils are preserved as composite moulds, although the state of preservation is not always good. The majority of the specimens are in sandstone and thus the fine sculpture is often smothered and obscured, especially that occurring in the middle and um-
Fig. 3 - Scatter diagram of measurements of the length and height of the valve distinguished into two groups on the basis of sculpture pattern: group A with only concentric elements, group B with concentric and radial elements. If both groups belong to a single bio-species then it has an early growth stage with only concentric sculpture (small-sized specimens of group A), a polytypic middle stage (area of superimposition between the two groups) and a late ontogenetic stage (large-sized specimens of group B) with specimens all radially-ornamented. Legend: 1, 2 specimens of group A with complete (1) or broken (2) margins; 3, 4 specimens of group B with complete (3) or broken (4) margins. Broken lines delimit the specimens with a complete outline so that they show the real scattering of the sample. Measurements and groups are in Tab 1.

Fig. 4 - Histogram of the subgroups based on the sculpture pattern described in text. Specimens of subgroup A3 are interpreted as being early growth stages of subgroup B2; frequencies of A1 and A2 are overestimated because many of the small size specimens have to be considered as early stages of subgroup B1.

The largest specimens are all radially ornamented with ribs and costellae developed to a variable extent. In some specimens, the radial elements occur only on the ventral region (no. 18, MPUM 8005, Pl. 1, fig. 7) whereas in others they extend in the middle and prevail over the concentric ones (no. 11, MPUM 8006, Pl. 1, fig. 11). On the basis of the strength, extension and kind of sculpture, the following classification can be applied to the specimens examined: group A with only concentric sculpture; group B with concentric and radial sculpture (Tab. 1; Fig. 3). Each group is further subdivided into three subgroups (Fig. 4):

A1 - smooth or with fine growth lines.
A2 - concentric lines and irregular, weak concentric folds.
A3 - rather regular concentric folds.

PLATE 1

Claraia from the Claraia intermedia horizon (bed A), lower part of the Servino Fm. of the Cügnolella valley, Valassina (western Orobie Alps), Lecco Province. All specimens are natural size and whitened with magnesium fumes.

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Fig. 1-3, 4b, 5b - Claraia cf. aurita (Hauer, 1850). Morphospecies: Claraia cf. aurita (Hauer, 1850), fig. 1 (no. 15, MPUM 8013, left valve) and 5b (no. 52, MPUM 8012, left valve) (subgroup A1); Claraia cf. bittneri Ichikawa, 1958, fig. 2 (no. 48, MPUM 8007, left valve), 3 (no. 38, MPUM 8003, right valve) and 4b (no. 2, MPUM 8014, left valve) (subgroup A2).

Fig. 4a, 5a, 6-13 - Claraia intermedia (Bittner, 1901). Morphospecies: Claraia cesidea (Leonardi, 1929), fig. 4a (no. 1, MPUM 8215, right valve) and 6 (no. 47, MPUM 8008, right valve) (subgroup A3); C. intermedia (Bittner, 1901), fig. 7 (no. 18, MPUM 8005, left valve) and 8 (no. 12, MPUM 8009, left valve) (subgroup B1); C. cf. clarai (Emmrich, 1844) (transitional forms between C. clarai and C. intermedia), fig. 5a (no. 53, MPUM 8016, left valve), 9 (no. 16, MPUM 8010, left valve with acute concentric folds) and 10 (no. 4, MPUM 8002, left valve with rounded concentric folds) (subgroup B2); C. intermedia (Bittner, 1901), fig. 12 (no. 5, MPUM 8004, right valve) and C. radiata (Leonardi, 1929), fig. 11 (no. 11, MPUM 8006, left valve) and 13 (no. 27, MPUM 8011, left valve) (subgroup B3).
B1 - weak radial ribs and riblets with concentric lines and low folds occurring on the ventral region in adult stage; middle and umbonal parts smooth.

B2 - concentric folds or wrinkles arising in the middle part of the body with radial ribs and riblets; marginal region in adult stage reticulate, lacking concentric folds.

B3 - radial sculpture prevailing over concentric sculpture, mostly restricted to anterior and posterior regions.

Classification.

The genus Claraias currently consists of more than sixty species and subspecies. This excessive splitting and "taxonomic provincialism" (Assereto et al., 1973, p. 189) arises both from taphonomic and genetic factors. Lower Triassic formations frequently consist of terrigenous sediments to various degrees, and thus fossils are affected by deformation to different extent. Furthermore, Claraias can display a very high genetic plasticity (Broglie Loriga et al., 1983) which mostly affects the sculpture. Many of the past authors did not consider such sources of variability and applied a rigid morphological concept of species thus creating a rather confused taxonomy. Therefore for a chronological and biogeographical use of Claraias, as pointed out by Broglie Loriga et al. (1983) and Newell & Boyd (1995), a modern classification of species based on the population analysis becomes necessary.

The Claraias classification proposed by Ichikawa (1958) is mostly based on the sculpture pattern, on the basis of which he gathered the species into four informal groups: C. clarai, C. aurita, C. stachei and C. decidens. Later, Nakazawa (1977) split each of the former three species-groups into two subgroups, named A and B on the basis of the occurrence (A) or absence (B) of the posterior auricle differentiated from the body. Such a classification has a pure morphological value since species-groups "are not sharply defined from each other" (Nakazawa, 1977, p. 193), with transitional morphotypes connecting them. Besides, such a classification has no chronological value as each species-group yields species with different chronological distributions. Nakazawa (1977) noted that only the C. decidens group could be treated as a subgroup because it has a strongly inflated left valve with a dorsoventrally elongated outline (H > 1). For this species-group, Newell & Boyd (1995) have introduced the new genus Crittendenia.

Morphospecies. Claraias from the Valsassina are longer than higher and posteriorly auriculate, and therefore they do not belong to the C. decidens group and fall within subgroups A (posteriorly auriculate) of the other three groups of Ichikawa (1958) and Nakazawa (1977).

By applying a typological concept of species, the subgroups distinguished within the Orobie material can be classified into different morphospecies belonging to the C. clarai, C. stachei and C. aurita groups. Such a classification has been carried mostly on the basis of comparisons with the species erected in the Southern Alps, and thus the classical paleontological works on the Werfen Formation (Hauer, 1850; Tommasi, 1895; Bittner, 1901; Wittenburg, 1908; Ogilvie Gordon, 1927; Leonardi, 1935; etc.) have been used. Of particular interest is Leonardi's (1960) paper, in which most of the known Alpine species and their transitional forms are illustrated. This paper also provides a picture of the broad variability of this genus. However, a precise species determination for each subgroup proposed is not always possible because many of the known morphospecies have been erected on the basis of a few (or single) specimens representing the external morphology of populations with a broad variability and numerically dominated by intermediate forms.

Subgroups A1, A2: C. cf. aurita (Hauer, 1850) and C. cf. bittneri Ichikawa, 1958. On the basis of sculpture, subgroups A1 and A2 belong to the C. aurita group of Ichikawa (1958). However, typical forms of C. aurita are absent because the concentric lines are not regular and raised (e.g. no. 52, MPUM 8212, Pl. 1, fig. 5b), even though lack of this character could be linked to the bad state of preservation. Some of subgroup A2 (no. 48, 38, MPUM 8607, 8603, Pl. 1, fig. 2, 3) can be compared with C. bittneri [ex C. tridentina (Bittner, 1901)]. However, this species does not have a very differentiated posterior ear. Some specimens closely related, which are ovoidal and posteriorly elongated with irregular concentric folds and lines and a differentiated posterior ear, similar to those of subgroup A2, were classified by Ogilvie Gordon (1927, pl. 1, fig. 3) as C. intermedia (Bittner, 1951).

Subgroup A3: C. tesidea (Leonardi, 1929). These specimens, with only rounded concentric folds (e.g. no. 47, MPUM 8008, Pl. 1, fig. 6), should be considered to be an early growth stage of C. tesidea, which was originally erected as a variety of C. clarai. C. tesidea was originally described as having acute folds or wrinkles with radial ribs in some cases occurring on the ventral region of mature individuals, which makes the adult stage very similar to C. intermedia. However, Leonardi (1960, pl. 6, fig. 6) attributed a right valve of middle size, with rounded concentric folds lacking radial elements to C. tesidea. Therefore, subgroup A3 which yields small to middle-sized specimens can be attributed to C. tesidea (C. clarai group). This species is here considered as a possible juvenile morphotype of C. intermedia.

Subgroup B1: C. intermedia (Bittner, 1901). It belongs to C. intermedia (C. stachei group of Ichikawa,
forms previously illustrated by Hauer (1850, pl. 3, fig. 6, 9) and Leonardi (1960, pl. 7, fig. 3).

Subgroup B2: C. cf. clarai (Emmrich, 1844). These specimens show transitional features between C. clarai and C. intermedia (no. 16, 4, MPUM 8010, 8002, Pl. 1, fig. 9, 10), since the middle body has a clarai-type sculpture whereas the marginal region has a reticulate ornamentation of intermedia-type. Concentric folds are both rounded (Pl. 1, fig. 5a, 10) and acute (Pl. 1, fig. 9).

Subgroup B3: C. intermedia (Bittner, 1901) and C. radialis (Leonardi, 1929). These specimens fall within the C. radialis - C. intermedia group of Leonardi (1960), which was later considered by Nakazawa (1977) as C. intermedia. Some specimens (e.g. no. 11, 27, MPUM 8006, 8011, Pl. 1, fig. 11, 13) can be ascribed to C. radialis (Leonardi, 1929).

Species based on population analysis. As already recorded, various authors pointed out that the recognition of Claraia species needs a population analysis. Claraia belongs to the order Pectinoida Newell & Boyd, 1995 (Fam. Pterinopectinidae Newell, 1938), which yields many polytypic species with "strikingly variable" (Newell & Boyd, 1995, p. 22) populations.

The Claraia collection from the Ciugnoletta valley mostly comes from a single bed (A), thus the sample is nearly composed of coeval individuals. They have been previously gathered into six different subgroups, the extreme morphotypes of which are generally connected by intermediate forms. The occurrence of these transitional forms suggests the possibility that the majority of the morphospecies already recognized can be treated as morphotypes of a single (or few) species. The name assigned to this (or these) species will be that of the most abundant morphotype.

Subgroups B1 and B3 have been referred to C. intermedia, B2 yields transitional forms between C. clarai and C. intermedia, whereas A3 (C. tesidea) can be considered to be an early growth stage of subgroup B2; therefore C. intermedia and its transitional forms are predominant and characterize the Claraia horizon of the Ciugnoletta valley.

C. intermedia was erected by Bittner (1901) on the basis of specimens with transitional characters between C. clarai and C. aurita previously illustrated by Hauer (1850, pl. 3, fig. 6, 9). The type-specimens illustrated by Hauer (1850) have a prevailing concentric ornamentation made of irregularly-spaced folds and lines, while the radial ribs appear in the middle body (fig. 6) or in the ventral region (fig. 9) as also occurs in subgroup B1. Bittner (1901) named the specimens with an equal development of radial and concentric sculpture (reticulate pattern) as var. cancellata (Bittner, 1901, p. 28, pl. 24, fig. 12). In the same paper, Bittner noted that some specimens of the clarai group have a radial sculpture prevailing over the concentric one; for these forms he erected "Pseudomonotis (Claraia) stachei n. sp." (Bittner, 1901, p. 29, unfigured). According to Bittner, C. stachei has the greatest size of shell with respect to the other Alpine Claraia. On the basis of the same sculpture pattern, Leonardi (1929, p. 63, illustrated in Leonardi, 1932, pl. 1, fig. 8) proposed "Pseudomonotis Claraia Emm. var. radais var. n." which was elevated to specific level by Nakazawa (1977). [For discussion on the nomenclatural question about these two probably synonymous species, see Nakazawa (1977) and Yin (1985). The present authors accept the reasons expressed by Nakazawa (1977) for considering both species valid and for using C. stachei according to the meaning of Spath (1930) and Newell & Boyd (1995)].

Bittner (1901) erected C. intermedia and C. stachei on the basis of material coming from different localities and perhaps from different stratigraphic settings but he described them as if no morphological break existed among them. The coeval specimens collected in the Claraia horizon of the Valsassina have a very high morphological variability. They display all the possible intermediate and extreme morphotypes of a Claraia population which could correspond with the transition between the C. clarai and C. aurita stages recognized in the Dolomites. Therefore the absence of the typical forms of these species may be related to the evolutionary stage recorded in the Valsassina, even if other causes can not be ruled out such as diagenesis which, in particular, could have obscured the aurita-like pattern sculpture.

In conclusion, the majority of the Claraia specimens of the Valsassina (A3, B1, B2, B3 subgroups) can be considered to belong to C. intermedia which, besides the typical forms, yields morphotypes with transitional characters towards C. clarai and C. radialis, with C. radialis as a possible adult extreme morphotype and with C. tesidea among the juvenile morphotypes.

As to the specimens ascribed to subgroups A1 and A2 (C. aurita group), many of those small and middle sizes probably have to be considered as juvenile stages of subgroup B1, and thus the frequency of the C. aurita group (Fig. 4) is overestimated. For the large-sized specimens of subgroup A1 (e.g. no. 52, MPUM 8012, Pl. 1, fig. 5b) and A2 (e.g. no. 38, MPUM 8003, Pl. 1, fig. 3) there are two different possibilities: they can be considered either as belonging to a species distinct from C. intermedia and comparable to C. aurita or else as another extreme morphotype of C. intermedia, as is suggested by the scatter diagram of Fig. 3 and by the original meaning given to C. intermedia. Because of the bad state of preservation of the present material, we prefer to classify them as C. cf. aurita for the moment.
Among the specimens assigned to the C. aurita group, a further distinction could be made on the basis of the shape and obliquity (i.e. nearly suborbicular, adine morphotypes and ovoidal, prosocline morphotypes). However, specimens of the present material of which the outline is well-preserved enough to make an objective recognition of the obliquity possible are too few for a population analysis. Besides, at the moment, there is no data in the literature on the stratigraphical distribution in the Southern Alps of the different morphotypes of C. aurita group based on these features, which are frequently affected by diagenetic deformation in marly lithotypes. Further stratigraphical and taxonomical research within the C. aurita beds needs to assess the biostatigraphical meaning of these taxonomical features.

Correlation with the Claraia subzones in the Dolomites.

The Claraia Zone has been divided in the Dolomites into three subzones: C. wangi-griesbachii, C. clarai and C. aurita, with C. dalpiazi beds at the top of this youngest subzone (Broglio Loriga et al., 1983, 1990). These subzones correspond to the upper Mazzin Member, the lower Siusi Member and the middle Siusi Member of the Werfen Formation respectively. The Claraia beds of the Valsassina do not yield any of the index-species of the Dolomites, and thus only an indirect correlation is possible. The large size of the shell and the occurrence of specimens with radial sculpture rule out their correlation with the C. wangi-griesbachii subzone.

The occurrence of specimens with transitional features towards C. clarai (subgroup B2) could be used for a tentative correlation with the C. clarai subzone of the western Dolomites, which is about 20-25 m-thick (Broglio Loriga et al., 1983). Such a hypothesis is supported by the absence of specimens with a strong radial sculpture in the C. aurita subzone (about 20 m-thick) and by the report of C. radialis and C. intermedia in the C. clarai subzone of the Dolomites (Broglio Loriga et al., 1983, p. 559). However, the occurrence in the Valsassina sample of C. cf. aurita seems to exclude the possibility of a direct correlation with this subzone. Therefore the Claraia horizon of the Cugnoletta valley can be correlated with the transitional beds between the clarai and aurita subzones of the Dolomites. Leonardi (1960) recorded C. intermedia at Tesero (Dolomites), where it is reported from the upper C. clarai beds (? last 10 m of the C. clarai subzone of Broglio Loriga et al., 1983) to the lower C. aurita beds, where its acme occurs (Tab. 2). At Tesero, C. aurita is predominant over C. clarai (185 versus 8 specimens) and all the morphospecies recognized in the Valsassina also occur. In the next fossiliferous horizons at Tesero, characterized by C. aurita and C. dalpiazi (C. aurita subzone of Broglio Loriga et al., 1983), C. intermedia disappears.
In conclusion, the *Claraia* beds of the Valsassina can be correlated with the transitional beds between the *C. clarai* and *C. aurita* subzones of the Dolomites, where typical forms of *C. aurita* are already present. In such a way the absence of the typical *C. aurita* specimens in the Valsassina may depend on diagenetic factors, which smoothed and obscured these sculptures in the specimens of subgroups A1 and A2.

**Age.**

The ages assigned to the *Claraia* subzones of the Dolomites have been obtained by means of the associated conodonts and by correlations with sequences bearing ammonoids and *Claraia*, of which the nearest occur in Iran (Julfa and Abadeh). The lower limit of the C. *wangi-griesbachii* subzone roughly coincides with the appearance of the conodont *Isarcicella isarcica* (Huckriede, 1958), and thus it marks the beginning of the upper Griesbachian (Brocchi G.ogr. et al., 1988). The *C. clarai* and *C. aurita* subzones have been tentatively considered to be latest Griesbachian and Dienerian respectively, mostly on the basis of correlations with the Iranian sequences. Therefore the Griesbachian/Dienerian boundary in the Dolomites has been tentatively drawn at the limit between these two subzones (Brocchi G.ogr. et al., 1983, 1990). According to the finding of *Neospathodus dieneri* Sweet, 1970 in the topmost part of the Mazzin Member (Perri, 1991), the age assignment of the *C. clarai* subzone should be Dienerian, excluding the topmost Griesbachian. Further research seems to be necessary to definitely assess this point.

In Iran, *C. intermedia* is reported in the upper *Isarcicella isarcica* Zone (upper Griesbachian) of Unit a in the Abadeh region (Iranian-Japanese Research Group, 1981). It appears earlier than *C. aurita* as at Julfa (Nakazawa, 1977), where both species fall within the *Gyronites* Zone (lower Dienerian). Therefore the Iranian *C. intermedia* beds have an age ranging from the uppermost Griesbachian to the lower Dienerian, and thus the *Claraia intermedia* horizon of the Valsassina would fall within such a time-interval.

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