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GEOLOGY

Correlation of the Tithonian in Central Sector of the Betic Cordilleras (Spain) in the Light of Recent Studies

by

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Summary. The studies carried out in the last decade give fairly accurate characteristics of Mediterranean Tithonian, making it both possible and desirable to correlate subdivisions recently proposed for that stage in this and other provinces. Ammonite associations of the Mediterranean nature appear appropriate for establishing subdivision of the Tithonian as there is growing evidence for a trend to regression [19] and resulting increase in provinciality of ammonite faunas throughout this stage. The paper presents the subdivision, established on the basis of our studies, into sections in the Betic Cordilleras, its correlations with other subdivisions proposed for that and other parts of the Mediterranean province and other provinces and a brief discussion of boundaries of this stage.

The Tithonian stage has been the subject of vivid discussions for a long time. This is due to the fact it was proposed by Oppel [33] without indicating typical or characteristic area and with rather vague characteristics of its limits (for a wider discussion see [12]). The resulting difficulties were additionally increased by incompleteness and ambiguities of strata referable to that stage in areas most frequently studied and regarded as classic, especially those in the pre-Alpine chains (Le Pouzin, Aizy, Chomerac and Saint-Concors in SE France, Solnhofen and Neuburg in Franconia), Apennines (Monte Catria, Monte Acuto, Canfaito), NE Italian Alps (Volano, Folgaria, Roveredo, Toldi), Sicily and Carpathians (Stramberk and Rogoźnik). Of recent studies in those areas, special attention should be paid to those of Zeiss [45], giving detailed stratigraphy of Submediterranean Lower Tithonian in S Franconia and biogeography of ammonite fauna.

The last decade witnessed marked progress in the knowledge of the Tithonian *sensu stricto*, i.e. Mediterranean. Enay and Geyssant [16] studied the successions and stratigraphic value of ammonite faunas in the Subbetic region (Spain), Sapunov [35, 36]—Bulgarian fauna, displaying features intermediate between Mediterranean and Submediterranean ones but closer to the latter, and Olóriz [26]—Lower Tithonian fauna in central sector of the Subbetic

Zone. Moreover, Olóriz and Tavera [28] made an attempt to synthetize the results of studies on the Tithonian in central sector of the Subbetic Zone, taking also into account new data on stratigraphic distribution of tintinoids [29].

The available data give fairly accurate characteristics of Mediterranean Tithonian, making it both possible and desirable to correlate these sequences and those known from other parts of Europe (see also [28]). This stage, accepted as the uppermost stage of the Jurassic, should be subdivided on the basis of most uniform faunistic associations. Associations of Mediterranean character seem most appropriate for that purpose, especially if we take into account evidence in favour of trends to regression, increasing throughout the Tithonian (see [19], pp. 15, 23, 27). Therefore, we must reject opinions according to which the key to understand the Tithonian may only be found in SE France ([12], p. p. 361) or (in the case of Lower-Middle Tithonian)— in Franconia ([3], p. 333). Such opinions have to be rejected in the light of undeniable differences in composition of fauna, related to differences in ecological conditions.

The Lower Tithonian. Lower boundary of the Tithonian is widely accepted as defined by a transition from *Hybonoticeras beckeri* to *H. hybonotum* whereas the upper is still the subject of controversy, despite discussions which took place during the Lyon–Neuchâtel Conference in 1973. The boundary accepted here coincides with that between the Jurassic and Cretaceous (see below). We tentatively accept here the subdivision of the Tithonian into two parts ("Gallic") but it does not mean that we consider subdivision into three parts (i.e. that accepted in Franconia and Bulgaria) as invalid.

As we stated above, the base of the Tithonian is defined by the first appearance of *Hybonoticeras hybonotum* (Oppel).

The Hybonotum zone (taxon-range zone [16, 26]) is widely accepted as the lowest one. The index species is accompanied by other representatives of the same genus, *Hybopeltoceras, Glochiceras (Paralingulaticeras) lithographicum* (Oppel), *Pseudolissoceras rasile* (Zitt.), subspherical and smooth (except for tubercles) *Physodoceras, Pseudodiscosphinctes ardescicus* (Font.) and *P. geron* (Zitt.) sensu lato, *Lithacoceras* aff. *ulmensis* (Oppel) and affined forms, *Subplanites, Torqatisphinctes, Pachyspidoceras* and *Virgalithacoceras* as well as *Neochetoceras* of the *N. steraspis* group, bituberculated forms of the *N. rogosnicense* and *zeuschneri* groups, *Physodoceras neoburgense-cyclotum* group and some *Taramelliceras*. Top parts of this zone yield *Parastreblites, Fontannesiella valentiana* (Font.), *"Parapallasiceras"* cf. *pseudocontiguus* (Donze et Enay) and occasional *Parakeratinites*. Of changes traceable at the Kimmeridgian-Tithonian boundary, a special attention should be paid to the disappearance of *Sowerbyceras* (occurring throughout both the former and Oxfordian) or its replacement by *Phycophylloceras* and *Haploceras*.

The next, recently proposed [26], **Albertinum zone** (taxon-range zone),

is characterized by rare *Virgatosimoceras micrum* Oloriz, some *Parakeratinites* and *"Parapallasiceras"*, *Pseudolissoceras rasile* (Zitt.) and its allies, diversified assemblage of *Neochetoceras: N. mucronatum* (Berck. et Hölder), *N. darwini* (Neum.) and *N. pseudodarwini* (Oloriz), *Haploceras, Fontannesiella*, bituberculated *Aspidoceras* also known from the lower zone, *Physodoceras, Torqatisphinctes* and first *Subplanitoides*. From that part of the section upwards, there appear clear differences between zonations proposed for individual regions. In the Submediterranean province [44], a zone is distinguished with *Neochetoceras mucronatum* (Berck. et Hölder) as index species, and characterized by the presence of highly diversified assemblage of perisphinctids. The latter make possible its further subdivision, similarly as in the case of the Hybonotum zone. Different zones were proposed for correlable strata in the Mediterranean provinces: zones with *N. darwini* (Neum.) and *Virgatosimoceras albertinum* as index species ([16] and [26], respectively). The former index appears unsatisfactory as it is quite rare and more difficult to separate from closely allied species than the latter [26, 28]. There is growing evidence for the commonness of *V. albertinum* (Cat.) and specimens referable or very close to it recently used to be reported as the example of Mediterranean influences in the Submediterranean province. For example, this species appears very common in Mediterranean fauna found in the strata separating those of the Hybonotum and Semiforme zones in the Neuburg section (bed 22—[4], pp. 27, 33; [3], table 1). The zone proposed by Enay and Geyssant [16] was distinguished in the Rogoźnik section by Kutek and Wierzbowski [21] but these authors did not find its index species and poor preservation of the recorded fauna precluded the assignment of the strata to that zone without making a reservation ([21], p. 203). These authors also emphasized (pp. 197–198) small size (up to 30–40 mm) of the fauna, which makes identification hazardous except for Haploceratacеae, the grading off in size of ammonite remains in individual layers and abundance of pelecypods and crinoids among accompanying invertebrates. Ecological and taphonomic factors decipherable in data given by these authors seem to give quite convincing answer why *V. albertinum* (Cat.) and its allies, i.e. typical Mediterranean forms, are lacking in the Rogoźnik section. Taking this into account it may be assumed that ammonite spectrum given by these authors ([21], p. 199) is consistent with our scheme [31, 32], well illustrating the situation. It appears that the differences are here mainly connected with the share of perisphinctids and aspidoceratids and they should also be traceable in the case of other invertebrates. Attention should also be paid to the lack of *Neochetoceras darwini* (Neum.) as Streblitinae are well represented here as well as in lower, Hybonotum zone.

Ammonite fauna of Bulgaria appears intermediate between Mediterranean and Submediterranean ones [35, 36]. Sapunov's assemblage appears fairly close to the Submediterranean ones of FRG and the zones distinguished there (Subplanitoides schwertschlageri and Franconites vimineus zones) are correlable

with the Albertinum zone. Attention should be paid to the lack of *Pseudolissoceras* and the presence of Phylloceratinae and Lytoceratinae.

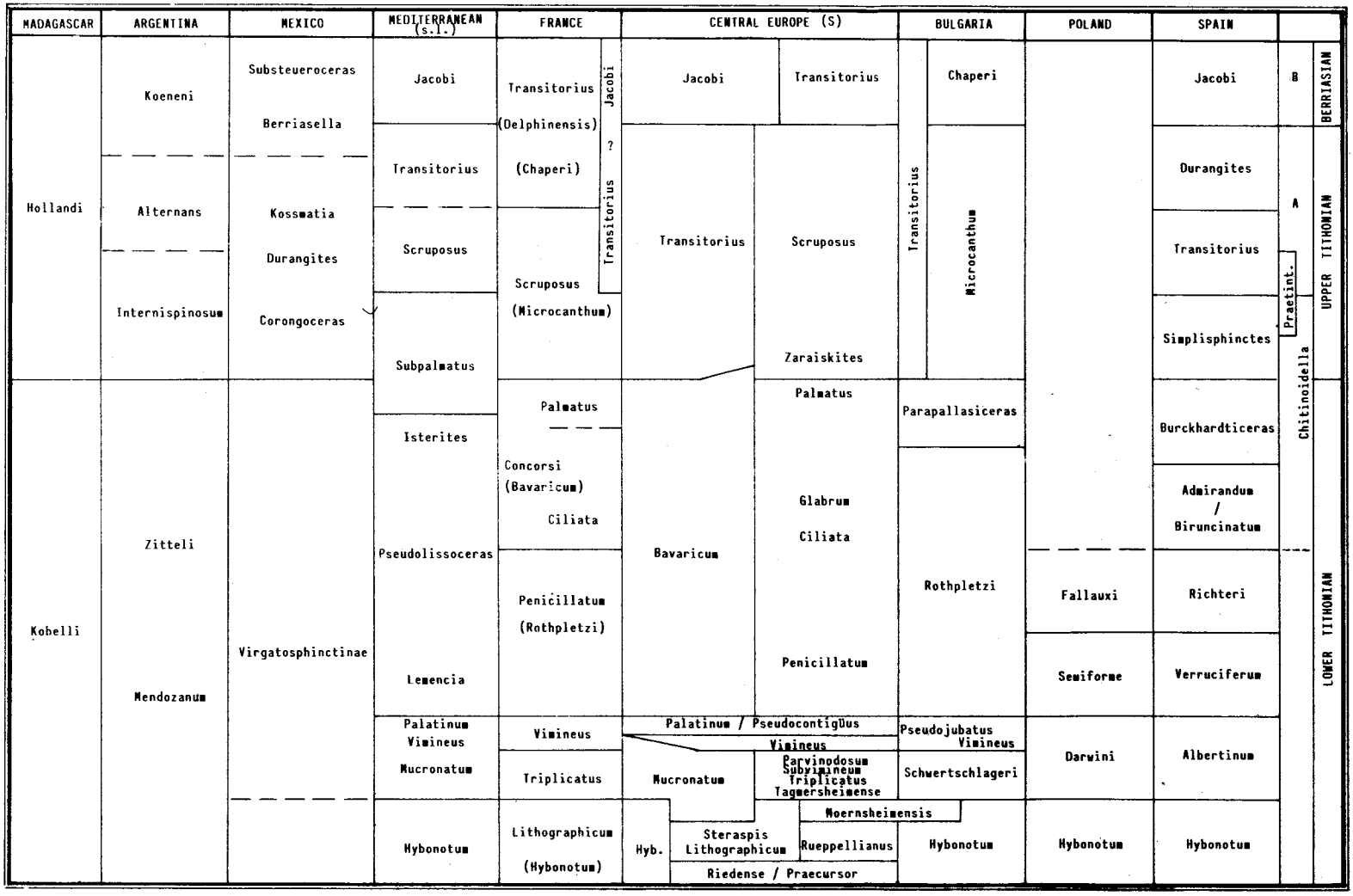
The Verruciferum zone ("taxon-range zone" [26]) is characterized by the index species, forms of the *Semiformiceras semiforme* group: *S. semiforme semiforme* (Oppel), *S. s. tuberosum* Oloriz and *S. rotundus* Oloriz, diversified *Haploceras* fauna inclusing some rare forms such as *H. tomephorum* (Zittel) and first representatives of *"H." carachteis* (Zeusch.) and exotic ones like *Pseudohimalayites* and *Simocosmoceras*. The assemblage also comprises *Pseudolissoceras bavaricum* Barthel, *P. planiusculum* (Zittel) and allies, *"Parapallasioceras" pseudocontiguus* group, *Danubisphinctes, Dorsoplanitoides, Subplanitoides, Pseudodiscosphinctoides, Usseliceras,* innumerous *Sublithacoceras* and *Franconites, Torquatisphinctes, Biplisphinctes,* Mediterranean *Subdichotomoceras pseudocolubrinus* (Kilian) group, *Virgatosimoceras rothpletzi* group, *Neochetoceras,* smooth *Physodoceras* and bituberculated *Aspidoceras*, generally similar as in the underlaying zone but comprising some forms resembling those of the *A. longispinum* group. Attention should be paid to the records of first representatives of *Simoceras* gr. *volanense* (Oppel), *"Aulacosphinctes" rectefurcatus* (Zittel) and *Lithacoceras chalmasi* (Kilian). Top parts of this zone yielded some *Paraberriasella, Richterella* gr. *richteri* (Oppel) and other forms.

This zone belongs to the above-mentioned time interval of differentiation of ammonite fauna in the European part of the Tethys. Any more accurate correlation of that zone and the Bavaricum "superzone" of Zeiss [44] is not possible. However, the records of *Virgatosimoceras rothpletzi* (Schneid) and similar forms as well as *Sublithacoceras glaber* (Schneid), first appearance of *"Haploceras" carachtheis* (Zeuschn.) and the last records of *Aspidoceras* gr. *rafaeli* (Oppel) [1–3] suggest that the former may be an equivalent of lower parts of the latter.

For the relevant part of the section in central Subbetic Zone there was also distinguished the Semiforme zone [16]. That zone is classic one, proposed as early as 1871 by M. Neumayr and we are dealing here with a successive redefinition. Olóriz [26] decided to choose *Haploceras verruciferum* (Menegh.) as index species for zone for that part of the section as it matches better the requirements of such species ([26], pp. 23–25, 67–68, 683–694; [28]). It should be added here that there is no evidence for *S. semiforme* (Oppel) in Ardeche, Sicily and Maritime Alps, i.e. areas where *H. verruciferum* (Menegh.) has been found in at least 4 localities. The latter is also more common in Central Apennines and NE Italian Alps, being known from 8 or 9 localities whilst the former—from 2 only. For references to the finds of *S. semiforme* (Oppel) in other areas see Enay ([14], fig. 2). That author reported *Semiformiceras* from Ardeche but the cooccurrence of *"K." richteri* (Oppel) suggests that we may be (or are) dealing with *S. fallauxi* (Oppel). In that paper he speaks about distribution of that genus and not individual species when he reports it to cooccur with *"Haploceras (gr. verruciferum)"*.

TABLE

Proposed correlation's scheme



SPAIN (Betic Mountains) according to Olóriz and Tavera, modified by Olóriz and Tavera [28–31].

POLAND (Rogoznik) according to Kutek and Wierzbowski [21] in adaptation of Enay and Geyssant [16] for the Southern Spain (Betic Mountains), although this zonal scheme is only partially verified in the Polish studied profile.

BULGARIA according to Sapunov [35, 36].

CENTRAL EUROPE (S), (Southern Franconia), according to Zeiss [44]. For the upper Tithonian (III) facies-faunal district, according to Sapunov und Ziegler (1976) cited by Sapunov [35].

FRANCE, Southern Europe, according to Enay [13] and for the upper Tithonian (SE France) by le Hegarat [24].

MEDITERRANEAN (s.l.) (Mediterranean and Submediterranean) according to Kutek and Zeiss [46].

MEXICO according to Verma and Westermann [43].

ARGENTINA according to Leanza [22].

MADAGASCAR according to Collignon [6].

He did not state the presence of the latter in Ardeche there so it is not clear whether or not he thinks about cooccurrence of these taxa. If Enay meant the presence of at least one of them, the situation would be much closer to that outlined [45, 17, 7, 5, 42] or indirectly suggested [8–11, 39] in the literature.

The only place where proportions are quite clearly reversed is Rogoźnik (Carpathians), wherefrom Zittel [45] reported 15 specimens of *S. semiforme* (Oppel) and a single *H. verruciferum* (Menegh.). As we noted above, faunistic association of that section appears quite strange in comparison with those typical of more internal parts of the Mediterranean province. Widespread sparitic textures and "more internal sediments" with micritic textures and tintinoids ([21], p. 197) suggest that we may be dealing here with some environmental factors which may be responsible for the fact that the *Semiformiceras* series begins here with *S. gemmellaroi*, a species undoubtedly of Carpathian origin, and not *S. semiforme* (Oppel). The latter appears here after *H. verruciferum* (Menegh.), which is less frequent than usually.

In Bulgaria, the appearance of *Virgatosimoceras* and *Danubisphinctes* makes possible drawing a boundary of strata with fauna clearly resembling the south German. The Rothpletzi zone, distinguished there [35], comprises strata with *Richterella* and some other perisphinctids which means that only its lower part may be correlated with the Verruciferum zone (see below). It should be emphasized here that the available data [35, 36] suggest the lack of *Lemencia* and appearance of *Richterella* in rocks directly overlaying those with *F. vimineus*.

The Richteri zone [26] is characterized by acme of *Richterella*, various species of *Haploceras*, including very rare *H. woehleri* (Oppel), *Pseudolissoceras*, *Neochetoceras*, *Substreblites* (rare), *Semiformiceras fallauxi* (Oppel), bituberculated *Aspidoceras* (less frequent than below), *Physodoceras*, *"Parapallasioceras"* including last representatives of *"P." pseudocontiguus* group, *Subdichotomoceras* mainly of the Kilian's *S. pseudocolubrinus* group, *Paraberiasella* (a few specimens), *Pseudodiscosphinctes*, *Lithacoceras chalmasi* (Kilian), *Sublithacoceras* and *Virgatosimoceras* close to *V. achiardii* (Campana) and *V. steindachneri* Blaschke.

As in the above cases, correlation of that zone with Submediterranean subdivision appears difficult. The presence of *Sublithacoceras* and the last typical *Virgatosimoceras* suggests that it may correspond to top parts of the Penicillatum–Rothpletzi zone of Enay [13] as well as a part of the Ciliate subzone. Comparison with the subdivision proposed for Bulgarian succession [35] showed that this zone corresponds to the upper part of the Rothpletzi zone, displaying the maximum development of *R. richteri* (Oppel).

In proposing Mediterranean subdivision, Enay and Geyssant [16] differentiated a wide interval above the last strata with *H. verruciferum* (Menegh.) and *S. semiforme* (Oppel) and characterized by the presence of *S. fallauxi* (Oppel).

The range of the latter species comprises beds with *R. richteri* (Oppel). Oloriz [26] proposed subdivision of so interpreted Fallauxi zone into two zones, the lower of which is the above-presented Richteri zone. The latter subdivision was introduced to achieve a closer survey of the two parts of the former zone, lower and upper, especially as the index species, *S. fallauxi* (Oppel) is very rare and there is still no evidence for its presence in strata overlaying those referable to the Richteri zone in our material and literature. Similar conclusions concerning distribution of *R. richteri* (Oppel) were drawn by Kutek and Wierzbowski in their study on the Rogoźnik section ([21], pp. 201–202), in which they accepted the subdivision proposed by Enay and Geyssant [16]. The possibilities of differentiation of the Richteri zone in the Mediterranean area were indirectly shown by Enay ([14], figs. 1 and 5; [15], fig. 2).

The Admirandum/Biruncinatum zone [26] is characterized by high frequency of its two index species as well as several species of *Haploceras*, including first representatives of *H. rhinotonum* (Zittel), innumerous *Physodoceras* and *Aspidoceras* of the *A. rogosnicense-zeuschneri* group, first *Lemencia* proper, *Pseudodiscosphinctoides*, *Subdichotomoceras*, *Parapallasiceras* and *Semiformiceras gemmellaroi* (Zittel). The latter species is very rare and exotic in this area. It should be noted here that identification of that species in southern Spain by Oloriz [26] was questioned by Kutek and Wierzbowski in their analysis of the Rogoźnik section [21]. These authors stated that their 12 specimens are comparable with those figured by Zittel ([45], pl. 4, figs. 10, 11), especially in *U/D* (umbilical diameter to diameter of shell), equal to 0.33 in the case of the specimen figured by Zittel ([45] in plate 4, fig. 11), and that this species is typical of the Semiforme zone but endemic, not known outside Poland. They questioned the Spanish material on account of too high *U/D* value (0.41). However, it should be noted that the other specimen figured by Zittel ([45], pl. 4, fig. 10, said to be shown in natural size) has *U/D* equal to 0.40, i.e. almost the same as in the Spanish material. The appearance of this species in Spain in a higher horizon than in the Rogoźnik section seems explainable in terms of delayed migration to more southern parts of the Mediterranean province.

The correlation with Submediterranean zonation is also difficult in the case of the Admirandum/Biruncinatum zone and it may be only stated that this zone roughly corresponds to the upper parts of the Ciliate subzone in Enay [13]. Enay and Geyssant ([16], p. 52) think that the explosion of *Lemencia* in the uppermost zone of the Lower Tithonian may not be strictly contemporaneous with bloom of that fauna in Neuburg area and that expansion traceable in the Betic Cordilleras is related to somewhat higher horizons. These questions are rather difficult to solve but the comparison of the available material and casts of Schneid's originals (kindly provided by Dr. Scheirer of Munich) makes it possible to state that the upper boundary of the Ciliate subzone passes much higher than that of the Admi-

randum/Biruncinatum zone. The latter may be differentiated in markedly smaller part of the Mediterranean province proper than the Richteri zone which may also be differentiated in the Submediterranean province.

The Lower Tithonian ends with strata directly overlain by those with Himalayitinae fauna. This interval is characterized by predominance of the *Simoceras volanense* group, *Lytogyroceras* and *Lemencia* as well as numerous forms of the genus *Burckhardticeras*, occupying an intermediate position between perisphinctoids and Himalayitinae and representing ancestors for the majority of taxa of the latter subfamily [26]. Stratigraphic range of the genus *Burckhardticeras* made it possible to propose the Burckhardticeras zone [26].

The Burckhardticeras zone is characterized by the presence of the index taxon, rare *Djurjuriceras ponti* Fallot et Termier, *armonicus* Oloriz and *annularis* Oloriz, the *Subdichotomoceras pseudocolubrinus* (Kilian) group and *Parapallasiceras*. Other taxa such as *Pseudodiscosphinctoides, Franconites, Danubisphinctes, Sublithacoceras* cf. *spinctum* Donze et Enay, occasional *S. (Simolytoceras) andaluciense* Oloriz and *Substreblites* are less important whilst *Haploceras* and *Aspidoceratinae* are represented by conservative forms. Top parts of that zone gave *Cordubiceras* [30] and single *Aulacosphinctes, Micracanthoceras and Corongoceras*.

Boundaries of this zone are easy to delineate in the Mediterranean areas so difficulties may only arise in attempts to correlate it with zonations proposed for the Submediterranean province [44, 13]. This is due to the development of endemic forms as *Isterites* and the lack of typical Mediterranean elements in areas of the latter province. The correlations may be made on the basis of *Lemencia* fauna but their results will remain debatable (see [16] and above).

Bulgarian sections, with the lack of *Simoceras, Lemencia* and other taxa, occupy an intermediate position [35, 36]. The Parapallasiceras zone, differentiated there, is characterized by disappearance of *Virgatosimoceras* and its top is defined by first appearances of *Micracanthoceras* and *Paraulacosphinctes*.

The Burckhardticeras zone may be easily correlated with the Ponti zone, also differentiated in the Mediterranean province [16]. The index of the latter, *Djurjuriceras ponti* Fallot et Termier i.e. one of numerous but still poorly known primitive Himalayitinae, is also stratigraphically important but less common ([26], pp. 644, 669, 684; [28, 29]). The question which of the index taxa is better should be left open here as, unfortunately, not much attention was paid to the relevant strata in other areas of the Mediterranean province and most southern parts of the Submediterranean in the latest papers (e.g. [21]).

The Upper Tithonian. The results of our studies on the Lower–Upper Tithonian boundary and changes in ammonite fauna at that boundary were given elsewhere [29, 30]. Lower boundary of the Upper Tithonian is defined

by the appearance of *Simplisphinctes* (Himalayitinae) which, at the same time, was accepted as index taxon of the lowermost zone of the Upper Tithonian (Simplisphinctes zone in [41], Simplisphinctes subzone in [29]).

The Simplisphinctes zone is characterized by some forms referable to the index genus as well as the last simoceratid *Cordubiceras* Oloriz et Tavera [30] (including its synonym, *Baeticoceras* Geyssant *et al.* in [18]), declining *Lytogyroceras, Lemencia, Oloriziceras* [41], *Pseudodiscosphinctes* and highly diversified assemblage of Himalayitinae: *Micracanthoceras, Corongoceras, Protacanthodiscus, Djurjuriceras, Aulacosphinctes* and *Tithopeltoceras*. The last of Himalayitinae generas may also be present along with exotic *Simospiticeras* in basal part of the next zone [27]. It should also be noted that at the very base of the Simplisphinctes zone there was found a single specimen of *Hemisimoceras*, regarded as endemic from the Hollandi zone in Madagascar.

Difficulties encountered in attempts to correlate the above unit with zonations proposed for other areas may be explained by an increase in provinciality. There are only a few taxa in common with assemblages known from Submediterranean province and provinciality of American faunas is very high. The only zonation usable for Mediterranean province, i.e. that of Enay and Geyssant [16], still should be treated as provisional as detailed paleontological study is still missing and, therefore, characteristic features of the fauna are insufficiently known.

Outside the studied region, the genus *Simplisphinctes* has been reported under the name of *Himalayites? abnormis* n. sp. from Djurjura (Algeria) by Roman [34]. Lower boundary of the Simplisphinctes zone appears easily correlable with the base of the Microcanthum subzone in Bulgaria [35, 36], Hollandi zone in Madagascar [6] and even the Internispinosum zone in Argentina [22]*) and the Kossmatia-Durangites-Corongoceras association in Mexico [43]. The upper boundary is characterized by the disappearance of the zonal index as well as *Chitinoidella* [29] and the zone may be treated as an equivalent of lower parts of the Microcanthum subzone in Bulgaria and the Kossmatia–Durangites–Corongoceras association in Mexico and a part if not the whole Internispinosum zone in Argentina. It should be noted here

*) When this paper was completed, we found a new correlation of the Andean and Mediterranean subdivisions, proposed by Leanza [23]. This author recorded some species morphologically close to the Betic ones [26] in Cerro Lotena sections, Neuquen province, Argentina, using them as a new basis for correlation. The fauna coming from the Internispinosum zone suggests that the boundary between the Middle and Upper Tithonian as interpreted in Argentina or the Lower and Upper Tithonian as accepted here, may be passing in that zone. In turn, the cooccurrence of ammonites of the Burckhardticeras zone and himalayitids suggests that either 1) the fossils are Upper Tithonian and we are dealing with early arrival of Mediterranean forms or 2) himalayitids developed in the Andean region earlier than in Europe. The data presented there [23] also show that Andean *Aulacosphinctes* evolved earlier than its Mediterranean allies which gives support for the above viewpoint of Leanza. However, the Andean–Mediterranean correlations still remain hazardous.

that strata with *Windhauseniceras internispinosum* (Krantz) also yielded a form very strange in morphology, which Leanza [22] interpreted as impossible to accomodate in any available genera and described as *Wichmanniceras mirum* nov. gen. n. sp. ([22], p. 83, pl. 1, figs. 4, 5). It is not excluded that this form, coming from the strata correlable with those with *Simplisphinctes* in Mediterranean province, may be of Mediterranean origin.

The next, **Transitorius zone** ([41], Transitorius subzone [29]) has its base defined by the appearance of isocostate perisphinctoids with ventral smooth band. The forms are grouped around the genus *Paraulacosphinctes*, created by Schindewolf [37] for Oppel's species *A. senex* (type) and *A. transitorius*. The material gathered above strata with the two species in the Betic Cordilleras comprises some other morphotypes with ventral smooth band, for which some new taxa of generic rank were proposed. The new genera, comprising some species well established in literature as well as new ones, include: *Moravisphinctes* (*moravicus* Oppel, *fischeri* Kilian), *Zittelia* (*eudichotomus* Zittel, *linoptychus* Uhling and other species reported from Spiti, Madagascar and Argentina) and *Neoperisphinctes* (*falloti* Kilian). New species were assigned to the above genera as well as *Andalusphinctes*, which may also comprise *Perisphinctes praetransitorius* Font. The bloom of that fauna has taken place in the Transitorius zone. Some species pass into the next, Durangites zone, characterized by the development of *Neoperisphinctes* fauna. The results presented above form a part of D. Sc. thesis of the junior author (J.M.T. [41]).

The above-mentioned taxa are accompanied by *Micracanthoceras microcanthum* (Oppel) and other species, *Corongoceras*, *Aulacosphinctes*, *Protacanthodiscus*, *Djurjuriceras*, etc.

The base of this zone is also defined by the appearance of calpionellids proper [29, 28] which, at present, is the only firm criterion for correlations in the Mediterranean province. The Simplisphinctes and Transitorius zones may be treated as an equivalent of the Microcanthum zone as interpreted by Enay and Geyssant [16]. The latter would be better treated as corresponding to the Micracanthoceras acme as *M. microcanthum* (Oppel) seems limited to the Transitorius zone only [28].

The Transitorius zone may be correlated with the Hollandi zone of Madagascar [6], the Kossmatia–Durangites–Corongoceras association in Mexico [43] and the Microcanthum subzone in Bulgaria [35, 36] and a part of the Alternans zone and possibly upper part of the Internispinosum zone in Argentina [22].

The Durangites zone [16] is characterized by the presence of the index taxon of American origin as well as *Protacanthodiscus* at the peak of its development, innumerous *Micracanthoceras*, *Corongoceras* and *Aulacosphinctes*. *Paraulacosphinctes* is rarer than below and *Neoperisphinctes* seems limited to upper parts of this zone. Attention should be paid to first occurrences of *Berriasella* proper (unknown from older strata) and *Substeueroceras* and *Kossmatia*, the latter two represented by two specimens of each only.

The composition of the whole assemblage suggests that this zone corresponds to upper parts of the Microcanthum zone as interpreted in Bulgaria by Sapunov [35, 36], upper part of the Alternans zone and lower part of the Koeneni zone in Argentina [22], upper part of the Kossmatia–Durangites–Corongoceras association and lower part of the Substeueroceras–Berriasella association in Mexico [43] and a part of the Hollandi zone in Madagascar [6].

The base of this zone cannot be correlated with any zonal boundary hitherto proposed and the upper boundary, interpreted by us as an equivalent of the Jurassic–Cretaceous boundary, will be discussed below.

The Jurassic–Cretaceous boundary. Following decisions taken at the 1973 Lyon–Neuchâtel Symposium, several authors used to accept the boundary between the Durangites and Jacobi-Grandis zones as the Tithonian–Berriasian and, at the same time, Jurassic–Cretaceous bondary. The change in ammonite fauna, taking place at that boundary, is considerable. Great explosion of Berriasellinae and decline of Perisphinctidae and Himalayitinae indicate the type of ammonite spectrum that will be typical of the Berriasian. *Protacanthodiscus* is the only genus passing into the Jacobi zone which is characterized by *Pseudosubplanites, Malbosiceras, Mazenoticeras, Delphinella, Jabronella, Dalmasiceras, Elenaella, Subalpinites* and *Spiticeras* proper [40]. The change is similar to that between the Microcanthum and Chaperi subzones in Bulgaria [35, fig. 3] and Sapunov treats the boundaries as synchroneous. This seems the only reliable correlation in the Mediterranean area *sensu lato* as the bases as defined in the Betic Cordilleras [40] and Bulgaria [35] cannot be correlated with the base of the Jacobi zone as delineated in SE France [24]. In the latter area, lower part of the Jacobi zone seems to be missing or Tithonian–Berriasian junction beds may be condensed (e.g. in Aizy and Chomerac sections) as comparisons with faunal successions in the Betic Cordilleras indicate mixed nature of the fauna.

The correlation of subdivisions proposed for the above interval in the Mediterranean province and the Americas [25] appears troublesome (see above) as forms known to occur in both areas are innumerous and of limited value. The record of two individuals of *Substeueroceras* in the Durangites zone in the Betic Cordilleras may be treated as incidental and this genus, well represented in the American region, appears to be of American origin. All the references to its presence in the Mediterranean area are debatable, except for that from N Iran ([38], p. 97). Allocation of *Ammonites carpathicus* Zittel [43] and some other species (*davidi?, allobrogense?, suprajurense?, flandrini* and *beneckei*—see [20]) in this genus is questionable. The presence of *Substeueroceras* in the Durangites zone in the Betic Cordilleras suggests that this zone corresponds to lower part of the Koeneni zone in Argentina and Mexico (see above). To sum up, if we accept the Durangites–Jacobi boundary as the Jurassic–Cretaceous one in the Mediterranean province

sensu lato it would not agree with that accepted at present in the Americas (Alternans–Koenigi boundary). However, at the present state of knowledge it may be stated that selection of any other boundary would not reduce the problems, not to say about solving them.

Correlations with subdivisions proposed for the Boreal Realm are out of scope of this paper as there are no common elements in the studied fauna. It may only be added that before such attempt is made, much attention should be paid to correlations of the Submediterranean and Subboreal, i.e. transitional subdivisions.

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Ф. Олорез, Х. М. Тавера, **Корреляция титона в центральной части Бетыцкой гряды (Испания) в свете новых исследований**

Исследования последнего десятилетия позволяют достаточно точно охарактеризовать титон (самая верхняя часть юры средиземноморской провинции), делают возможной и желательной корреляцию стратиграфического разреза этой провинции с другими районами Европы. Ассоциации аммонитов средиземноморского типа оказываются наиболее соответствующими для составления расчлененности этого яруса т.к. находится все больше и больше доказательств регрессии и как следствие все большего провинциализма аммонитовых фаун. В данной статье предлагается расчленение, основанное на изучении разреза титона и самых низов берриаса в Бетыцкой гряде, а также на корреляции с другими стратификациями, предлагаемыми для этой и других частей Средиземноморской провинции в Европе и более отдаленных регионах (Мексика, Аргентина и Мадагаскар). Сокращенно описаны границы киммеридж-титон, нижний-верхний титон и титон-берриас (т.е. юрамел).