

OXFORDIAN BIOSTRATIGRAPHY AND AMMONITE ASSOCIATIONS FROM WEST SICILY: BIOSTRATIGRAPHIC SUCCESSION OF GENUS *GREGORYCERAS* AND CORRELATION WITH TETHYAN PERISPHINCTID SCALE

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Abstract. Middle to lower upper Oxfordian ammonite successions from northwest Sicily, are mainly composed of groups showing a typical Mediterranean character. These include common representatives of suborder Phylloceratina. Among Ammonitina, the bulk of recorded associations is formed by representatives of Mediterranean subfamilies Passendorferiinae, Euaspidoceratinae and Peltoceratinae, with a minor representation of family Oppeliidae. The studied ammonite associations include over two hundred specimens, from which, a whole of one hundred and fifty have been identified and described. They have been collected from three sections located on the southern side of Mount Erice, southwest from the town of Erice (Trapani province).

Taphonomic features displayed by the recorded ammonites indicate, on one hand, sedimentation conditions on an open hemipelagic platform under low turbulence conditions and low sedimentation rate values. On the other hand, Perisphinctid (Passendorferiinae) and Aspidoceratidae assemblages appear dominated by juvenile or pre-adult specimens, indicating palaeobiological entities probably colonizing the area and spreading to epicontinental areas farther North from the southern slope of Tethys.

From the biostratigraphic point of view, stratigraphic succession of representatives of genus *Gregoryceras* has allowed recognising a biostratigraphic succession in the Mediterranean Province, which can closely correlate with the one established with representatives of *Passendorferia* and *Perisphinctes* for the Submediterranean Province.

Riassunto. Le associazioni ad ammoniti dell'Oxfordiano medio-superiore della Sicilia occidentale sono composte da gruppi con tipici caratteri mediterranei. In queste associazioni dominano i rappresentanti del sottordine Phylloceratina. Tra gli Ammonitina prevalgono i rappresentanti delle sottofamiglie Passendorferiinae, Euaspidoceratinae e Peltoceratinae; sono presenti pochi esemplari della famiglia Oppeliidae.

Le ammoniti studiate provengono da tre sezioni localizzate lungo il versante Sud del Monte Erice, ed esattamente a sud-ovest dell'abitato di Erice, in provincia di Trapani. Le associazioni sono costi-

tuite da più di duecento esemplari, dei quali, circa centocinquanta sono stati determinati e descritti.

Le caratteristiche tafonomiche degli esemplari collezionati sono indicative di una sedimentazione avvenuta su una piattaforma emipelagica aperta con condizioni di bassa turbolenza e basso tasso di sedimentazione. Un altro dato importante è la prevalenza di individui giovani o allo stadio pre-adulto nelle associazioni a Perisphinctidae (Passendorferiinae) ed Aspidoceratidae. Questo sembrerebbe indicare una vera popolazione paleobiologica che ha colonizzato l'area, e che dal margine meridionale della Tetide si è irradiata più a Nord in aree epicontinentali.

Dal punto di vista biostratigrafico, la successione stratigrafica dei rappresentanti del genere *Gregoryceras* ha permesso di individuare una successione biostratigrafica nella Provincia Mediterranea, che può essere facilmente correlata con le scale stabilite con i rappresentanti dei generi *Passendorferia* e *Perisphinctes* per la Provincia Submediterranea.

Introduction

Middle Oxfordian of West Sicily (in the province of Trapani), has historically been the subject of research for many authors. However, few monographs are known on the Oxfordian stratigraphy and ammonite successions of this specific area (Gemmellaro 1875, 1877; Arkell 1954; Christ 1960; Gygi 1977, 1990 on the genus *Gregoryceras*, Cecca et al. 2001). Among the recent palaeontological monographs analysing similar successions in other European areas are those of Enay (1966), Brochwicz-Lewinski (1973), Sequeiros (1974), and Meléndez (1989). Fözy & Meléndez (1996) and Fözy et al. (1997) have carried out further detailed analyses and descriptions of Oxfordian ammonite successions in the Transdanubian Central Range (Gerecse Mts) and Mecsek Mts, in southern Hungary. D'Arpa & Meléndez (2001, 2002)

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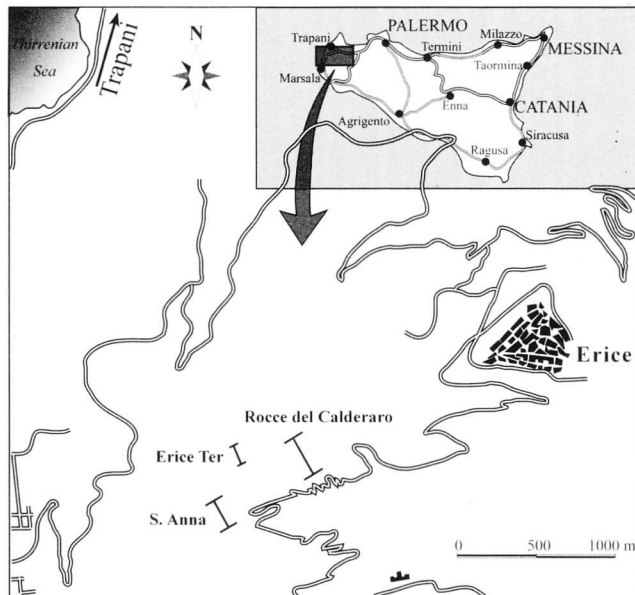


Fig. 1 - Geographic map of the study area, in West Sicily around Mount Erice, showing the precise location of the recorded sections (Rocce del Calderaro, Erice Ter, and Erice S. Anna).

have recently started a new re-examination of Oxfordian ammonite collections housed in the G.G. Gemmellaro Museum of Palermo, gathering new material from some classical sections of Mount Erice (West Sicily), in the surroundings of Trapani.

The purpose of this work is to show the results of new recent ammonite collections in these classical sections first studied by Gemmellaro, in order to provide further information on Oxfordian Tethyan ammonite successions, most particularly on the genus *Gregoryceras*, and its correlation possibilities with classical Oxfordian perisphinctid successions portrayed from typical submediterranean areas. According to the biogeographic classification proposed by Enay (1980) for the Jurassic marine realms, the Submediterranean Province would extend along the northern margin of Tethys including most of shallow epicontinental platforms from southern Europe. Oxfordian ammonite successions from these areas as described by several authors (Cariou 1966; Enay 1966; Malinowska 1972; Meléndez 1989) are mainly characterised by the dominant occurrence of representatives of subfamily Perisphinctinae and Oppeliidae. Such groups as Euaspidoceratinae, Peltoceratinae and Passendorferiinae are generally less common whilst representatives of suborder Lytoceratina and Phylloceratina are clearly anecdotic. In contrast, truly Mediterranean areas (= Tethyan Province proper) as described by Cariou (1973) would be characterised by the mass occurrence of representatives of Lytoceratina and Phylloceratina. After this clear definition, new studies by subsequent authors (Brochwic-Lewiński 1973; Brochwic-Lewiński & Rózak 1976; Sequeiros 1974; Meléndez

1989) have contributed to add further precision to this definition by remarking the high share of such groups as Pachiceratidae (genus *Tornquistes*), Passendorferiinae, Peltoceratinae (gen. *Gregoryceras*), and Euaspidoceratinae as typical features of Oxfordian Mediterranean ammonite successions.

The recorded sections are Erice-S. Anna (E.S.), Erice-Ter (E.T.) and Rocce del Calderaro, formerly referred to as Erice-Difali (E.D.) due to its vicinity to the Difali fountain (Fig. 1). Oxfordian ammonite successions from these sections were first described by Gemmellaro (1877). The Jurassic sequences from Mount Erice around Trapani were briefly described by Renz (1924) whilst the ammonite successions of western Sicily were subsequently described by Arkell (1954; in Warman & Arkell). A detailed description of Oxfordian stratigraphy and ammonite succession was recently carried out by the present authors (D'Arpa & Meléndez 2001, 2002.) According to them, the section of Rocce del Calderaro probably represents the type-locality of many Gemmellaro's species.

Material and Methods

The present study has also included the taxonomic revision of main Oxfordian specimens and taxa originally described and illustrated by G.G. Gemmellaro in his classical monographs between 1872 and 1882. The thickness of Oxfordian interval ranges between fifty centimetres in the section Erice-Ter (ET) and three metres in the section Erice-S. Anna (ES). This suggests the presence of common local stratigraphic gaps or else a rapid wedging out of some levels from one outcrop to another.

Detailed bed by bed sampling in the sections of Rocce del Calderaro and Erice-S. Anna has allowed establishing a standard biostratigraphic succession for the Mediterranean Province. Preliminary results from the first section were summarised in a previous work (D'Arpa & Meléndez 2001). Ammonite associations allow to precisely characterise the biozones and subbiozones of middle and lower upper Oxfordian. The recognised species succession of genera *Passendorferia* and *Gregoryceras* allows to establish a detailed biostratigraphic correlation with other areas of the Submediterranean Province (Meléndez 1989; Meléndez & Fontana 1993). The studied ammonite assemblages include over one hundred specimens from Rocce del Calderaro, of which 67 specimens have been studied in detail, and some 60 specimens from Erice-S. Anna (50 specimens studied and measured in detail). Some further scattered specimens from the near section of Erice-Ter, C. da Diesi quarry (Baldanza et al. 2002) and other sections and from Monte Inici are still under study. Besides the basic taxonomic determination and measures, we have made a detailed taphonomic description of every specimen. These include, on one side, the mechanical state of preservation and, on the other side, the description of most relevant taphonomic features, such as the degree and type of infilling of the shell, the degree and type of fragmentation and/or deformation and any other relevant taphonomic feature; abrasion surfaces or similar. Systematic and biostratigraphic analyses are first steps to characterise the Mediterranean ammonite assemblages and correlation with Submediterranean areas. Taphonomic analysis in turn, is a basic fundamental step to infer the environmental and sedimentary conditions as well as the composition of palaeobiological entities and a previous, necessary condition for biostratigraphic interpretations.

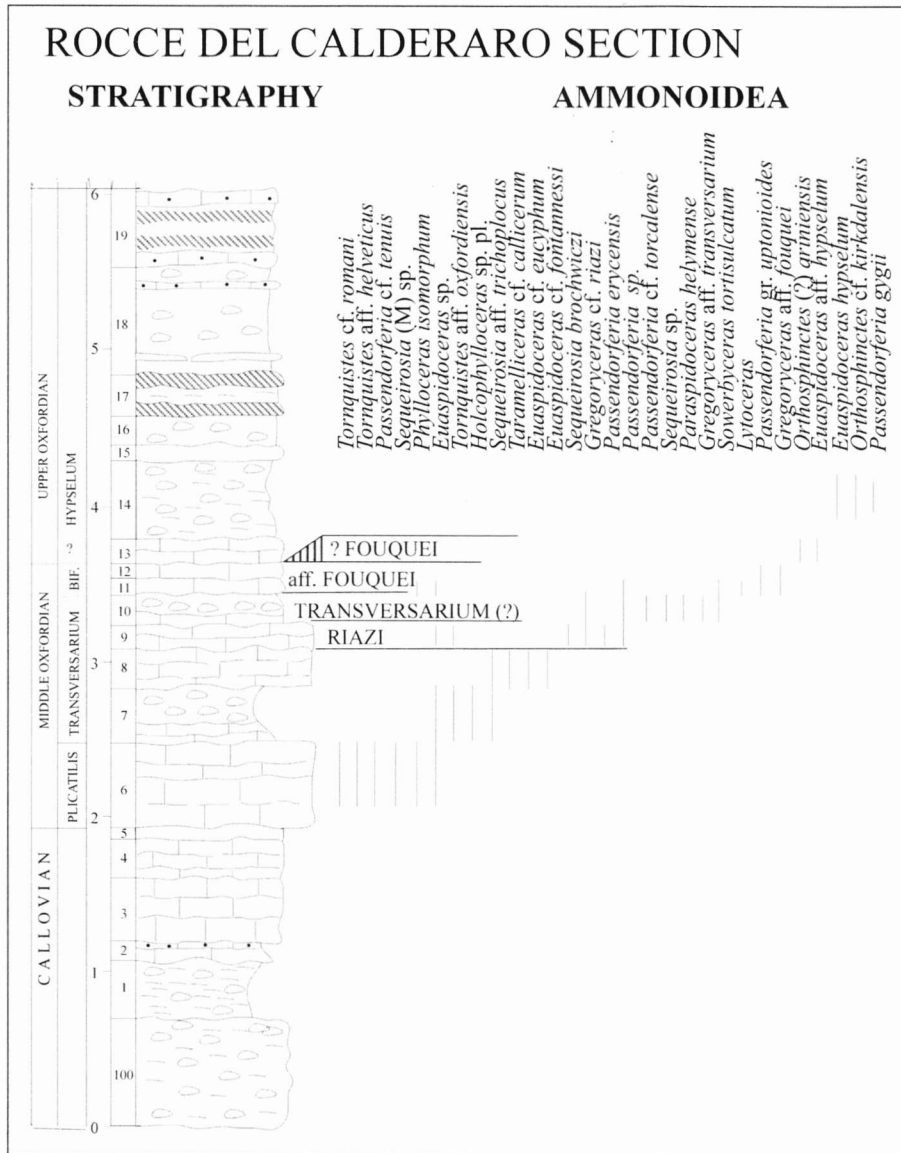


Fig. 2 - Stratigraphic succession of Callovian and Oxfordian at the Rocce del Calderaro section, Mount Erice. The stratigraphic succession of oxfordian ammonite taxa has allowed characterising the main biostratigraphic units of middle and upper Oxfordian from Plicatilis to Hypselum Zone and the corresponding *Gregoryceras* horizons from the here proposed scale. In this point, the record of such forms characterising the lower horizon of Hypselum Zone directly over the levels containing *Gregoryceras* aff. *fouquei* (Kilian) regarded here as a prior, transitional form to the species of Kilian, suggests a small gap of the Fouquei Horizon, so the level 13 might be tentatively assigned to Hypselum Zone, Ariniensis Horizon.

Stratigraphic Descriptions

Rocce del Calderaro section

The studied section, near the Difali Fountain, takes place at the same time with the source place of many specimens that Gemmellaro has studied. The most complete section is located on the southern side of Mount Erice, 1500 to 2000 meters southwest from the town of Erice (Fig. 1). Upper Jurassic in this area is represented by a monotonous sequence of pink micritic, nodular cemented limestones, stratified in dm-thick beds with occasional thin marly layers, showing irregular bedding surfaces. They are referred to the so-called: Rosso Ammonitico Superiore (upper "Rosso Ammonitico" unit). Middle Oxfordian comprises a 1 to 2 m thick limestone sequence formed by regular, decimetric (10 to 40 cm thick) limestone banks (Fig. 2). Levels from 1 to 5 correspond to the Callovian. Level 5 may correspond to the Callovian/Oxfordian transition level, yet its low content of fossils makes it difficult to determine its precise age. Levels 6 to 13 correspond to the middle Oxfordian. The recorded successive ammonite associations allowed to characterise most of the defined subzones and horizons of upper Plicatilis, Transversarium and Bifurcatus biozones. Plicatilis Zone is characterised by the record of several specimens of *Tornquistes* close to the groups *romani* (Douville) - *helvetiae* (Tornquist) and some early representatives of *Passendorferia*. The species *Tornquistes helvetiae* (Tornquist) has been reported by Thierry & Charpy (1982, p. 636) from the Plicatilis

Zone across the Submediterranean and Subboreal provinces in different levels from Vertebrale to Antecedens subzones. Levels 7 to 10 have yielded common specimens of *Gregoryceras* of the *riazi* (Grossouvre) - *transversarium* (Quenstedt) groups, which allow to assign this interval to the middle-upper part of Transversarium Zone. Attention should be paid to the record of *Tornquistes* aff. *oxfordiensis* (Tornquist) from the lower part of level 7. This form has been reported by Thierry & Charpy (loc. cit., p. 639) from the Plicatilis zone (see also a reference by the authors to a specimen of this species from western Sicily). Also remarkable is the record of *Passendorferia erycensis* Meléndez (= *Passendorferia tenuis* Meléndez, 1989; non Enay, 1966; also *Passendorferia* aff. *birmensdorfensis* Fontana, 1990; non Moesch, 1867), characterising the Schilli Subzone. Levels 11 to 12 are clearly assigned to Bifurcatus Zone on the basis of scarce records of *Passendorferia* of the *teresiformis* Brochwicz-Lewinski - *uptonioides* Enay groups and the common occurrence of *Gregoryceras* aff. *fouquei* (Kilian). Level 13 contains few specimens of *Euaspidoceras* close to *E. hypselum* (Oppel) group and *Orthosphinctes* of the *O. ariniensis* Meléndez group. These forms are usually found at the Grossouvrei-Hypselum transition beds and would make this level already assignable to the basal horizon of the upper Oxfordian Hypselum Zone, Ariniensis Horizon (Atrops et al. 1997). Level 14 has yielded, together with several specimens of *Euaspidoceras hypselum* (Oppel) a specimen of *Orthosphinctes cf. kirkdalensis*, Enay (non Arkell) and *Passendorferia cf. gygii* (Brochwicz-Lewinski). These spe-

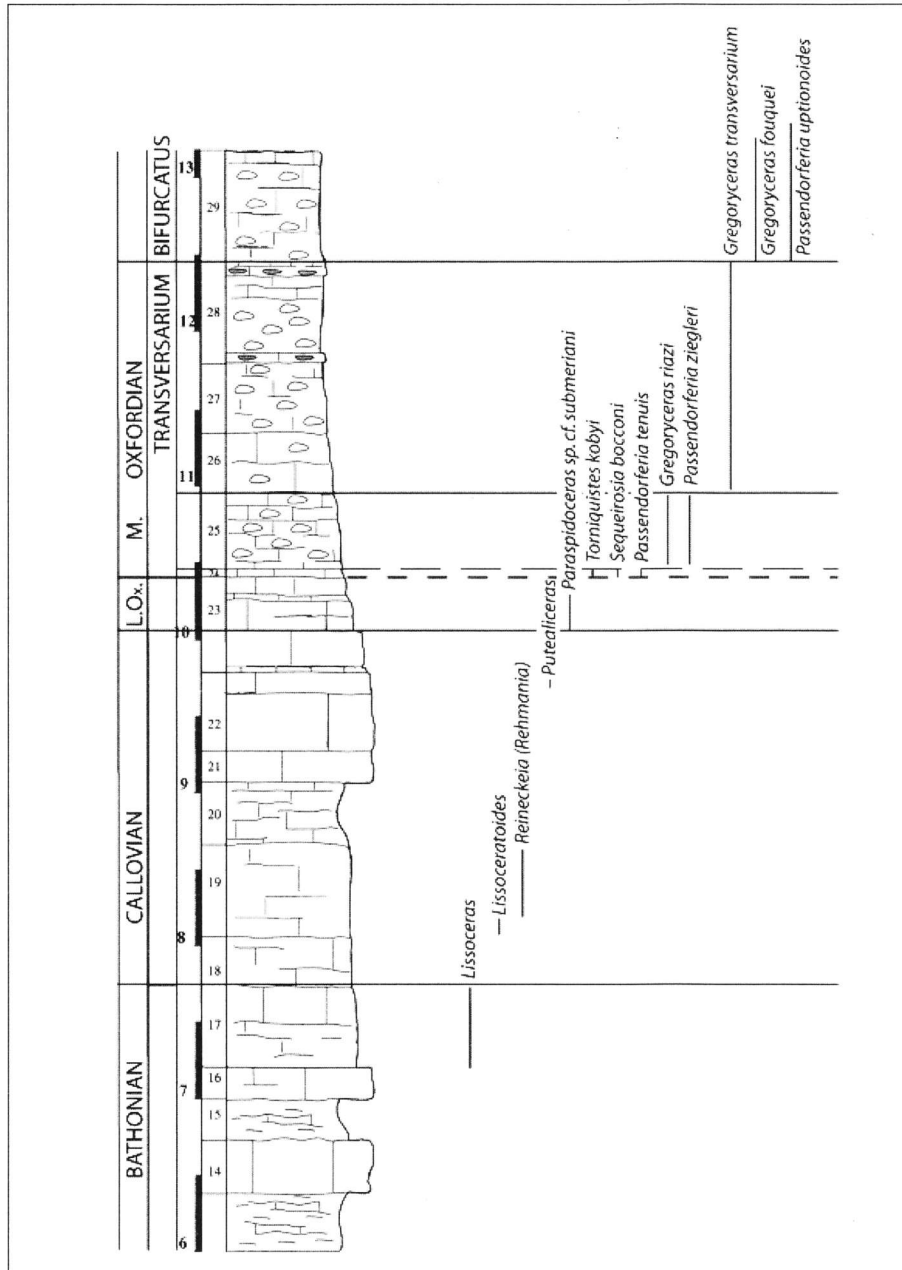


Fig. 3 - Stratigraphic succession of Bathonian-Oxfordian at the Erice-S. Anna Section. The record of Lissoceratoides, with *Reineckeia (Rehmania)*, and *Putealicerias* in levels 18 to 22 allows to recognise the lower and upper Callovian in this interval. Level 24 contains an association of ammonites probably characteristic of Antecedens Subzone. However, they show clear traces of reelaboration so this level might, in fact, correspond to a higher biostratigraphic interval. The presence of such forms as *Gregoryceras riazi* (Grossouvre), *Sequeirosia brochwiczi* (Sequeiros) and *Passendorferia ziegleri* (Brochwicz-Lewinski) allows to characterise the Riazi Horizon between levels 25 and 28. Level 29 contains several successive ammonite associations characteristic of Transversarium and Fouquei horizons. However, most of elements from the upper association show clear traces of reelaboration, so the upper part of this interval might in fact correspond to the higher biostratigraphic unit, the Hypselum Zone.

cies characterise a higher horizon, the "Kirkdalenensis" Horizon, within the upper Oxfordian Hypselum Biozone (Atrops et al. 1997). On the other hand, the record of such forms characterising the lower Hypselum Biozone directly over the levels containing *Gregoryceras* aff. *fouquei* (Kilian) regarded here as a prior, transitional form to the species of Kilian, suggests a small gap in this section of the interval with true *Gregoryceras fouquei* (Kilian) at the Bifurcatus-Hypselum zone boundary i.e. the Fouquei Horizon (see below).

The ammonite succession, especially that of genus *Gregoryceras*, is also comparable to that described in other areas from the Mediterranean Province, in the Betic Range (Sequeiros 1974) or in Hungary, in the Transdanubian Central Range and in the Mecsek mountains (Fözy et al. 1997).

Erice S. Anna section

This section is located along the path leading to the ancient convent of S. Anna, from the winding road of the southern side of Mount Erice, some 500 m before the historical Difali Fountain ("Fontana Difali", Fig. 1).

The recorded section comprises a 7.50 m thick limestone interval stratified in tabular to nodular dm beds with thin marly or argillaceous interbedding, and ranging from upper Bathonian to upper middle Oxfordian (Bifurcatus Zone). Oxfordian deposits (levels 23 to 30) form the upper 3.3 m interval. They form massive, cemented irregular pink limestone banks showing typical nodular aspect of the upper Rosso Ammonitico Fm. Bathonian to Callovian beds (levels 14 to 22) show a tabular regular stratification in thick banks with thin more nodular, marly intercalations (Fig. 3).

The middle-upper Bathonian boundary is marked in this outcrop by an irregular, remobilization level containing common reelaborated specimens from the middle Bathonian. Above this level, the upper Bathonian is still identified in level 17 by the record of a specimen of *Lissoceras*. Above this interval, the lower Callovian is recognised in level 19 by the record of a specimen of *Lissoceratoides* and several specimens of *Rehmania*, which would indicate the lower Callovian, upper Bullatus to Gracilis Zone. Above this interval, a nodular layer on top of level 22 has yielded a specimen of the upper Callovian Hecticoce-
ratinae *Putealicerias*.

Level 23 (a) might represent the Callovian-Oxfordian transition bed although it has not yielded any characteristic ammonite so far. In turn, level 23 (b) has yielded one specimen of *Paraspidoceras* cf. *submeriani* Zeiss, and few fragmentary specimens of *Perisphinctes* close to the *P. antecedens* Salfeld – *helenae* De Riaz group, which might characterise the upper Plicatilis Zone, Antecedens Subzone. From the base of level 24 comes a specimen of *Tornquistes helvetiae* (Tornquist) or perhaps close to the group of *T. kobyi* (De Loriol). This specimen, an incomplete fragmented internal mould, displays a disarticulation surface along a septum and shows clear traces of reelaboration. Also relevant are some incomplete specimens of “*Passendorferia*” close to the group of *Kranaosphinctes cyrilli*, Enay (non Neumann) and a specimen of *Euaspidoceras oegir* (Oppel). Attention should be paid to the record of a well-preserved specimen of *Sequeirosia bocconii* (Gemmellaro), wholly septate at a diameter of 238 mm, which would permit locate this form in its presumably right stratigraphic position, at the lowermost part of Transversarium Zone.

All specimens from the base of level 24 show clear traces of taphonomic reelaboration. They are preserved as cemented, as micritic internal moulds of non-deformed ammonites, showing lithological and structural discontinuity with the surrounding argillaceous shaly matrix. In some cases the disarticulation surfaces along a septum are in structural discontinuity with the matrix, or the truncational facets are not congruent with the stratification surface. It seems therefore that this reworked association from the base of level 24 might actually correspond to a stratigraphic gap affecting the upper part of Antecedens Subzone and, most probably, the lowermost part of Transversarium Zone, i.e. the Parandieri Subzone.

Level 25 contains common specimens of *Gregoryceras* of the *riazi* (Grossouvre) group associated with scarce specimens of *Passendorferia ziegleri* (M) Brochwicz-Lewinski and *Passendorferia birmensdorfensis* (m) (Moesch), which typically characterise the middle Transversarium Zone, Luciaeformis Subzone. Specimens from this level are generally preserved as resedimented i.e. non-reelaborated elements. They are normally non-deformed, cemented micritic ammonite internal moulds and can also be classified as Fragmented shells (Fs) or, more rarely, shell fragments (Sf). None of the recorded specimens preserves the peristome, the aptychus or the articulated siphon. Further up, in levels 26 to 29 (base) the presence of some fragmentary specimens of *Sequeirosia brochwiczi* Sequeiros, *Passendorferia* gr. *ziegleri* (M) Brochwicz-Lewinski showing transitional features to *Passendorferia erycensis* Meléndez, and *Gregoryceras* closer to *G. transversarium* (Quenstedt) group might characterise an upper interval within the Transversarium Zone, most probably the Schilli – Rotoides Subzone.

In level 29, the record of few specimens of *Gregoryceras* close to *G. fouquei* (Kilian) together with *Passendorferia* gr. *uptonioides* (Enay) characterises the lower Bifurcatus Zone. Typical representatives of *G. fouquei* (Kilian) have been recorded on top of level 29 together with *Euaspidoceras* sp., aff. *E. perarmatum* Sowerby and *Passendorferia tereisformis* Brochwicz-Lewinski, allowing to characterise the upper part of Bifurcatus Zone. All specimens from this upper interval of level 29 are preserved as fragmented micritic internal moulds of ammonites showing truncational facets incongruent with the stratification surface and/or disarticulation surfaces along a septum. They have structural and lithologic discontinuity with the shaly argillaceous matrix. They are hence reelaborated elements. Their record within this level probably indicates the presence of a further stratigraphic gap of the upper Bifurcatus Zone (= Fouquei Horizon) in this section. The real age of this level is still difficult to precise since no resedimented (i.e. non-reelaborated) specimens, and so coeval with embedding rock, have been found so far. Then, level 29 might represent a higher horizon within the Bifurcatus Zone or it might even represent the lower part of the Hypselum Zone.

Higher levels in this sequence appear less well exposed; however, from the lower part of level 30 comes a specimen of (?) *Orthosphinctes* close to the groups of *O. ariniensis* (Meléndez) – *O. kirkdalensis*, (Enay, non Arkell), which would characterise the lower part of the upper Oxfordian Hypselum Zone. This specimen, again, shows clear traces of taphonomic reelaboration, such as a truncational facet non-congruent

		PERISPINCTID ZONATION	GREGORYCERAS SUCCESSION
		MIDDLE OXFORDIAN	BIFURCATUS
STENOCYCLOIDES	aff. <i>FOUQUEI</i>		
TRANSVERSARIUM	ROTOIDES		<i>TRANSVERSARIUM</i>
	SCHILLI		
	LUCIAEFORMIS		<i>RIAZI</i>
	PARANDIERI		<i>ROMANI</i>
PLICATILIS	ANTECEDENS		<i>TOUCASIANUM</i>
	PATURATTENSIS		

Fig. 4 – Biostratigraphic succession of genus *Gregoryceras* in the Mediterranean Province showing the proposed correspondence with the standard *Perisphinctes* zonation of the Submediterranean Province. The biostratigraphic units proposed have so far the status of informal horizons and the precise correspondence with the zones and subzones of the Perisphinctid zonation is still tentative.

with the stratification surface and a structural and lithologic discontinuity between the micritic infill and the surrounding argillaceous matrix. This fact would confirm the existence in this section, as in the Rocce del Calderaro section, of a discontinuity and an important stratigraphic gap at the middle-upper Oxfordian boundary, affecting at least the upper part of the Bifurcatus Zone (the Fouquei Horizon) and the lowermost part of the Hypselum Zone (the Ariniensis Horizon).

Biostratigraphic succession of genus *Gregoryceras* in the Mediterranean Province

As previously remarked by Sequeiros (1974, 1975) in the Betic Range (Southern Spain), within the Mediterranean Province the species of genus *Gregoryceras* form a well defined biostratigraphic succession during the middle Oxfordian, from late Plicatilis Zone, Antecedens Subzone, to upper middle Oxfordian Bifurcatus Zone (Fig. 4). According to this author, such forms as *G. toucasianum* (D’Orbigny) and *G. romani* (Grossouvre) would occupy a lower stratigraphic position. The species

G. riazii (Grossouvre) appears widespread in the middle part of Transversarium Zone. This led the author to propose a general Riazii Zone for the studied area in the Mediterranean Province, which would roughly correspond to the middle Transversarium Zone: Luciaeformis Subzone in the Submediterranean Province, as defined by Cariou et al. 1991 and Meléndez & Fontana 1993 (= Wartae Subzone, in Meléndez 1989). A higher horizon, marked by the common occurrence of *Gregoryceras fouquei* (Kilian) in the Betic Range would roughly correspond to the upper part of Bifurcatus Zone.

This biostratigraphic distribution received further support in the Iberian Basin, within the Submediterranean Province (Meléndez 1989) by the finding of *G. toucasianum* (D'Orbigny) in the basal level of the middle Oxfordian sequence in Riela (S. Zaragoza). The proposed succession was further confirmed by the finding of some fragmentary specimens of *G. romani* (Grossouvre) in the lower levels of Transversarium Zone (Parandieri Subzone) and by the general record of *G. riazii* (Grossouvre) in the levels of Luciaeformis Subzone. Despite the general scarcity of representatives of genus *Gregoryceras* in the Iberian Range, the species *G. fouquei* (Kilian) has been recently collected in several localities within the middle – upper levels of Bifurcatus Zone.

Morphological differences between *G. riazii* (Grossouvre) and *G. transversarium* (Quenstedt) might appear difficult to put in evidence. Sequeiros (loc. cit.) cast some doubts on the acceptance of Quenstedt's species itself arguing that the original illustration and description of the type specimen would not correspond to a single individual but rather to an "idealized" synthetical figure of several different specimens. It should be admitted that both forms of *Gregoryceras*, might be almost indistinguishable when dealing with insufficient or fragmentary material. *G. riazii* would be characterised by its more rounded, later trapezoid regular whorl section showing a longer persistence of the "retroverse" stage of ribbing, formed by thick primaries bent backwards and bifurcated at the mid height of the flank, with scarce intercalaries or singles. *G. transversarium* (Quenstedt) in turn, would rather be characterised by the more regular trapezoid whorl section, showing a typical "campaniform" (bell-shaped) shape, with somewhat concave flanks. The ornamentation would show an earlier ontogenetic appearance of subradial ribbing, characterised by the less accentuated bending backwards of the ribs on the flank, the lowering of the point of furcation of ribs on the flank and the earlier appearance of intercalaries or singles. These differences, however, may be in fact difficult to recognise and doubtful.

Gygi (1977, 1990) in the Submediterranean Province, and Gygi & Hillebrandt (1991) in northern Chile, made major contributions to the knowledge of the genus *Gregoryceras*. Further progress on the biostratigraphic distribution of species of this genus was

achieved by Krishna et al. (1996) from the region of Kachchh, in the southeastern end of Tethyan realm. The authors showed that some forms of *Gregoryceras* close to the type-species, *G. transversarium* (Quenstedt) might appear associated to a Perisphinctid assemblage typical of the upper Transversarium Zone, most probably of Schilli to Rotoides Subzone. In addition to that, Fözy & Meléndez (1996) and Fözy et al., (1997) in the Transdanubian Central Range (Gerecse mountains) in Hungary were able to define a new form within this succession showing transitional features between the species *G. transversarium* (Quenstedt) and *G. fouquei* (Kilian), i.e. a trend to develop single, radial, prominent lateral ribs, but still showing biplicate, somewhat rursiradiate ribs on the whorl side. This form was referred to as *G. aff. fouquei* (Kilian) and has been identified in wide areas throughout the Tethyan Realm. It has been recently reported from west Sicily by D'Arpa & Meléndez (2001, 2002). Its stratigraphic position would be also intermediate between both forms, from upper Transversarium Zone, Rotoides Subzone to lower Bifurcatus Zone, Stenocycloides Subzone.

A revision of the forms figured by Sequeiros (1974) from the Betic Range shows that some of the figured specimens might also match this interpretation. This would be perhaps the case of the specimen KH1/R/26 from Transversarium Zone, described as *Gregoryceras fouquei* (Kilian) "var. 2", and figured in Pl. XXVIII, fig. 2. This specimen was designed as one of paratypes (paratype 2) of this species by the same author in a subsequent revision of the species (Sequeiros 1975). This might be also the case of the specimen figured by Gemmellaro (1875, pl. XIII fig. 1-2) as *Peltoceras transversarium* (Quenstedt). Similarly, the specimen figured by Gygi (1977, pl. 9 fig. 3) as *Gregoryceras aff. fouquei* (Kilian) reported from upper Transversarium Zone might be tentatively accepted as a component of this form.

G. fouquei (Kilian) is clearly characterised by the sharp trapezoidal thick whorl section and "regular" radial ribbing formed by dominant single ribs, with none, or very scarce biplicate ribs or umbilical bifurcations and the progressive development of a smooth band at the lower part of the whorl side. Such features, clearly exposed on the holotype of Kilian, are also visible in the specimens described and figured by Sequeiros (loc. cit.) This author who illustrated true topotypes of this form from the Betic Ranges confirmed the precise stratigraphic position of this species, at the upper Bifurcatus Zone, associated to *Perisphinctes (Dichotomoceras) bifurcatus* (Quenstedt).

Therefore, a general biostratigraphic succession of the successive species of genus *Gregoryceras* may be proposed for the middle Oxfordian of Submediterranean and Mediterranean provinces, including tentatively the Indo-Malgasian Province (Fig. 4). This succession may serve as a useful tool for biostratigraphic correla-

tion with the reference Perisphinctid biozonation for the Submediterranean middle Oxfordian (Meléndez & Fontana 1993). This proposed *Gregoryceras* succession, still tentative and incomplete will be fulfilled with the increasing knowledge of correlation with the Submediterranean Province.

Gregoryceras toucasianum (D'Orbigny), generally the lowest of the recorded species of *Gregoryceras* in the Mediterranean Province areas, characterises a lower Toucasianum Horizon, roughly equivalent to the Antecedens Subzone of the Plicatilis Zone. Some characteristic species from this interval are *Tornquistes* of the *T. helveticus* and *T. romani* groups, *Paraspidoceras submeriani* Zeiss, and probably, *Passendorferia tenuis* Enay. Attention should be paid to the recent finding of *Sequeirosia bocconii* (Gemmellaro) in this same interval.

Gregoryceras romani (Grossouvre), characterised by its small size (70 to 120 mm) and evolute coiling with rounded whorl section and, strongly bent backwards, biplicate ribbing, is still a poorly known form in the Mediterranean Province. Further knowledge is still needed to precise its stratigraphic position. Yet it might occupy a slightly higher horizon, in the lower part of Transversarium Zone, roughly equivalent to Parandieri Subzone. Possible records of this form among the studied material in the S. Anna section include poorly preserved fragmentary specimens, still insufficient to set any conclusion on this point. In the section of Rocce del Calderaro, the level 7, below the typical levels with *Gregoryceras riasi* (Grossouvre) and containing *Tornquistes* close to the *T. oxfordiensis* (Tornquist) group, might correspond to this interval.

Gregoryceras riasi (Grossouvre) is a widespread form in the middle part of Transversarium Zone. The classical "Riasi Zone" proposed by Sequeiros (1974) might be here accepted as the Riasi Horizon within this here proposed succession, roughly equivalent to the Luciaeformis Subzone. In the Submediterranean Province this stratigraphic position is further supported by the record of this form together with *P. (Dichotomosphinctes) luciaeformis* Enay and *Passendorferia* of the groups *zieglerei* (M) (Brochwicz-Lewinski) – *birmensdorfensis* (m) (Moesch). The record of this form together with *Passendorferia erycensis* Meléndez in some of the studied sections of Mount Erice, a species typically spread in the Schilli Subzone of the Submediterranean Province, seems to indicate that this Riasi Horizon might also partly correspond to this Subzone. However, as stated above, it should be taken into account that incomplete specimens of *G. transversarium* (Quenstedt) may be difficult to separate from *G. riasi* (Grossouvre).

The species *Gregoryceras transversarium* (Quenstedt) has been the subject of numerous debates and diverse interpretations. It was first rejected, or accepted with reservation by Sequeiros (1974, 1975) and subsequently accepted by most authors. Recently, Gygi

(2001, see also ref. therein) has proposed a different stratigraphic position for this species, at the lower part of Plicatilis Zone, on the basis of a revision of the type locality of the species. The proposal has been commented by Meléndez (2002). In the studied areas of Mediterranean Province, specimens fitting the diagnosis of Quenstedt's species are generally found clearly above the levels with *G. riasi* (Grossouvre), in the same levels as *Passendorferia erycensis* Meléndez and *Sequeirosia* of the *brochwiczi* (Sequeiros) – *trichoplocus* (Gemmellaro) groups, or in a slightly higher level, between the record of this species and that of such forms typical of Bifurcatus Zone, as *Passendorferia torcalense* (Kilian) or *Passendorferia uptonioides* (Enay). Therefore, all available evidence rather supports the idea that the Transversarium Horizon would correspond to a higher interval within the Transversarium Zone, roughly equivalent to Schilli and Rotoides Subzone.

The form here described as *Gregoryceras* sp. aff. *G. fouquei* (Kilian) has been often assumed and accepted as a true representative of Kilian's species. However, as stated above, differences with this form are clear, and true representatives of *G. fouquei* (Kilian), characterised by the slightly involute coiling with straight radial ribbing and the development of a smooth band on the lower part of the whorl side, are morphologically well defined and restricted to a higher horizon within the Bifurcatus Zone. Therefore, these two forms allow to distinguish two separate horizons. Below, the *G. aff. fouquei* Horizon, roughly equivalent to the Stenocycloides and perhaps, partly, the Rotoides Subzone, associated to *Passendorferia torcalense* (Kilian) and close forms. Above, the true Fouquei Horizon, roughly equivalent to Grossouvrei Subzone and associated with *Passendorferia*, of the groups *uptonioides* (Enay) – *teresiformis* (Brochwicz-Lewinski).

The proposed biostratigraphic succession for the genus *Gregoryceras* appears especially useful and adequate for the Mediterranean Province since it can easily match the succession of genus *Passendorferia* long discussed, and proposed by different authors (Brochwicz-Lewinski 1973; Meléndez 1989; Meléndez & Fontana 1993; Fözy & Meléndez 1996; D'Arpa & Meléndez 2001), and correlate with the classical perisphinctid succession of Submediterranean Province (Meléndez & Fontana 1993, see also Page et al., this volume). On the other hand, within Ammonitina, the Peltoceratinae are the group showing the widest biogeographic distribution throughout the Tethyan and Pacific realms. In addition, representatives of Passendorferiinae and Peltoceratinae are the most abundant groups in the middle Oxfordian of Mediterranean Province, showing also higher values of stratigraphic persistence. With the exception of Euaspidoceratinae, a group still poorly known for this interval (Fig. 5).

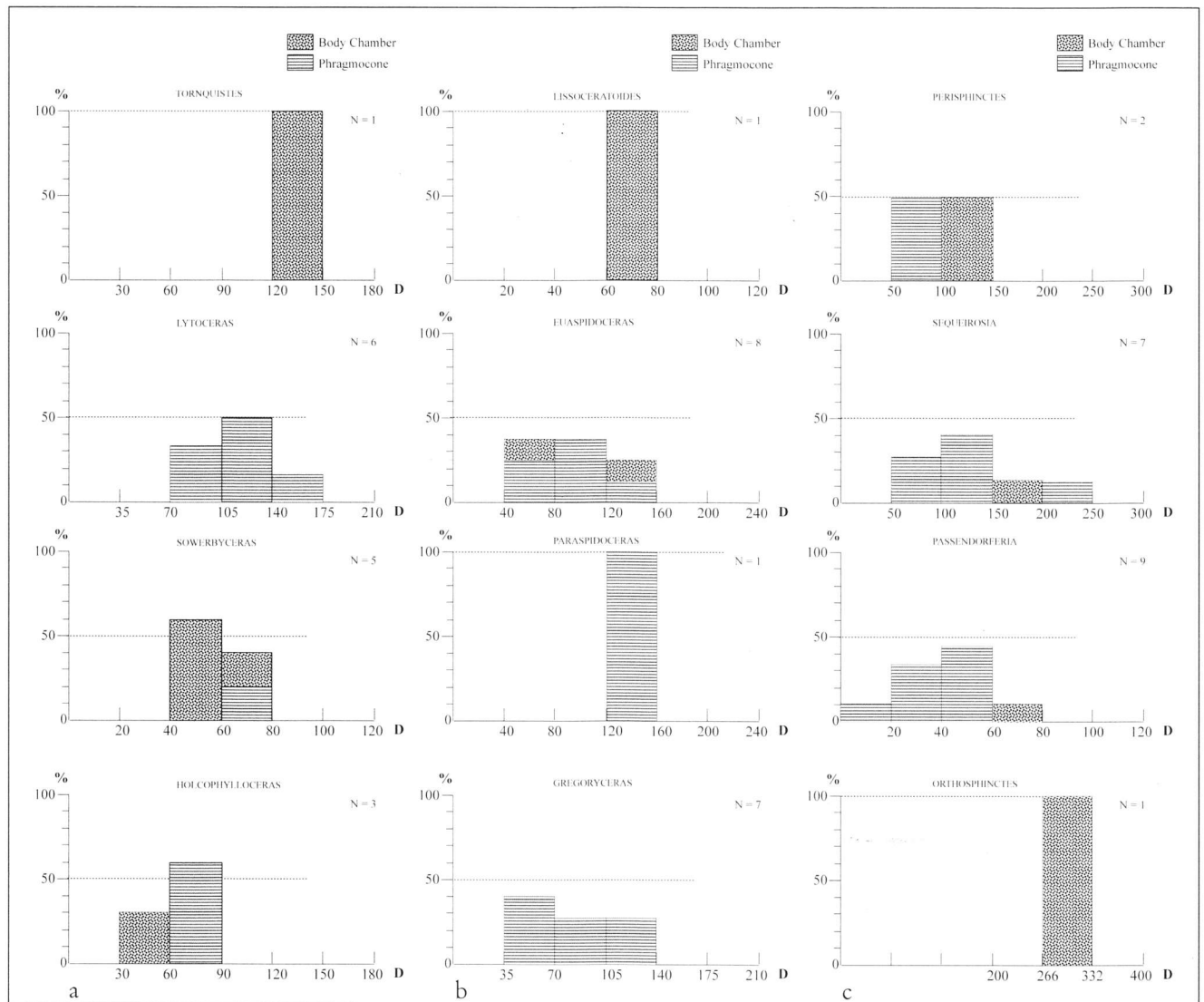


Fig. 5 (a-c) - Size-frequency distribution plots of the ammonite genera, from the middle Oxfordian of S. Anna section, to show the type of taphonic populations. Specimens with body chamber (black dots) are plotted against incomplete phragmocones (horizontal bar grid). On the horizontal axis (X) the estimated maximum value of diameter for these genera is subdivided into six size-intervals, corresponding to ontogenetic stages. On the vertical axis (Y) the percentage of recorded specimens (N) of each genus is represented, to show the size-frequency plot. A frequency pick at higher values formed by incomplete phragmocones would mean a clear predominance of adults, indicating a taphonic population of type 3, which would correspond to allochthonous assemblages. On the contrary, a frequency peak at the lowest values (smallest size) formed by specimens with body chamber would mean a recorded association dominated by small juveniles, interpreted as a taphonic population of type 1, and interpreted to correspond to endemic palaeobiological entities (Fernández-López 1995). Intermediate plots are typified as taphonic populations of type 2, interpreted as occasional invaders or immigrants (miademic palaeobiological entities). As it can be seen, most of the plots for the recorded genera seem rather to represent taphonic populations of type 3. None of them would clearly correspond to taphonic populations of type 1, whilst representatives of *Sowerbyceras*, *Holcophylloceras*, *Euaspidoceras* and perhaps *Passendorferia* and *Perisphinctes* seem to form taphonic populations of type 2.

Taphonomic analysis

Taphonomic analysis of ontogenetic stages represented in the recorded taxa shows a size distribution of specimens of separate genera allowing their classification in taphonic populations of type 2 or 3 (Fig. 5), following the categories established by Fernández-López (1995). According to this author, taphonic populations of type 1 are characterised by unimodal frequency size-distribution curves showing positive skew. They form

monospecific assemblages showing high values of the ratio between number of specimens and number of taxa, dominated by juvenile individuals and predominance of microconchs over macroconchs. They constitute autochthonous recorded entities and represent endemic biological populations.

Taphonic populations of type 2, display unimodal frequency size-distribution curves with high degree of kurtosis. They form mono- or polyspecific assemblages

showing medium values of the ratio between number of specimens and number of taxa, and a mixing of juvenile and adult individuals as well as micro and macroconchs. They would represent demic biological populations but show no trace of interbreeding assemblages, so they probably correspond to occasional inhabitants or immigrants.

Taphonic populations of type 3, display bimodal frequency size-distribution curves with negative skew. They form polyspecific assemblages showing low values (close to 1) of the ratio between number of specimens and number of taxa, dominated by adult individuals and predominance of macroconchs over microconchs. They constitute allochthonous assemblages, and represent ademic biological populations showing no trace of colonization or interbreeding assemblages.

As noted by the present authors (D'Arpa & Meléndez 2002) the studied middle Oxfordian ammonite assemblage from the section of Rocce del Calderaro (Erice Difali), mainly Passendorferiinae and Peltoceratinae, was to some extent formed by juvenile individuals, showing no trace of adult variation of coiling or ornamentation and, in the case of macroconchs, no trace of variocostation. This would make them to be categorised as taphonic populations of type 1 or, rather, of type 2. The detailed analysis carried out here on the recorded associations of ammonites from the middle Oxfordian of the section Erice-S. Anna, as typified in Fig. 5 (a-c), allows adding further precision to these first results. Data from this section, however, should take into account the scarcity of available specimens so far in some of the studied taxa, so it is not excluded that new future collections might contribute to precise the composition of taphonic populations.

The associations of taxa as *Tornquistes*, *Lytoceras*, *Lissoceratoides*, *Paraspidoceras*, *Gregoryceras* and *Orthosphinctes* would constitute taphonic populations of type 3, showing a clear trend to give unimodal frequency plots with negative skew and specimens with body chamber concentrated at larger diameters. On the other hand, the higher presence of large size individuals would reflect a predominance of macro-over microconchs. In contrast, such genera as *Sowerbyceras*, *Holcophylloceras*, *Euaspidoceras*, and perhaps, *Perisphinctes*, would clearly constitute taphonic populations of type 2. Specimens of these taxa show low values of diameter for shells still maintaining the body chamber and flat-top (high values of kurtosis) frequency curves. Assemblages of genera *Sequeirosia* and *Passendorferia* from the section of S. Anna are so far difficult to interpret. They include some immature specimens but their record is mainly formed by medium to large size wholly septate specimens (fig. 5c). This would set these assemblages close to taphonic populations of type 3. However, as remarked in the section of Rocce del Calderaro (D'Arpa & Meléndez 2002) the common occurrence of immature specimens would suggest that they might constitute, in fact, taphonic populations of type 2.

Taphonomic features displayed by the recorded specimens in the studied sections appear remarkably homogeneous. In the section of Rocce del Calderaro ammonite assemblages are generally dominated by incomplete specimens showing homogeneous micritic infilling of the shell until the internal whorls of the phragmocone. They usually maintain the original shape and volume, without or with very slight deformation by compaction. They can be taphonomically classified as fragmented shells (Fernández-López & Suárez-Vega 1979, p. 232), and are generally resedimented specimens, mostly incomplete phragmocones and none of them so far preserving the peristome. Reelaborated elements are scarce or accidental.

In the section of S. Anna, however, assemblages from levels 24 and 29.b to 30 are dominated by reelaborated elements. They generally constitute fragmented internal micritic, non-deformed internal moulds of ammonites showing a disarticulation surface along a septum and a structural and lithologic discontinuity with the surrounding matrix. Some scarce specimens show a truncation surface non-congruent with the bed plane. They can be taphonomically classified as fragmented or disarticulated moulds. Some of them can also constitute truncated moulds (Fernández-López & Suárez-Vega 1979) and are hence reelaborated elements. Specimens from other stratigraphic levels are resedimented elements as in the section of Rocce del Calderaro.

The presence of some taphonomic alternative features such as shell fragmentation and abrasion surfaces on reelaborated ammonite moulds has been related with changes in sedimentary environment conditions (Fernández-López & Meléndez 1995). According to these authors, "positive taphonomic gradients of remobilization and abrasion indicate increasing of environmental turbulence, commonly associated with an increase in the degree of oxygenation and a decrease in depth". The analysis of the taphonomic features for the ammonite associations from Rocce del Calderaro and Erice S. Anna, allowed to recognise a transition from an ammonite assemblage formed by resedimented to reelaborated elements. The former, mainly consisting of fragmented shells, shows lithologic and structural continuity between the infilling and the surrounding matrix and no trace of gravitational crushing, i.e. maintains the original shape and volume. The latter includes common reelaborated elements formed by fragmented micritic internal moulds, showing disarticulation surfaces along a septum and sometimes truncation facets, and lithologic and structural discontinuity between the micritic infill and the surrounding shaly argillaceous matrix. This change in the ammonite assemblages is clearly traceable at S. Anna section, in level 24 and at the junction between levels 29 and 30. It reflects a taphonomic gradient indicating the environmental transition from moderately deep subtidal to shallow subtidal conditions. On the other hand, the increasing number of reelaborated elements showing homogeneous micritic infill of the phragmocone until the inner whorls

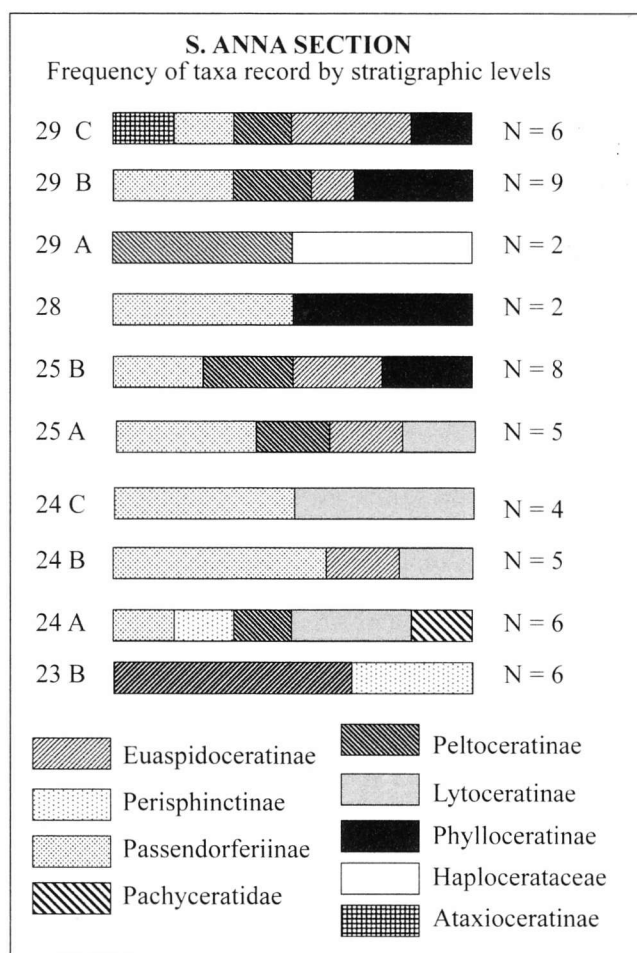


Fig. 6 - Quantitative distribution of ammonite subfamily taxa in successive stratigraphic levels of S. Anna section.

and no deformation or crushing by diagenetic compaction, are taphonomic features indicating low rate of sedimentation and early cementation of micrite-filled shells. This is underlined by the relative size selection shown by preserved shells, remarked by the virtual absence of shells of the smallest size classes, which might indicate the probable removal and transport by currents.

Biogeographic Remarks

General composition of the studied ammonite assemblages shows a clear Mediterranean (Tethyan) affinity (Fig. 6). Components of Lyto and Phylloceratina (Liostraca) are generally dominant and show the highest values of stratigraphical persistence. Perisphinctids are almost exclusively represented by components of subfamily Passendorferiinae, the true representatives of Perisphinctinae being mostly accidental and doubtful. Attention should be also paid to the scarce but constant presence of representatives of family Haplocerataceae; a specimen of *Lissoceras* in the upper Bathonian and rare specimens of *Lissoceratoides* in the Callovian and Ox-

fordian, and Pachyceratidae (*Tornquistes*) first reported from these sections (D'Arpa & Meléndez 2001). On what concerns the cosmopolitan subfamilies Euaspidoceratinae and Peltoceratinae, they are also classically a main component of Tethyan assemblages.

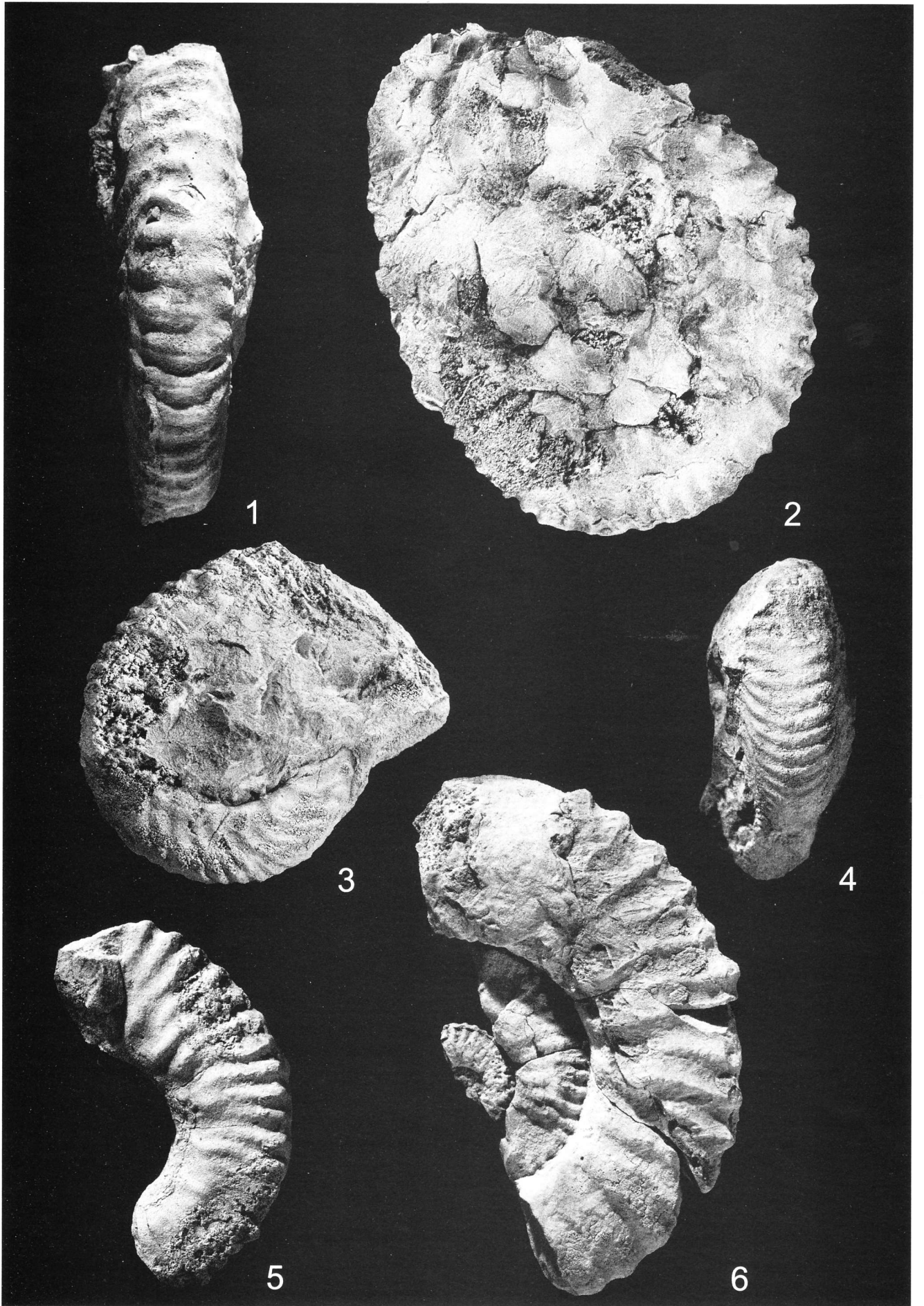
From upper Bifurcatus to lower Hypselum Biozone, come the first representatives of subfamily Ataxioceratinae. These are represented by scarce specimens showing transitional features between *Passendorferia* and *Orthosphinctes*. The presence of such intermediate forms has a special interest as it has already been recognised and proposed elsewhere in some areas of Submediterranean Province such as Iberian Range and SE France (Atrops & Meléndez 1993).

New representatives of Haplocerataceae (Oppeliidae), besides the classically described specimens of *Proscaphites* and *Trimarginites* by Gemmellaro have been recently reported from the area of Erice, in the Rocce del Calderaro section (D'Arpa & Meléndez, loc. cit.) Yet they may be regarded as rare in comparison to Submediterranean areas, and are so far virtually absent in the section of S. Anna.

The available taphonomic and biogeographic data point to the studied area as a part of the true Mediterranean Province within the Tethyan Realm during the middle Oxfordian, showing close similarities in facies and fossil content (ammonite associations) with other typical near Mediterranean areas, such as Betic Ranges, Southern Alps (Rosso Ammonitico Veronese) and Hungary. Similarities with near North African areas (Algeria) have been also shown by Atrops & Benest (1981, 1984, 1986). Taphonomic data, such as relative abundance and structure of taphonic populations, besides representatives of Phylloceratinae, point to representatives of Passendorferiinae and Euaspidoceratinae as the main groups inhabiting the basin (Meléndez & D'Arpa 2002). Further evidence is, however, still needed to demonstrate if they were true inhabitants forming real interbreeding populations, i.e. endemic palaeobiological entities, or they were just occasional invaders or immigrants, colonizing the basin without forming true interbreeding populations, hence being interpreted as miademic palaeobiological entities (Fernández-López 2000, p. 75).

PLATE 1

- Fig. 1, 2 - *Gregoryceras* aff. *fouquei* (Kilian); specimen R.S. Erice Rocce del Calderaro 10.2. 1) ventral side x 0,7. 2) lateral side x 0,7.
- Fig. 3, 4 - *Gregoryceras riazzi* (de Grossouvre); specimen R.S. Erice Sant'Anna 25.1. 3) lateral side x 1. 4) ventral side x 1.
- Fig. 5 - *Gregoryceras transversarium* (Quenstedt); specimen R.S. Erice Sant'Anna 26.1., lateral side x 1.
- Fig. 6 - *Gregoryceras fouquei* (Kilian); specimen R.S. Erice Rocce del Calderaro 10.5., lateral side x 0,7.



Conclusions

Middle Oxfordian ammonite successions from western Sicily allowed to recognise a biostratigraphic succession comparable with that long established for Submediterranean areas. The presence of some taxa classically recorded in epicontinental Submediterranean platforms, from subfamilies Passendorferiinae, Peltoceratinae, Pachyceratinae, Euaspidoceratinae and Ataxioceratinae permitted to characterise the successive standard biostratigraphic subzones of the Transversarium and Bifurcatus zones. However, the detailed succession of species of genus *Gregoryceras* led to the tentative proposal of a zonal scheme correlatable with that based on species of genus *Perisphinctes* in the Submediterranean Province.

Sedimentation during the middle Oxfordian in West Sicily area took place in an epiocenic pelagic platform, mainly under typical Rosso Ammonitico facies. The Callovian – Oxfordian transition was marked by a wide stratigraphic gap ranging presumably from upper Callovian to middle Oxfordian, upper Plicatilis Zone, Antecedens Subzone. From this point until the upper Oxfordian the ammonite record was more or less complete, whilst the sedimentary record shows the presence of frequent small stratigraphic gaps. Sedimentary and bathymetric conditions were periodically changing from moderately deep subtidal to shallow subtidal. In these conditions low values of rate of sedimentation and in some cases, low values of instant rate of accumulation of sediment led to the development of condensed sequences and condensed sediments. The stratigraphic condensation was higher in the section of Erice S. Anna, where the Plicatilis-Trans-

versarium and Bifurcatus-Hypselum zone boundaries are marked by stratigraphic gaps affecting respectively the upper Plicatilis Antecedens Subzone and early Transversarium Parandieri Subzone, and the late Bifurcatus Gros-souvrei Subzone (= equivalent to the Fouquei Horizon in the here proposed scale).

The biogeographic status of the studied ammonite associations can be clearly recognised as typically Mediterranean, underlined by the common occurrence of representatives of Lytoceratina and Phylloceratina, as well as subfamilies Passendorferiinae, Peltoceratinae, Lis-soceratinae and also Euaspidoceratinae (to some extent). The fact that some of these groups are also widespread in the near Submediterranean or even in Pacific provinces provides advantageous possibilities for biostratigraphic correlation with these areas. Such groups as Euaspidoceratinae and possibly also Passendorferiinae, seem to form taphonic populations of type 2. They may be probably regarded as true colonisers of this area. However, it is still under debate whether they were forming true interbreeding biological populations (eudemic) or were mostly occasional colonizers or immigrants (miademic palaeobiological entities).

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