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MAIOLICA – A UNIQUE FACIES OF THE WESTERN TETHYS

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Abstract: Light-coloured pelagic limestones with cherts, known as maiolica, are a distinctive uppermost Jurassic–Lower Cretaceous facies of the Western Tethys. This facies originated in both, oceanic bottoms and in continental margins, mainly in deep basins but also on drawned platforms and on submarine elevations. It reflects the greatest facies unification in the Mesozoic history of the Western Tethys.

The development of maiolica in the Western Tethys may be related to: (*i*) the restriction of deep-water connections with the Eastern Tethys, (*ii*) the establishment of antiestuarine circulation, (*iii*) subevaporitic conditions, (*iv*) the development of calcareous nannoplankton, (*v*) the lowering of CCD in response to factors (*i*)–(*iv*).

Key words: Maiolica, Western Tethys, palaeogeography, palaeobathymetry, palaeoceanography, facies distribution, Alpides, Late Jurassic, Early Cretaceous.

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INTRODUCTION

Light-coloured (white to grey) pelagic limestones with cherts, occurring in the uppermost Jurassic and Lower Cretaceous in the Alpides of Europe and in the Atlantic, belong to the characteristic facies of the Western Tethys. These limestones, which have different local names in various areas, are referred to in this paper under a common name – *maiolica facies*. The typical maiolica facies usually encompasses the Upper Tithonian and Berriasian but its stratigraphic extent is somewhat different in various regions.

The maiolica facies has long attracted the attention of stratigraphers, and recently also of sedimentologists. This study stresses the palaeogeographical conditions of the occurrence of this facies. The paper includes the results of the author's studies in the Tatra Mts., the Pieniny Mts., and the Southern Alps.

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NOMENCLATURE

The name maiolica (from the Italian *maiolica* – a variety of pottery) has been used to denote white, well stratified, pelitic limestones with cherts in the uppermost Jurassic and the Lower Cretaceous of the Lombardian Alps since 1819 (*cf.* Dal Piaz & Trevisan, 1956). In the Venetian

Alps the name biancone (from the Italian *bianco* – white) has been used for very similar sequences since 1824 (Dal Piaz & Trevisan, 1956). The name biancone became more popular outside Italy. It has been used in the Carpathians (*cf.* Andrusov, 1959; Birkenmajer, 1977), in Hungary (*cf.* Kázmér, 1986), and in northern Yugoslavia (Babič, 1973; Buser, 1979).

In Poland, the name maiolica has hardly been used. In the Alpine area, the names maiolica and biancone are commonly used as synonyms for the same type of limestone facies (Bernoulli, 1972; Cita, 1965).

In recent years the name maiolica, which has the priority, is more and more frequently used outside the Lombardian Alps. In the Lombardian Alps, maiolica is not only the name of a facies, but also of a lithostratigraphic unit. In the latter sense it is used in the papers written by Italian geologists (*cf.* Desio, 1973). This lithostratigraphic name does not conform to the rules of Hedbergian stratigraphy (Hedberg, 1976), but it conforms to the Italian code (Azzaroli *et al.*, 1968), which protects the traditional stratigraphic names.

The Swiss geologist H. Weissert (1979) proposed to use the following divisions: Lombardische Maiolica, with its type section in Breggia, and Venetische Maiolica, with its type section in Spiazzi. However, the author of this proposal does not follow it himself when he uses the names Lombardian Maiolica Formation and Venetian Biancone Formation or just Maiolica Formation in a later paper (Weissert, 1981). This abbreviated term – Maiolica Formation – is also used by other authors for both the Lombardian and the Venetian Alps, often interchangeably with the name maiolica facies (e.g. Winterer & Bosellini, 1981). Geologists often confuse the facies and formation concepts, using also for example the term Radiolarite Formation (Hsü, 1976; Winterer & Bosellini, 1981), which does not concern a concretely defined lithostratigraphic unit.

The deposits belonging to the maiolica facies are included in various lithostratigraphic units (in different areas). These may be both formal, conforming to the rules of Hedbergian stratigraphy, and informal, although frequently well defined units. Both groups are listed in Table 1.

It is expected that with the increasing use of the Hedbergian rules of stratigraphy which is taking place, the number of the lithostratigraphic units distinguished within the maiolica facies will increase further. This process is inevitable, because well defined and individually named lithostratigraphic divisions are necessary for their presentation on geological maps and sections. Full unification of lithostratigraphic nomenclature is not possible (*cf.* Wieczorek, 1988a,b), and the use of the term Maiolica Formation in all the area of the occurrence of this facies would be unjustified.

It is possible and justifiable to use one name for a distinctive facies in various regions. The use of maiolica as the name of a facies in especially helpful when discussing facies-palaeogeographic questions. A similar example is provided by a more popular term – *ammonitico rosso* (correct usage-rosso *ammonitico*, see Farinacci & Elmi, 1981), used for definite lithostratigraphic divisions in the Southern Alps as well as, in a very wide sense, for a recurrent

Maiolica facies – lithostratigraphic names

Name	Area	Stratigraphical position	References
Formal names			
Lombardian Maiolica Fm.	Lombardian Alps	U. Tithonian – Barremian	Weissert, 1979, 1981
Russenna – Aptychenkalk Fm.	Central Alps (Austroalpine units)	U. Tithonian – L. Aptian	Dössegger *et al.*, 1982
Pieniny Limestone Fm.	Pieniny Klippen Belt	Tithonian – Barremian	Birkenmajer, 1977
(?) Lucivna Fm.	Western Inner Carpathians	U. Berriasian – L. Albian	Polák & Bujnovsky, 1979
Murguceva Fm.	S. Carpathians	Tithonian – Hauterivian	Avram, 1976, 1984
Mogyrosdomb Limestone Fm.	Bakony	Tithonian – L. Barremian	Kazmer, 1986
Márevar Limestone Fm.	Mecsek	U. Tithonian	Kazmer, 1986
Chiaramonte Fm.	SE Sicily	U. Tithonian – L. Hauterivian	Patacca *et al.*, 1979
Moro Fm.	Maio, Cape Verde Islands	Tithonian – Albian	Robertson, 1984a
Blake-Bahama Fm.	Blake-Bahama Basin	U. Tithonian – Barremian	Iansa *et al.*, 1979
(?)Tumbitas Mb. (Guasasa Fm.)	Sierra de Los Organos, Cuba	U. Berriasian – L. Hauterivian	Pszczółkowski, 1978
(?)Sumidero Mb. (Artemisa Fm.)	Sierra del Rosario, Cuba	Berriasian – Hauterivian	Pszczółkowski, 1978
Informal names			
Venetian Biancone Fm.	Venetian Alps	U. Tithonian – L. Aptian	Weissert, 1981
Maiolica Fm.	Southern Alps	U. Tithonian – L. Aptian	Baumgarter, 1984; Renz Habicht, 1985
Calcare di Soccher (partly)	A. Alps (Belluno)	Oxfordian – Campanian	Gnaccolini, 1968; Casati & Tomai, 1969
Calcare Rupestre	Apennines	U. Tithonian – L. Aptian	Bartolotti *et, al.*, 1970
Lattimusa	Sicily	U. Tithonian – L. Cretaceous	Wendt, 1969
Vigla Limestone (partly)	Hellenides	Tithonian – M. Cretaceous	Bernoulli, 1972
Aptychenkalke	Northern Calcareous Alps (Albania)	Tithonian – Berriasian	Prey, 1980
Oberalm Beds	Northern Calcareous Alps	U. Tithonian – M. Cretaceous	Patzelt, 1971
Svaljavska svita	Pieniny Klippen Belt (Ukrainian sector)	Tithonian – L. Berriasian	Flügel & Fenninger, 1966; Garrision, 1970
		Tithonian – L. Barremian	Kruglov, 1979
Hornsteinkalk (old name)	Pieniny Klippen Belt	Tithonian – Barremian	see Birkenmajer, 1977

facies in different regions and of different age (cf. Farinacci & Elmi, 1981; Wieczorek, 1983).

The list in Table 1 does not include the area of the Tatra Mts. where maiolica occurs in the Križna sequence and was recently distinguished as a unit, which was named the Pieniny Limestone Formation (Lefeld, 1985). However, the use of the names from the Pieniny Klippen Belt for the units in the Tatra is not appropriate, the more so because there are significant differences between the Pieniny and Tatra sequences (*cf.* Wieczorek, 1988b).

Using the name maiolica or biancone for a type of rock is not appropriate as these terms denote facies and not petrographical types. Similarly as the turbidite intercalations in a pelagic sequence should not be termed flysch, pelagic limestone intercalations in a sequence of allodapic limestones should not be termed maiolica or biancone (see Nowak, 1973, p. 406).

DESCRIPTION OF THE MAIOLICA FACIES

The sequences of the maiolica facies are dominated by white to grey, compact, well stratified pelitic limestones with dark cherst (Pl. I: 1, Pl. II: 1, Pl. III). The bedding of the limestones is very distinct; the bed thickness varies usually from 5 to 30 cm. Lamination within the beds is rare (*cf.* Robertson & Bliefnick, 1983; Robertson, 1984a,b) due to the obliteration of the original lamination through the intense penetration of the sediments by organisms (Pls. II – IV). Slump deformations of the bedding are frequent (Pl. I: 2; Weissert, 1979, 1981). A characteristic feature of this facies is the presence of nodular or layered cherst (Pls. II 1, III; Mišik, 1973). Stylolites are also common.

Some differentiation in the lithology of the maiolica facies can be observed. Basinal sequences, for example those in the Lombardian Alps and in the Pieniny Klippen Belt (Branisko-Pieniny succession) usually attain thicknesses of over one hundred metres. Besides pelitic limestones, consisting mainly of calcareous nannofossils, there are numerous calcarenites and calcirudites deposited by turbidity currents. Intercalations of marls and black shales are also frequent. It should be stressed, however, that there are also condensed sequences, from less than ten to some tens of metres thick, devoid of turbidite intercalations, e.g. the Grajcarek sequence and the Križna sequence in the Carpathians.

In the sequences of submarine rises or drawned carbonate platforms (e.g. the Trento platform in the Southern Alps) the thickness of the maiolica facies does not usually exceed one hundred metres. Granular intercalations and the layers of marls and black shales are less numerous here, while dolomitization is more frequent (Colaccichi & Pialli, 1967; Bernoulli & Renz, 1970). In some sequences the limestones are distinctly nodular (*maiolica nodulare* – see Chiocchini *et al.*, 1980).

The limestones of the maiolica facies are built mainly of calcareous nanofossils, among which the main rock-building role belongs to the genus *Nannoconus* (Bronnimann, 1955; Grunau, 1959; Cita, 1965). Coccoliths (Canuti & Marcucci, 1969; Flügel & Keupp, 1979) and calcispheres (Borza, 1969; Obermajer, 1986) are numerous but calpionellids are more abundant (e. g. Grunau, 1959; Remane, 1983) so that this facies is often referred to as the *Calpionella* limestones. Radiolarian skeletons are important rock-forming element of the maiolica facies (Baumgartner, 1984; Gorican, 1983). Spicules of siliceous sponges (Flügel & Meixner, 1972) occur less frequently, as well as foraminifers (Canuti & Marcucci, 1969), ostracods (Garrison & Fischer, 1969), and dinoflagellates (Habib & Drugg, 1983).

Macrofauna is represented mainly by aptychi which may be locally abundant (Parona, 1881; Gąsiorowski, 1962; Renz, 1983; Renz & Habicht, 1985), so that the limestones are locally called *Aptychenkalk*, especially in the Eastern Alps. Rhyncholites (Gąsiorowski, 1973) and belemnite rostra (Rodighiero, 1919; Renz, 1983) are encountered rarely. Ammonites include int. al.: *Phylloceras*, *Lyptoceras*, *Neocomites*, *Berriasella*, *Corongoceras*, *Crioceratites* (Parona, 1881; Rodighiero, 1919; Lefeld, 1974; Avram, 1976; Rieber, 1977; Myczyński, 1977; Renz, 1983; Cecca, 1985). Brachiopods – *Terebratulidae* and *Pygope* – occur locally in the Southern Alps (*cf.* Dieni & Middlemiss, 1981; Benigni, 1983).

Rich benthic life is documented by numerous trace fossils characteristic of the maiolica facies (Pls. II – IV). The most frequent are *Chondrites* traces (Pl. II: 1, 2; Pl. IV: 3), also locally numerous are *Zoophycos* traces (Pl. IV: 1, 2). *Teichichnus* traces (Pl. II: 1) and vertical traces (Pl. II: 2) have been observed sporadically.

Accumulation rate. The rate of accumulation of the maiolica facies calculated without the correction for compaction, and based on the geological time scale of Harland *et al.* (1982) equals:

Southern Alps:	
Lombardian Basin	5.4 m/10^6 years
Trento Platform	ca. 4 m/10^6 years
Apennines:	
Tuscan sequences	23 m/10^6 years
Umbrian sequences	20 m/10^6 years
Northern Calcareous Alps	
Oberalm Schichten	17 – 51 m/10^6 years (see Garrison & Fischer, 1969)
Carpathians	
Murguceva Formation	ca. 4 m/10^6 years
Grajcarek sequence	0.08 – 0.24 m/10^6 years
Niedzica sequence	0.17 – 0.25 m/10^6 years
Branisko sequence	4.8 m/10^6 years
Križna sequence	5 m/10^6 years
Atlantic	
Moro Formation	4.8 – 9.4 m/10^6 years
Blake-Bahama Formation	25 – 30 m/10^6 years

The high accumulation rate of the Oberalm Schichten and of the Tuscan sequence is related to the presence of numerous turbidite intercalations. The same regards the Blake-Bahama Formation that, additionally, was not subject to as much compaction as the sequences now exposed in the Alpides. The accumulation rate of pelitic sequences is usually about 5 m/10^6 years. The anomalously low accumulation rate of some sequences, e. g. that of the Grajcarek sequence, may reflect conditions unfavourable for the development of calcareous nannoplankton.

MAIOLICA AND THE TETHYS PALAEOGEOGRAPHY

The maiolica facies is characteristic of the western part of the Tethys, and it is known from the Mediterranean as well as the Atlantic and Caribbean regions (Fig. 1). In the Eastern Tethys the maiolica facies is known from only a few profiles in Indonesia (Bemmelen, 1949). In this part of the Tethys siliceous deposition is characteristic of the Jurassic/Cretaceous transition.

The Late Jurassic and Early Cretaceous was a time of widening of the Western Tethys which became connected to the Pacific between the South and North America. The other important event was the restriction of the connections between the western and eastern part of the Tethys as a result of

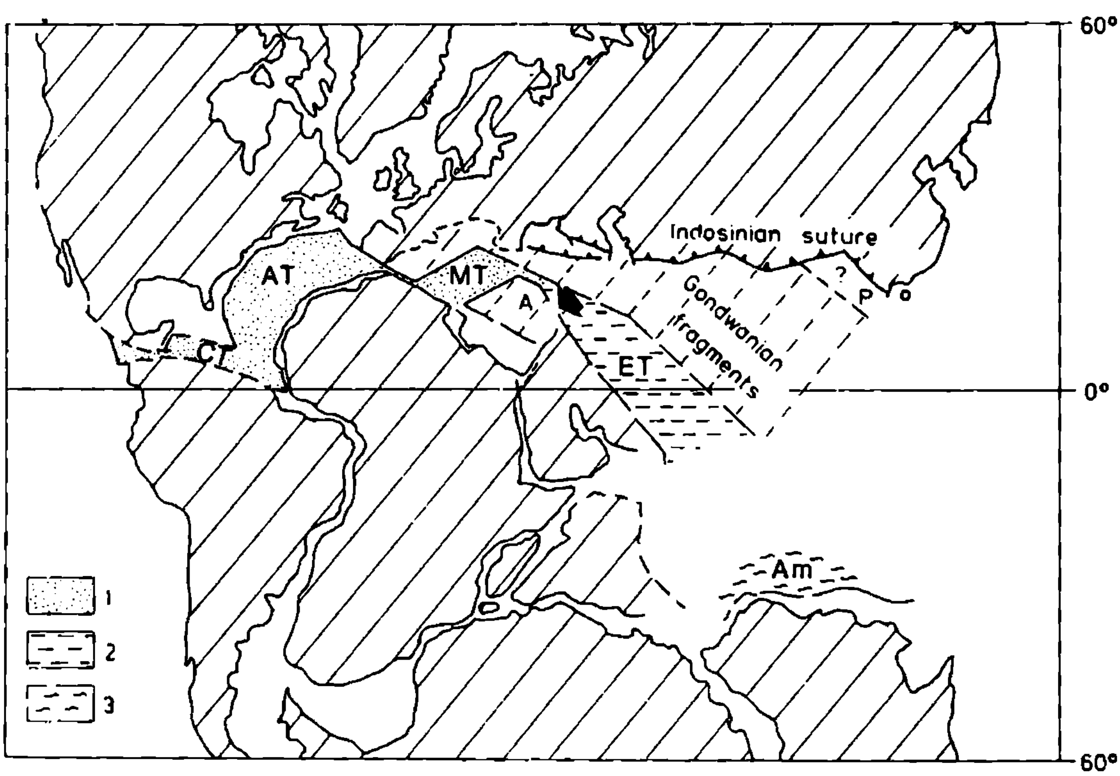


Fig. 1. Main basins of the Late Jurassic Tethys, after Bernoulli & Lemoine (1980), slightly modified. *1* – maiolica facies; *2* – radiolarites; *3* – marls; *CT* – Caribbean Tethys; *AT* – Atlantic Tethys; *MT* – Mediterranean Tethys; *ET* – Eastern Tethys; *A* – Adria (Apulia) block; *Am* – Austrialian margin; *P* – possible remnants of Paleotethys

the closing of the Vardar zone (*cf.* *Ogg et al.*, 1983). These events controlled the palaeogeographical extent of the maiolica facies.

The maiolica facies is best known from the Mediterranean sector of the Tethys (Fig. 1, 2) where its type locality occurs in the Southern Alps. Palaeogeography of this sector of the Tethys has been widely discussed in the recent years (e.g. Laubscher & Bernoulli, 1977; Dercourt *et al.*, 1985; Wieczorek in press). The main axial basin of this sector was the Ligurian-Piemont "ocean" connected through the zone of transform faults with the Atlantic sector. The Ligurian-Piemont "ocean" was a narrow zone underlain by oceanic crust, whose continuation to the east is not clear.

The maiolica is known from the zone of the Ligurian-Piemont "ocean" where it is usually underlain by radiolarites directly overlying oceanic crust. Locally maiolica may directly overlie ophiolites (*cf.* Decandia & Elter, 1972; Barrett, 1982a,b), probably reflecting a differentiated topography of the basement that was subject to synsedimentary tectonic movements (Weissert & Bernoulli, 1985).

The "oceanic" maiolica facies is present in the section in Liguria, on the Elba island (Decandia & Elter, 1972; Barrett, 1982a), in the Southern Apennines (Ogniben, 1969; Vezzani, 1969) and in the Cottian Alps – Chabriere series (Lemoine, 1980).

The main area of deposition of the maiolica facies was Adria (Apulia). Towards the end of the Jurassic the margins of Adria formed a distinctive system of submarine basins and rises and more extensive, shallow carbonate platforms (Fig. 2; Channel *et al.*, 1979; Bernoulli *et al.*, 1979). The deep-water basins along the margins of Adria included the Lombardian Basin with its very differentiated topography of submarine throughs and ridges. In the Lombardian Basin the maiolica usually overlies red radiolarian marls (*rosso ad aptici*) and is covered with variegated marls (*scaglia variegata*). The most complete sections of this facies, up to 150 m thick, are known from the deeper parts of the basin (Monte Nudo Trough, Monte Generoso Trough, Sebino Trough; see Gaetani, 1975; Weissert, 1979), while on submarine rises the sections are thinned and the maiolica facies even directly overlies a Liassic basement (e.g. Lugano Sill zone – Gaetani, 1975; Weissert, 1979).

A similar topography was characteristic for the Northern Apennines (Bernoulli *et al.*, 1979) where the sequences of maiolica attain 700 metres in thickness due to the deposition in the basins not only of pelagic material, but also of shallow-water limestones, which were redeposited from elevated carbonate platforms (*cf.* Bernoulli, 1967).

The maiolica facies is also present in the sections of the Calcare di Soccher in the Belluno Trough (Gnaccolini, 1968; Casati Tomai, 1969). Submarine slumps are common in this sequence. The maiolica includes an admixture of shallow-water material redeposited from the Friuli platform (Prof. F. Massari – oral communication, 1986). The basinal sequences of maiolica, occurring around Adria, also occur in the Lagonegro Basin, from the Slovenian (Julian)

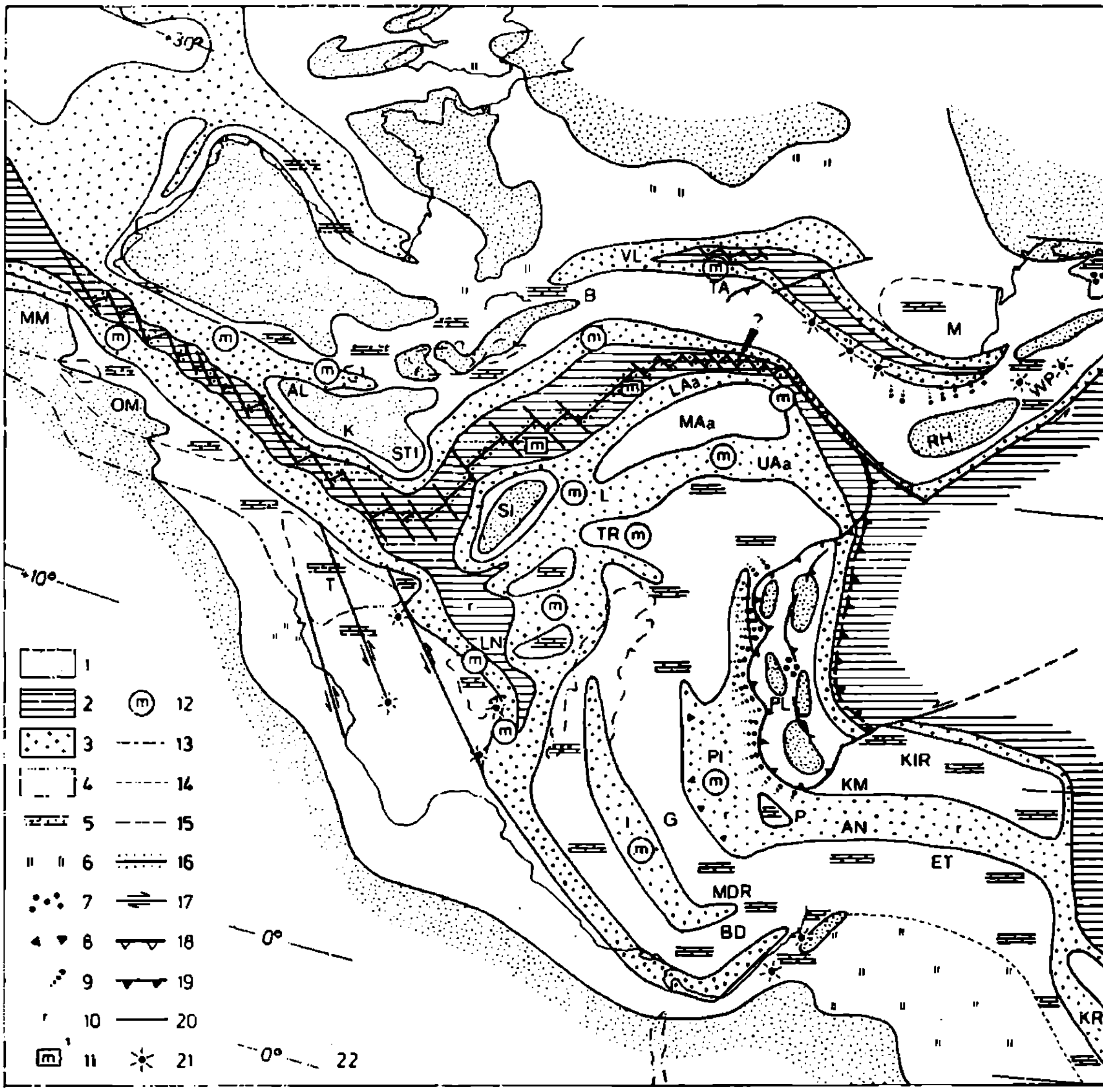


Fig. 2. Distribution of maiolica facies in Mediterranean Tethys. Paleogeography after Dercourt *et al.* (1985). *1* – emerged land; *2* – oceanic crust; *3* – thin continental crust; *4* – thick continental crust; *5* – platform limestone; *6* – evaporite; *7* – conglomerate; *8* – breccia; *9* – flysch; *10* – radiolarite; *11* – maiolica facies on oceanic crust; *12* – maiolica facies on continental crust; *13* – outer limits of Alpine domain; *14* – facies boundaries; *15* – boundaries of block; *16* – active spreading ridge; *17* – transform fault; *18* – oceanic subduction; *19* – thrust; *20* – fault; *21* – volcanism; *22* – palaeoalititude *AL* – Alboran; *AN* – Antalya; *B* – Brianconnais; *BD* – Bey Daglari; *ET* – Eastern Taurides; *G* – Gavrovo; *I* – Ionian Trench; *K* – Kabylia; *KIR* – Kirsehir; *KM* – Kemer; *KR* – Kermanshah; *L* – Lombardian basin; *LAa* – Lower Austroalpine realm; *LN* – Lagonegro; *M* – Moesia; *MAa* – Middle Austroalpine realm; *MDR* – Menderes; *MM* – Moroccan Meseta; *OM* – Oranese Meseta; *P* – Parnassus; *PI* – Pindus; *PL* – Pelagonian Massif; *RH* – Rhodope; *STI* – Stilo; *SI* – Sila; *T* – Tunisia *TA* – Tatricum; *TR* – Trento platform; UAa – Upper Austroalpine realm; *VL* – Valais; *WP* – Western Pontides

Trench (*cf.* Aubouin, 1963; Cousin, 1973), from the Ionian Trench (Bernoulli & Renz, 1970), and from the Pindos Trench in the Hellenides where this facies is confined to the Jurassic/Cretaceous transition, within the Jurassic-Cretaceous radiolarite sequence (Baltuch, 1982; Baumgartner, 1984).

A sequence typical for the carbonate platforms, which surrounded the "oceanic" Tethys and were subsiding at the end of the Jurassic, may be observed on the Trento platform (Venetian Alps). The maiolica facies occurring here is underlain with red nodular limestones – Rosso Ammonitico Superiore. The thickness of the maiolica is variable, usually less than 100 metres (Castellarin, 1972; Weissert, 1979).

In the Austroalpine units, basinal sequences of maiolica occur in the Salzburg area (Garrison & Fischer, 1969) and in Engandine (Dosseger *et al.*, 1982), while in the Central Carpathians such sequences are characteristic for the Križna nappe (Michalik *et al.*, 1987).

In the Tatra Mts. pelagic limestones attributable to the maiolica facies occur in the Upper Tithonian and Berriasian (Lefeld, 1974). This facies is underlain by radiolarites, red nodular limestones and greenish-pink marls equivalent to the rosso ad aptici facies. Though this is a basinal sequence, it lacks turbidite intercalations with redeposited shallow-water material.

The maiolica facies in its typical development occurs in the Pieniny Klippen Belt where it is a characteristic element of the Branisko-Pieniny sequence, and attains more than 180 metres in thickness (Birkenmajer, 1977). Thinner sections occur in the Niedzica and Czertezik sequences. Here the lack of turbidite intercalations with shallow-water material is characteristic, although tectally active ridges were present on the south and north at the Jurassic/Createaceous transition (Birkenmajer, 1975, 1986). The northernmost basin with the maiolica facies was the South-Magura Basin (Grajcarek sequence) where the sequences of this facies are strongly thinned (Birkenmajer, 1977; Obermajer, 1986).

In the western part of the Mediterranean sector the maiolica facies is characteristic for the basinal sequences in the Balearic Islands (Majorca) and in the Sub-Betic zone (Colom, 1955, 1973; Seyfried, 1978).

In the Atlantic sector the maiolica has been found mainly in the drillings in the Blake-Bahama Basin (Jansa *et al.*, 1979; Robertson & Bliefnick, 1983). The maiolica here is usually underlain by the facies of reddish marls (equivalent of the rosso ad aptici facies), and locally it overlies the oceanic basement. The deposits are undeformed tectonically.

In the eastern part of the Central Atlantic the "oceanic" maiolica facies is found in boreholes in the Cape Verde Basin and appears on the surface on Maio island in the Cape Verde Islands (Robertson, 1984b). On Maio island the maiolica directly overlies ophiolites, witch are considered to be the remnant of Late Jurassic – Early Cretaceous mid-oceanic ridge (Robertson, 1984a).

The passive margins of the Central Atlantic at the Jurassic/Cretaceous transition received sediments in shallow-water facies (coral and coral-sponge bioherms) though, as in the Mediterranean sector, some blocks were subsiding and were the site of accumulation of pelagic sediments, including the maiolica facies recently found on the Mazagan Plateau (Jansa *et al.*, 1984).

In the Carribean sector of the Tethys the basinal sequences similar to the maiolica occur in Cuba (*cf.* Pszczólkowski, 1978).

The problem of bathymetry

The occurrence of the maiolica facies on an oceanic as well as continental basement, in basins as well as on submarine rises, indicates that these pelagic deposits were laid down at different depths. The maiolica was deposited above the calcite compensation depth (CCD) and below the aragonite compensation depth (ACD). This depth range is indicated by the presence of calcite skeletons (aptychi, calcareous nanofossils, sometimes brachiopods) and the lack of aragonite ones. This determination of the depth is however very imprecise. ACD is very unstable and CCD in modern oceans is situated at different depths (Berger, 1981) and steeply rises towards the basin margins. The position of CCD depends on many oceanographic, climatic, and ecological factors (Ramsay, 1973; Berger & Winterer, 1974; Berger, 1981), hence the data on the position of CCD in modern oceans can not be directly applied to ancient basins. The CCD position in the geological past depend also on the development of calcareous nannoplankton which appeared in abundance only in the very late Jurassic. For this reason the pre-Tithonian pelagic deposition can not be considered as actualistic. The oceanic crust in the Ligurian-Piemont zone is directly overlain by radiolarites, and radiolarian-rich mudstones are the first Callovian deposits directly overlying the crust of the then opening Central Atlantic. At present, the first deposits in the zones of sea-floor spreading and oceanic crust formation are pelagic limestones. It may be thus supposed, that at the Middle/Late Jurassic transition, CCD was situated much higher (at least in the Western Tethys area) than it is today in the Atlantic. Such oscillation in the CCD position occurred several times in the Earth's history (van Andel, 1975; Berger, 1981) and is also postulated for the Jurassic and Cretaceous (Winterer & Bosellini, 1981). It should also be noted that the CCD position in small oceanic basins could be different to that in great oceans. Hence, the fluctuations recognized in the great oceans do not necessarily correspond to those that might have occurred in small basins. For this reason the conclusion that a sediment was laid down below or above CCD says but little about the basin's depth.

A more dependable bathymetric criterium is provided by the Sclater curve (age-versus-depth curve) which relates the depth changes of oceanic basins to the sea-floor spreading and subsidence of the oceanic crust (Sclater *et al.*, 1977; Berger & Winterer, 1974). Using this curve the depth of the Central Atlantic Basin during the deposition of the Blake-Bahama Formation was determined at 3300 – 3650 m (Robertson & Bliefnick, 1983), and the depth of the Ligurian

Basin (Appenines) during the deposition of Calcari a Calpionelle at 3–4 km (Hsü, 1976) or about 4.5 km (Laubscher & Bernoulli, 1977). Using modified Sclater curves for the Southern Alps, the depth of the basins situated on continental crust has also been calculated (Winterer & Bosellini, 1981). The depth of the Lombardian Basin at the Jurassic/Cretaceous transition has been estimated at 2.4–3 km, and of the Trento Platform at 1–1.3 km (Winterer & Bosellini, 1981).

The shallow-water origin of the maiolica facies may be ruled out. The facies does not include shallow-water fossils or structures indicative of shallow-water facies. Ichnofossils in the maiolica facies sequences are not good bathymetric indicators, but they are ones frequently encounterd in deep-water facies. Shallow-water (*Thalassinoides*) structures are unknown in maiolica facies.

It should be stressed that the presence of the maiolica facies does not necessarily indicate the shallowing of the basins in which radiolarites were being deposited earlier. The occurrence of the maiolica, as well as of other pelagic facies (radiolarites and the rosso ammonitico facies) depends greatly on the position of CCD. Increased subsidence of basins favours siliceous deposition (Baumgartner, 1984), and lower subsidence favours calcareous deposition, but the nature of the pelagic sediments depends more on other factors, e. g. on the change in circulation and availability of nutrients for plankton (Steinberg, 1981; Jenkyns & Winterer, 1982). It is unlikely that different geotectonic zones (mid-oceanic ridges, transform fault zones, trenches adjoining the oceanic basins just being closed, passive continental margins) in which the maiolica facies has occurred, were subject simultaneously to similar subsidence and attained similar depths at the same time. On the contrary, eustatic sea-level variations could be reflected in similar ways in different regions of the sea. The sea-level oscillations during the Jurassic and Cretaceous attained some tens, perhaps even more than one hundred metres (Vail *et al.*, 1980) and had little direct influence on the characteristics of pelagic sediments. More significant were indirect consequences of the eustatic movements such as changes in oceanic circulation, climatic changes, environmental changes. The eustatic lowering of the sea-level at the beginning of the Valanginian resulted in an increased clastic supply to the Central Atlantic Basin, due to the erosion of exposed shelves (Robertson & Bliefnick, 1983). It is noteworthy, however, that this lowering did not result in facies changes in the maiolica sequences deposited on submarine rises.

Oceanographic conditions

The oceanographic conditions in the Tethys were changing during the Jurassic and Cretaceous in response to palaeogeographic changes. The development of oceanic zones of western part of the Tethys during the Middle Jurassic (Lemoine, 1983) and good, deep-water connections with the Eastern Tethys permitted the development of estuarine circulation in the Western

Tethys (*cf.* Kocher, 1981). This system featured the presence of upwellings the high fertility of waters, that permitted the development of radiolarian plankton (Berger, 1970, 1976). This circulation system also enhanced the development of the radiolarite facies in the Callovian and Oxfordian in the Mediterranean sector of the Tethys which was at that time a silica-rich basin.

Numerous hiathuses and stratigraphical condensations at the Callovian/Oxfordian transition, that occurred both in the Tethyan sequences (on platforms and submarine rises) and on the northern shelf, indicate a crisis in carbonate deposition. CCD was apparently situated at a very shallow depth. Dark clays ("*terres noires*") or glauconite marls with phosphorites (*Ornaten Thone*), indicating increased productivity, were deposited in the deeper parts of the Tethyan shelf during the Callovian and Early Oxfordian. During the Middle to Late Oxfordian and Kimmeridgian the enrichment of the Tethys water in silica is also marked on the Tethyan shelf, by the presence of carbonate facies with cherts.

At the end of Jurassic the connections between the Eastern and Western Tethys became restricted due to the closing of the Vardar "ocean". This resulted in the establishment of the antiestuarine (lagoonal) type of circulation in the Western Tethys (*cf.* Kocher, 1981), marked by density stratification of the water column and lower fertility of the surface layer. These conditions favoured the development of the calcareous nannoplankton and brought in consequence a significant lowering of the CCD. Despite the progressive deepening of the laterally spreading Western Tethys basins, the siliceous sediments were being replaced by carbonates.

Progressive depletion of oxygen in the Western Tethys basins is also noticeable. This process is suggested by the following succession:

Kimmeridgian – Lower Tithonian – red nodular limestones and/or pink marls (rosso ammonitico and rosso ad aptici facies)
Upper Tithonian – Lower Cretaceous – light-coloured limestones (maiolica facies)
Middle Cretaceous – black shales and marls (black Cretaceous facies)

The changes in the oxidation of the environment progressed gradually and slowly, as is seen in the maiolica sequences. Some intercalactions of pink marls and limestones occur in the lower parts of the sections, while the black shale intercalations become more and more frequent in the upper parts (*cf.* Weissert, 1981). The increasing oxygen defficiency during the Jurassic-Cretaceous pelagic sedimentation is suggested by the common presence of *Chondrites* traces, indicative of oxygen-poor conditions (Bromley & Ekdale, 1984). The oxygen deficiency in the Western Tethys Basin may be related to the density stratification, resulting from the restricted connections with the Eastern Tethys, and with the subevaporitic conditions characteristic of partly closed basins situated in the tropical zone like the Western Tethys. Subevaporitic conditions are also postulated for the Tethyan shelf on which lithographic limestones were laid down during the Tithonian (Keupp, 1977). Evaporites are also found in the youngest Jurassic in the epicontinental areas of Europe and Africa (*cf.* Hallam, 1984, 1985).

Since the Aptian, in some areas even earlier, the maiolica facies is substituted in the Western Tethys by marly facies and dark shales and turbidites which indicate different conditions in the Tethys at that time (Graciansky *et al.*, 1981). In this period climatic conditions changed from more arid at the beginning of Cretaceous, to more humid beginning with the Barremian (Hallam, 1985). These changes are also reflected in pelagic sequences, by an increase in the proportion of marly sediments. It is noteworthy that even in the sediments of the Early Cretaceous the characteristic alternation of limestone and marl layers is observed in many regions (Vocontian Basin, Gulf of Mexico, Pacific; de Boer, 1980; Cotillon, 1985; Ferry & Schaaf, 1981). It is attributed by some authors to the cyclic climatic oscillations of astronomic origin (Milankovič cycles).

The development of the dark facies during the Middle Cretaceous resulted from both the restricted circulation and the increased supply of organic matter from the land (Stein *et al.*, 1986).

In the Mediterranean sector, compressional movements and the related commencing closure of this part of the Tethys (Trümply, 1982) had an important effect on the facies changes.

CONCLUSIONS

Maiolica is a characteristic facies of the Jurassic/Cretaceous transition. Its geographical distribution is limited mainly to the area of the Western Tethys *sensu lato*, i. e. comprising three sectors: Mediterranean, Atlantic and Caribbean. The maiolica was a facies of both the oceanic bottoms and continental margins. Its appearance coincides with the closure of the Vardar "ocean" and with the widening of the Central Atlantic and of the Ligurian-Piemont Basin. The appearance of the maiolica facies in the Tethys was preceded by the deposition of radiolarites or radiolarian marls or nodular limestones. The simultaneous development of these facies in the Western Tethys is fairly rare. Maiolica is more widely distributed in the Western Tethys than the older radiolarites which are not found in submarine rises nor moreover in the Central Atlantic. The maiolica is also more widely distributed than the rosso ammonitico facies which is limited mainly to submarine rises and their slopes. One ought to add that the radiolarite and rosso ammonitico facies are known not only from the Jurassic and may occur several times in various Tethyan sequences (*cf.*, Grunau, 1965; Farinacci & Elmi, 1981; Wieczorek, 1983). The maiolica facies does not occur in deposits older than the Upper Jurassic.

The maiolica has not only a narrower and more fixed stratigraphic range, as compared with the radiolarite and rosso ammonitico facies, but also a narrower and more precisely defined geographical distribution. Only locally is this facies known in the Eastern Tethys where the rosso ammonitico facies is found from the Jurassic as well as the Triassic, and the radiolarite facies occurred not only in the Triassic and Jurassic but also in the Early Cretaceous, synchronously with the maiolica in the Western Tethys. The radiolarite facies in the Eastern Tethys occurs not only in deep basins, but also on subsiding platforms (Watts & Garrison, 1986). Apparently, the Eastern Tethys was during the Early Cretaceous, a much more silica-rich basin than the Western Tethys.

The occurrence of the maiolica facies in the Western Tethys indicates the specific character of this basin at the end of Jurassic. The appearance of the maiolica facies in the Western Tethys may be related to the following factors: the limitation of the deep-water connections with the Eastern Tethys, the establishment of an antiestuarine circulation system, the development of calcareous nannoplankton, and the lowering of CCD as the result of the earlier listed factors. The appearance of the maiolica facies did not necessarily reflect a shallowing of the basins, relative to the time of radiolarite depositon. The maiolica could be laid in basins of similar or even greater depth, after a strong lowering of CCD.

The greatest lateral distribution of the maiolica facies occurred in the latest Tithonian and Berriasian, but in most basins marly or argillaceous facies or even black shales or turbidites are present instead of maiolica only at the end of Barremian (locally even later, in the Aptian or even Albian). The transition is usually gradual in the Central Atlantic, and more distinct, sometimes marked with hiathuses, in the Mediterranean Tethys (Graciansky *et al.*, 1981).

The maiolica was a unique facies, distinctive for a specific stage, lasting about 30 million years, in the evolution of the Tethys. It also reflects the greatest facies unification in the history of the Western Tethys.

REFERENCES

Andel, T. H., van 1975. Mesozoic/Cenozoic calcite compensation depth and the global distribution of calcareous sediments. *Earth. Planet. Sci. Lett.*, 26: 187–194.

Andrusov, D., 1959. *Geologia Československych Karpat*, vol. II. Slov. Akad. Vcd., Bratislava, 135 pp.

Aubouin, J., 1963. Essei sur la peléogéographie post-triassique et l'evolution secondaire et tertiarie du versant sud des Alpes orientales (Alpes méridionales:Lombardie et Vénétie, Italie; Slovénie occidentale, Yougoslavie). *Bull. Soc. Geol. France*, sér. 7, 5: 730–766.

Avram E., 1976. La succession des dépots tithoniques et crétacés inférieus de la région Svinița (Banat). *Dari Seama Inst. Geol. Geofiz.* 4. *Stratigrafie*, 62: 53–71.

Avram, E., 1984. Remarques stratigraphiques sur la formation de Murguceva (Tithonique supérieur-Hauterivien) de la région de Svinita (Banat), basées sur l'étude des Calpionelles. *Dari Seama Inst. Geol. Geofiz.*, 4. *Stratigrafie*, 68: 17–34.

Azzaroli, A., Cita, M. B. & Selli, R., 1968. Codice Italiano di Nomenclatura Stratigrafica. *Boll. Serv. Geol. Ital.*, 89: 3–22.

Babič, L., 1973. Bezenski sedimenti gornjego titona, beriasa i valendisa zapadno od Bregane. *Geol. Vjesnik*, 26: 11–28. Zagreb.

Baltuch, M., 1982. Provenance and distribution of Tethyan pelagic and hemipelagic siliceous sediments, Pindos Mountains, Greece. *Sedim. Geol.* 31: 63–88.

Barrett, T. J., 1982a. Review of stratigraphic aspects of the ophiolitic rocks and pelagic sediments of the Vara Complex, North Apennines, Italy. *Ofioliti*, 7: 3–46.

Barrett, T. J., 1982b. Stratigraphy and sedimentology of Jurassic bedded chert overlying ophiolites in the North Apennines, Italy. *Sedimentology*. 29: 353–373.

Baumgartner, P. O., 1984. A Middle Jurassic–Early Cretaceous law-latitude radiolarian zonation based on unitary associations and age of Tethyan radiolarites. *Eclogae Geol. Helv.*, 77: 729–837.

Bemmelen, R. W., van, 1949. *The geology of Indonesia*. vol. IA, *General Geology*. Government Printing Office, Hague, 732 pp.

Benigni, C., 1983. Nouva localita fossilifera a *Terebratulidae* (*Brachiopoda*) del Titonico superiore nel gruppe delle Tofane (Belluno). *Riv. Ital. Paleontol. Stratigr.*, 89: 47–80.

Berger, W. H., 1970. Biogenous deep-sea sediments: fractionation by deep-sea circulation. *Geol. Soc. Am. Bull.*, 81: 1385–1402.

Berger, W. H., 1976. Biogenous deep sea sediments: production, preservation and interpretation. In: Riley, J. P. & Chester, R. (eds.), *Chemical Oceanography*, 5: 265–388.

Berger, W. H., 1981. Paleoceanography: the deep-sea record. In: Emiliani, C. (ed.), *The Oceanic Lithosphere. The Sea*, 7: 1437–1519.

Berger, W. H. & Winterer, E. L., 1974. Plate stratigraphy and the fluctuating carbonate line. In: Hsü, K. J. & Jenkyns, H. S. (eds.), *Pelagic Sediments on Land und under the Sea. Int. Ass. Sedim. Spec. Publ.* 1: 11–48.

Bernoulli, D., 1967. Probleme der Sedimentation im Jura Westgrichenlandes und das zentralen Apennin. *Verhandl. Naturf. Ges. Basel*, 78: 35–54.

Bernoulli, D., 1972. North Atlantic and Mediterranean Mesozoic facies: a comparison. In: Holister, C. D., Ewing, J. L. *et al.*, *Init. Repts. D.S.D.P.*, 11: 801–871.

Bernoulli, D., Kälin, O. & Patacca, E., 1979. A sunken continental margin of the Mesozoic Tethys: the Northern and Central Apennines. In: *Symposium "Sedimentation jurassique W européen". A. S. F. Publ. Spec.*, 1: 197–210.

Bernoulli, D. & Lemoine, M., 1980. Birth and early evolution of the Tethys: the overall situation. In: Aubouin, J., Debelmas, J., Latreille, M. (eds.), *Geology of the Alpine chains born of the Tethys. Men. B.R.G.M.*, 115: 168–179.

Bernoulli, D. & Renz, O. 1970. Jurassic carbonate facies and new ammonite faunas from Western Greece. *Eclogae Geol. Helv.*, 63: 537–607.

Birkenmajer, K., 1975. Tectonic control of sedimentation at the Jurassic-Cretaceous boundary in the Pieniny Klippen Belt, Carpathians. In: *Colloque sur la limité Jurassique-Crétace, Lyon, 1973. Mem. B.R.G.M.* 86: 294–299.

Birkenmajer, K., 1977. Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geol. Polon.* 45: 158 pp.

Birkenmajer, K., 1986. Stages of structural evolution of the Pieniny Klippen Belt, Carpathians, *Studia Geol. Polon.*, 88: 7–32.

Boer, P. L. de, 1980. Aspects of Middle Cretaceous pelagic sedimentation in Southern Europe: production and storage of organic matter, stable isotopes, and astronomical influences. *Geol. Ultraiectina*. 31: 112 pp. Utrecht.

Borza, K., 1969. *Die Mikrofazies und Mikrofossilien des Oberjuras und der Unterkreide der Klippenzone der Westkarpaten*. Vyd. Slov. Akad. Ved., Bratislava, 301 pp.

Bortolotti, V., Passerini, P., Sagri, M. & Sestini, G., 1970. The miogeosynclinal sequences. In: Sestini, G. (ed.), *Development of the Northern Apennines geosyncline. Sedim. Geol.*, 4: 341–444.

Bromley, R. G. & Ekdale, A. A., 1984. Chondrites: a trace fossil indicator of anoxia in sediments. *Science*, 224: 872–874.

Bronnimann, P., 1955. Microfossils incerte sedis from the Upper Jurassic and Lower Cretaceous of Cuba. *Micropaleontology*. 1: 28–51.

Buser, S., 1979. Spodnekrende plasti v Bohinju. *Rudarsko-Metalurski Zbornik*, 26: 385—393. Ljubljana.

Canuti, S. P. & Marcucci, M., 1969. Osservazioni al microscopio elettronico sul calcare Maiolica in diversi affioramenti della Toscana centro-meridionale. *Boll. Soc. Geol. Ital.*, 88: 81—105.

Casati, P. & Tomai, M., 1969. Il Giurassico ed il Cretacio del versante settentrionale del Vallone Bellunese e del gruppo di M. Brandol. *Riv. Ital. Paleontol.*, 75: 205—340.

Castellarin, A., 1972. Evoluzione paleotettonica sinsedimentaria del limite tra "piattaforma veneta" e "bacino lombardo" a nordi di Riva del Garda. *Giorn. Geol.*, 38: 11—212.

Cecca, F., 1985. Alcune ammoniti provenienti dalla "Maiolica" dell Appennino Centrale (Umbria, Marche e Sabina). *Bol. Serv. Geol. Ital.*, 103: 133—162.

Channell, J. E. T., d'Argenio, B. & Horvath, F., 1979.Adria, the African promontory, in Mesozoic Mediterranean palaeogeography. *Earth-Sci. Rev.*, 15: 213—292.

Chiocchini, M., Manganelli, V. & Pannuzi, L., 1980. Recerche geologiche sul Mesozoico della Sabina (Lazio). II. I Monti Cornicolani. *Boll. Serv. Geol. Ital.*, 100: 235—265.

Cita, M. B., 1965. Jurassic, Cretaceous and Tertiary microfacies from the Southern Alps (northern Italy). In: Cuviller, J. Schürmann, H. M. E., (eds.). *Intern Sedim. Petrograph.* Ser., 8: 1—99.

Colaccichi, R. & Pialli, G., 1967. Dati a conferma di una lacuna dovuta ad emersione nel Giurese del Monte Cucco (Appennino Umbro). *Bol. Soc. Geol. Ital.*, 86:179—192.

Colom, G., 1955. Jurassic-Cretaceous pelagic sediments of the western Mediterranean zone and the Atlantic aera. *Micropaleontology*, 1: 109—124.

Colom, G., 1973. *Esbozo de las principales lito-facies de los depositos jurasico-cretaceos de las Baleares y su evolucion preorogenica.* Madrid, 116 pp.

Cotillon, P., 1985. Les variations a differents échelles du taux d'accumulation sédimentaire dans les séries pélagiques alternantes du Crétacé inférieur, conséquences de phénomenes globaux. Essai d'évaluation. *Bull. Soc. Geol. France*, sér. 8, 1: 59—68

Cousin, M., 1973. Le sillon slovene: les formations triasiques, jurassiques et néocomienes au Nord-Est de Tolmin (Slovénie occidentale, Alpes méridionales) et leur affinités dinariques. *Bull. Soc. Géol. France*, sér. 7, 15: 326—339.

Dal Piaz, G. & Trevisan, L., 1956. *Lexique Stratigraphique International.* vol. I. Europe, Fasc. II. Italia. Paris, 186 pp.

Decandia, E. A. & Elter, P., 1972. La "zona" ofiolitifera del Bracco nel settore comprese fra Levanto e la Val Graveglia (Appenino Ligure). *Mem. Soc. Geol. Ital.* 11: 503—530.

Dercourt, J. *et al.*, 1985. Présentation de 9 cartes paléogéographiques au 1/20 000 000 s'étendant de l'Atlantique au Pamir pour la période du Lias a l'Actuel. *Bull. Soc. Géol. France*, sér. 8, 1: 637—652.

Desio, A., 1973. *Geologia dell' Italia.* Torino, 1081 pp.

Dieni, I. & Middlemiss, F. A., 1981. Pygopid brachiopods from the Venetian Alps. *Bol. Soc. Paleont. Ital.*, 20: 19—48.

Dössegger, R., Furrer, H. & Müller, W. H., 1982. Die Sedimentserien der Engadiner Dolomiten und ihre Lithostratigraphische Gliederung (Teil 2). *Eclogae Geol. Helv.*, 75: 303—330.

Ferinacci, A. & Elmi, S. (eds.), 1981. *Rosso Ammonitico Symposium Proceedings.* Edizioni Tecnoscienza, Roma, 579 pp.

Ferry, S. & Schaaf, A., 1981. The Early Cretaceous environment at Deep Sea Drilling Project Site 463 (Mid-Pacific Mountains) with reference to the Vocontian Trough (French Subalpine range). In: Thiede, J., Vallier, T. L. *et al.*, *Init. Repts. D.S.D.P.* 62: 669—682.

Flügel, E. & Keupp, H. 1979. Coccolithen-Diagenese in Malm-Kalken (Solnhofen/Frankenalb, Oberalm/Salzburg). *Geol. Rundschau*, 68: 876—893.

Flügel, E. & Meixner, H. 1972. Pyritisierte Spongien-Nadeln und Radiolarien aus Oberalmer-Kalken (Malm) des Weissenbachtales SW Strobl/Wolgangsee (Salzburg). *Ann. Naturhist. Mus. Wien.*, 76: 187—194.

Flügel, H. & Fenninger, A., 1966. Die Lithogenese der Oberalmer Schichten und der mikritischen Plassen-Kalke (Tithonium, Nördliche Kalkalpen). *Neues Jb. Geol. Paläont. Abh.* 123: 249—280.

Gaetani, M., 1975. Jurassic stratigraphy of the Southern Alps. In: Squyers C. (ed.), *Geology of Italy*, Tripoli, pp. 377–402.

Garrison, R. E., 1967. Pelagic limestones of the Oberalm Beds (Upper Jurassic–Lower Cretaceous), Austrian Alps. *Bull. Canad. Petrol. Geol.*, 15: 21–49.

Garrison, R. E. & Fischer, A. G., 1969. Deep-water limestones and radiolarites. In: Friedman, G. M. (ed.), *Depositional environments in carbonate rocks. Soc. Econ. Paleont. Miner., Spec. Publ.* 14: 20–56.

Gąsiorowski, S. M., 1962. Aptychi from the Dogger, Malm and Neocomian in the Western Carpathians and thier stratigraphical value. *Studia Geol. Polon.*, 10, 144 pp.

Gąsiorowski, S. M., 1973. Les Rhyncholites. *Geobios*, 6: 127–196.

Gnaccolini, M., 1968. Sedimentologia del Calcare di Soccher nella regione compresa tra la Valle del T. Vajont (Pordenone) e l'Alpago (Belluno). *Riv. Ital. Paleont.*, 74: 829–864.

Gorican, S., 1983. Radiolarij v jurskem meljevcu med Perblo in Tominskimi Ravnami. *Geologija*, 26: 117–145. Ljubljana.

Graciansky, P. C. de, Bourbon, M., Lemoine, M. & Sigal, J., 1981. The sedimentary record of Mid-Cretaceous events in the Western Tethys and Central Atlantic Oceans and their continental margin. *Eclogae Geol. Helv.*, 74: 353–367.

Grunau, H. R., 1959. Mikrofazies und Schichtung ausgewählter, jungmezozoischer Radiolarit-führender Sedimentserien der Zentral-Alpen. *Inter. Sedim. Petrograph. Ser.* 4: 1–179.

Habib, D. & Drugg, W. S., 1983. Dinoflagellate age of Middle Jurassic-Early Cretaceous sediments in the Blake-Bahama Basin. In: Sheridan, R. E., Gradstein, F. M. *et al.*, *Init. Repts. D.S.D.P.*, 67: 623–638.

Hallam, A., 1984. Continental humid and arid zones during the Jurassic and Cretaceous. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 47: 195–223.

Hallam, A., 1985. A review of Mesozoic climates. *J. Geol. Soc.* London, 142: 433–445.

Harland, W. B., Cox, A. V., Llewellyn, P. G., Pickton, C. A. G., Smith, A. G. & Walters, R., 1982. *A Geologic Time Scale*. Cambridge Univ. Press. Cambridge, 131 pp.

Hedberg, H. (ed.), 1976. *International Stratigraphic Guide*. Wiley and Sons, New York, 200 pp.

Hsü, K. J., 1976. Paleoceanography of the Mesozoic Alpine Tethys. *Geol. Soc. Am. Spec. Pap.*, 170: 1–44.

Jansa, L. F., Enos, P., Tucholke, B. E., Gradstein, F. M. & Sheridan, R. E., 1979. Mesozoic-Cenozoic sedimentary formations of the North American Basin, Western North Atlantic. In: Talwani, M. & Ryan, W. B. F. (eds.), *Deep Drilling Results in the Atlantic Ocean. Continental Margins and Paleoenvironment. Maurice Ewing Series*, 3: 1–58.

Jansa, L. F., Steiger, T. H. & Bradshaw, M., 1984. Mesozoic carbonate deposition of the outer continental margin off Morocco. In: Hinz, K., Winterer, E. L. *et al.*, *Init. Repts. D.S.D.P.*, 79: 857–891.

Jenkyns, H. C. & Winterer, E. L., 1982. Palaeoceanography of Mesozoic ribbon radiolarites. *Earth. Planet. Sci. Lett.*, 60: 351–375.

Kázmér, M., 1986. Tectonic units of Hungary: thier boundaries and stratigraphy (a bibliographic guide). *Ann. Univ. Sci. Budapest. Rol. Eötvös Nom., Sect. Geol.*, 26: 45–120.

Keupp, H., 1977. Ultrafazies und Genese der Solnhofener Plattenkalke (Oberer Malm, Südliche Frankenalb.) *Abh. Naturhist. Ges. Nürnberg*, 37: 1–128.

Kocher, R. N., 1981. Biochronostratigraphische Untersuchungen oberjurassicher Radiolarien-führenden Gesteine, insbesondere der Südalpen. *Mitt. Geol. Inst. E.T.H. und Univ. Zürich*, 234: 1–184.

Kruglov, S. S., 1979. Svalyavskaya svita. In: *Stratigraficheskii Slovar SSSR*. Nedra, Leningrad, 354 pp.

Lubscher, H. & Bernoulli, D., 1977. Mediterranean and Tethys. In: Nairn, A. E. M., Kanes, W. H. & Stehli, F. G. (eds.), *The Ocean Basins and Margins*, Vol. 4A, *The Eastern Mediterranean*, pp. 1–28.

Lefeld, J., 1974. Middle-Upper Jurassic and Lower Cretaceous biostratigraphy and sedimentology of the sub-tatric succession in the Tatra Mts. (Western Carpathians). *Acta Geol. Polon.*, 24: 277–364.

Lefeld, J., 1985. Pieniny Limestone Formation. In: Lefeld, J. (ed.), Jurassic and Cretaceous lithostratigraphic units of the Tatra Mountains. *Studia Geol. Polon.*, 84: 76–77.

Lemoine, M., 1980. Serpentinites, gabbros and ophicalcites in the Piemont-Ligurian domain of the Western Alps: possible indicators of oceanic fracture zones and of associated serpentinite protrusions in the Jurassic-Cretaceous Tethys. *Arch. Sci.* 33: 103–115.

Lemoine, M., 1983. Rifting and early drifting: Mesozoic Central Atlantic and Ligurian Tethys. In: Sheridan, R. E., Gradstein, F. M. *et al.*, *Init. Repts.*, *D.S.D.P.*, 76: 885–895.

Michalik, J., Borza, K., Snopkova, P., Svobodova, M. & Vasicek, Z., 1987. Súcasné trendy v stratigrafii spodnokriedových utvarov a ich aplikácia na Západné Karpaty. *Geol. Prace, Zprávy*, 86: 179–195.

Mišik, M., 1973. Structures of the chert concretions from the limestones of Tithonian and Neocomian West Cerpathians Mts. *Geol. Zbornik. Geol. Carpathica*, 24: 141–162.

Myczyński, R., 1977. Lower Crataceous ammonites from Sierra del Rosario (Western Cuba). *Acta Palaeont. Polon.*, 22: 139–173.

Nowak, W., 1973. Karpaty zewnętrzne (fliszowe). In: Sokołowski, S. (ed.), *Budowa geologiczna Polski*. Tom. I. *Stratygrafia*. cz. 2. *Mezozoik*. Wyd. Geol., Waszawa. pp. 389–407.

Obermajer, M., 1986. Mikrofacje i wiek formacji wapienia pienińskiego (tyton-barrem) jednostki Grajcarka we wschodniej części pienińskiego pasa skałkowego. *Prz. Geol.*, 34: 317–323.

Ogniben, L., 1969. Schema introduttivo alla geologia del confine calabro-lucano. *Mem. Soc. Geol. Ital.*, 8: 453–763.

Ogg, J. G., Robertson, A. H. F. & Jansa, L. F., 1983. Jurassic sedimentation history of Site 534 (Western North Atlantic) and of the Atlantic-Tethys seaway. In: Sheridan, R. E., Gradstein F. M. *et al.*, *Init. Repts. D.S.D.P.*, 76: 829–884.

Parona, C. F., 1881. Di alcuni fossili del Giura superiore raccolti nelle Alpi venete occidentali. *Rend. Ist. Lombardo*, ser. II, 14: 1–8.

Patacca, E., Scandone, P., Giunta, G. & Liguori, V., 1979. Mesozoic paleotectonic evolution of the Ragusa zone (southeastern Sicily). *Geol. Romana*, 18: 331–369.

Patzelt, G., 1971. Beiträge zur Geologie das SW-Teils der Volksrepublik Albanien. *Geologie*, 69: 1–115. Berlin.

Polák, M. & Bujnovsky, A., 1979. The Lucivna formation (New designation of formal lithostratigraphical unit of the Lower Cretaceous of envelope groups in the Western Carpathians). *Geol. Prace. Zprávy*. 73: 61–70.

Prey, S., 1980. Das Frühalpidikum. In: Oberhauser, R. (ed.), *Der Geologische Aufbau Österreichs*. Springer, Wien, pp. 21–34.

Pszczółkowski, A., 1978. Geosynclinal sequences of the Cordillera de Guaniguancio in western Cuba, their lithostratigraphy, facies development, and paleogeography. *Acta Geol. Polon.*, 28: 1–96.

Ramsay, A. T. S., 1973. A history of organic siliceous sediments in oceans. In: Hughes, N. F. (ed.), *Organisms and Continents Through Time. Spec. Pap. Paleont.*, 12: 199–234.

Remane, J., 1983. Calpionellids and the Jurassic/Cretaceous boundary at deep sea Drilling Project Site 534, Western North Atlantic Ocean. In: Sheridan, E. R., Gradstein, F. M. *et al.*, *Init. Repts. D.S.D.P.*, 76: 561–567.

Renz, O. 1983. Early Cretaceous Cephalopoda from the Blake-Bahama Basin and thier correlation in the Atlantic and southwestern Tethys. In: Sheridan, R. E., Gradstein, F. M. *et al.*, *Init. Repts. D.S.D.P.*, 76: 639–644.

Renz, O. & Habicht, K., 1985. A correlation of the Tethyan Maiolica Formation of the Breggia section (southern Switzerland) with Early Cretaceous coccolith oozes of Site 534 A, D.S.D.P. Leg 76 in the western Atlantic. *Eclogae Geol. Helv.*, 78: 383–431.

Rieber, H., 1977. Eine Ammoniten Fauna aus der oberen Maiolica der Breggia-Schlucht (Tessin/Schweiz). Eclogae Geol. Helv., 70: 777–787.

Robertson, A. H. F., 1984a. Origin of varve-type lamination, graded claystones and limestone-shale "couplets" in the lower Cretaceous of the western North Atlantic. In: Stow, D. A. V. Piper, D. J. W. (eds.), *Fine-grained Sediments: Deep-Water Processes and Facies*. Blackwell Scientific Publ., Oxford, pp. 437–452.

Robertson, A. H. F., 1984b. Mesozoic deep-water and Tertiary volcaniclastics deposition of Maio, Cape Verde Islands: implications for Atlantic paleoenvironments and ocean island volcanism. *Geol. Soc. Am. Bull.*, 95: 433–453.

Robertson, A. H. F. & Bliefnick, D. M., 1983. Sedimentology and origin of Lower Cretaceous pelagic carbonates and redeposited clastics, Blake-Bahama Formation. Deep Sea Drilling Project Site 534, Western equatorial Atlantic. In: Sheridan, R. E., Gradstein, F. M. *et al.*, *Init. Repts. D.S.D.P.*, 76: 795–828.

Rodighiero, A., 1919. Il sistema Cretaceo del Veneto Occidentale compreso fra l'Adige e il Piave, con speciale riquardo al Neocomiano dei Sette Comuni. *Palaeontographica Ital.*, 25: 39–125.

Sclater, J. G., Helliger, S. & Tapscott, C., 1977. The paleobathymetry of the Atlantic ocean from the Jurassic to the present. *J. Geol.*, 85: 509–552.

Seyfried, H., 1978. Der subbetische Jura von Murcia (Südost-Spanien). *Geol. Jb.*, 29: 1–204.

Stein, R., Rullkötter, J. & Welte, D. H., 1986. Accumulation of organic-carbon-rich sediments in the Late Jurassic and Cretaceous Atlantic Ocean. *Chem. Geol.*, 65: 1–32.

Steinberg, M., 1981. Biosiliceous sedimentation, radiolarite periods and silica budget fluctuations. *Oceanol. Acta, Proc. 26th Intern. Geol. Congress, Geology of Oceans Symposium, Paris, July 7–17, 1980*, pp. 149–154.

Trümpy, R., 1982. Alpine paleogeography: a reappraisal. In: Hsü, K. J. (ed.), *Mountian Building Processes*. Academic Press, London, pp. 149–156.

Vail, P. R., Mitchum, R. M. Shipley, T. H. & Buffler, R. T., 1980. Unconformities of the North Atlantic. *Phil. Trans. Roy. Soc. London, Ser. A*, 294; 137–155.

Vezzani, L., 1969. La formazione del Frido (Neocomiano-Aptiano) tra il Pollino ed il Sinni (Lucania). *Geol. Romana*, 8: 129–176.

Watts, K. & Garrison, R. E., 1986. Sumeini Group, Oman – Evolution of a Mesozoic carbonate slope on a South Tethyan continental margin. *Sedim. Geol.*, 48: 107–168.

Weissert, H. J., 1979. Die Palaeozeanographie der Suedwestlichen Tethys in der Unterkreide. *Mitt. Geol. Inst. E. T. H. und Univ. Zuerich, N. F.*, 226: 1–174.

Weissert, H., 1981. Depositional processes in an ancient pelagic environment: the Lower Cretaceous Maiolica of the Southern Alps. *Eclogae Geol. Helv.*, 74: 339–352.

Weissert, H. J. & Bernoulli, D., 1985. A transform margin in the Mesozoic Tethys: evidence from the Swiss Alps. *Geol. Rundschau*, 74: 665–679.

Wendt, J., 1969. Die stratigraphische Entwicklung des Jura in Westsizilien. *Geol. Rundschau*, 58: 735–755.

Wieczorek, J., 1983. Uwagi o facji „ammonitico rosso". *Prz. Geol.*, 31: 247–252.

Wieczorek, J., 1988a. Zasady polskiej klasyfikacji stratygraficznej – ocena krytyczna. *Prz. Geol.*, 36: 98–102.

Wieczorek, J., 1988b. Jednostki litostratygraficzne jury i kredy Tatr – komentarz krytyczny. *Prz. Geol.*, 36 159–164.

Wieczorek, J., Główne etapy ewolucji Zachodniej Tetydy – zarys problematyki. *Kwart. Geol.* (in press).

Winterer, E. L. & Bosellini, A. 1981. Subsidence and sedimentation on Jurassic passive continental margin, Southern Alps, Italy. *Am. Assoc. Petrol. Geol. Bull.*, 65: 394–421.

Streszczenie

MAIOLICA – CHARAKTERYSTYCZNA FACJA ZACHODNIEJ TETYDY

Józef Wieczorek

Abstrakt: Pelagiczne wapienie z krzemieniami zwane maiolica są charakteystyczną facją pelagiczną przełomu jury i kredy Zachodniej Tetydy. Facja ta występowała zarówno na dnach oceanicznych, jak i na brzegach kontynentów, głównie w głębokich basenach, ale również na pogrążonych platformach czy wyniesieniach podmorskich. Jest wyrazem największego ujednolicenia facjalnego w mezozoicznej historii Zachodniej Tetydy.

Rozwój facji maiolica w Zachodniej Tetydzie można wiązać z: 1) ograniczeniem połączeń głębokowodnych ze Wschodnią Tetydą, 2) ukształtowaniem się antyestuariowego typu cyrkulacji, 3) subewaporacyjnymi warunkami, 4) rozwojem nannoplanktonu wapiennego, 5) obniżeniem poziomu kompensacji kalcytowej w wyniku działania wyżej wymienionych czynników.

Pelagiczne, białe wapienie z krzemieniami występujące w najwyższej jurze i dolnej kredzie w alpidach Europy i na Atlantyku należą do charakterystycznych facji Zachodniej Tetydy. W pracy przedstawiono analizę paleogeograficznych uwarunkowań występowania tej facji.

W basenowych sekwencjach facji maiolica oprócz dobrze uławiconych, na ogół białych wapieni z krzemieniami występują wkładki margli i ciemnych łupków oraz interkalacje węglanowych turbidytów. W sekwencjach wyniesień podmorskich czy pogrążanych platform takich interkalacji na ogół brak.

Wapienie facji maiolica zbudowane są głównie z nannoskamieniałości wapiennych (*Nannoconus*, kokolity). Spośród mikrofauny występują też kalpionelle, radiolarie, spikule gąbek, a makrofaunę reprezentują głównie aptychy oraz rynchollity, amonity i ramienionogi. Świadectwem bogatego życia bentonicznego są liczne skamieniałości śladowe typu *Chondrites*, *Zoophycos*, *Teichichnus* i in. W wyniku intensywnej działalności organizmów penetrujących w osadzie pierwotne struktury sedymentacyjne są zwykle zniszczone.

Tempo akumuacji pelitycznych sekwencji maiolica na ogół wynosiło ok. 5 m/mln lat. W niektórych sekwencjach tempo akumulacji jest kilkakrotnie większe ze względu na obecność licznych wkładek turbidytowych.

Utwory należące do facji maiolica wyodrębniane są na różnych obszarach w różne jednostki litostratygraficzne zarówno formalne, zgodne z zasadami hedbergiańskiej stratygrafii, jak i nieformalne, ale często dobrze określone jednostki (Tab. 1).

Można sądzić, że w przyszłości w miarę wprowadzania w życie hedbergiańskich zasad stratygrafii liczba jednostek litostratygraficznych wyróżnianych w obrębie facji maiolica wzrośnie. Jest to proces nieunikniony, gdyż dobrze sprecyzowane i obdarzone własnymi nazwami wydzielenia litostratygraficzne są konieczne, aby je przedstawić na mapach i profilach geologicznych. Pełna unifikacja nazewnictwa litostratygraficznego nie jest możliwa i stosowanie terminu Maiolica Formation na całym obszarze występowania facji maiolica nie byłoby uzasadnione. Możliwe jest i uzasadnione stosowanie w różnych regionach jednej nazwy dla określenia charakterystycznej facji. Stosowanie terminu maiolica jako nazwy facjalnej jest szczególnie pożyteczne przy rozpatrywaniu zagadnień facjalno-paleogeograficznych.

Facja maiolica jest charakterystyczna dla zachodniej części Tetydy i znana zarówno z sektora medyterańskiego, atlantyckiego, jak i karaibskiego. Rozwój facji maiolica przypada na okres rozszerzania się Zachodniej Tetydy i ograniczania połączeń z Tetydą Wschodnią. Pojawienie się facji maiolica w Zachodniej Tetydzie poprzedzone było sedymentacją radiolarytów lub margli krzemionkowych, czy też wapieni bulastych.

Na skorupie oceanicznej facja maiolica rozwinięta jest w sektorze medyterańskim: na obszarze Ligurii, na Elbie, w Apeninach Południowych i w Alpach Kotyjskich, a w sektorze atlantyckim: w basenie Blake Bahama, w basenie Cape Verde i na wyspie Maio (archipelag wysp Zielonego Przylądka). Basenowe sekwencje facji maiolica rozwinięte na ścienionej skorupie kontynentalnej stanowią profile w basenach położonych wokół Adrii (Apulii): w basenie lombardzkim, w basenie toskańskim, w basenie Lagonegro, w rowie Pindos, w rowie jońskim, w rowie słoweńskim, a także w basenach Północnych Alp Wapiennych. Do basenowych sekwencji należą również profile w Karpatach Zachodnich (sekwencje: Grajcarka, branisko-pienińska, kriżnańska) oraz w Karpatach Południowych (sekwencja Svinița). Przykłady facji maiolica rozwiniętej na pogrążonych platformach węglanowych mogą stanowić sekwencje na platformie Trento w Alpach Południowych oraz na Mazagan Plateau u marokańskich brzegów Afryki.

Występowanie facji maiolica na podłożu oceanicznym, jak i kontynentalnym, zarówno w basenach, jak i na wyniesieniach podmorskich, świadczy, że te pelagiczne osady gromadziły się na różnych głębokościach, ale płytkowodną genezę tej facji można wykluczyć. Maiolica była deponowana powyżej poziomu kompensacji kalcytu (CCD), zmiennego jednak na przełomie jury i kredy. Obecność facji maiolica nie musi oznaczać spłycenia basenów, w których wcześniej poniżej CCD były deponowane radiolaryty. Trudno przypuszczać, aby różne strefy geotektoniczne, w których facja maiolica występuje, podlegały w tym samym czasie podobnej subsydencji i w tym samym czasie osiągały podobne głębokości. Ważne znaczenie dla głębokowodnej sedymentacji mogły mieć konsekwencje zmian eustatycznych poziomu morza – jak zmiany cyrkulacji, zmiany warunków klimatycznych i in. Przerwanie głębokowodnych połączeń z Tetydą Wschodnią w wyniku zamykania oceanu Varadru w konsekwencji doprowadziło do zmiany typu cyrkulacji z estuariowego na antyestuariowy. Taki typ cyrkulacji preferował rozwój nannoplanktonu wapiennego, czego efektem jest szerokie rozprzestrzenienie facji maiolica w Tetydzie Zachodniej.

Facja maiolica sporadycznie jest notowana z Tetydy Wschodniej, gdzie na przełomie jury i kredy dominuje sedymentacja krzemionkowa. Radiolaryty w tej części Tetydy występują nie tylko w głębokich basenach, ale również na pogrążonych platformach. Widać, że wody Tetydy Wschodniej były wówczas znacznie bogatsze w krzemionkę niż wody Tetydy Zachodniej.

Występowanie facji maiolica w Zachodniej Tetydzie wskazuje na specyficzny charakter tego zbiornika pod koniec jury. Pojawienie się tej facji można wiązać z następującymi czynnikami:

1 – ograniczeniem połączeń głębokowodnych ze Wschodnią Tetydą,
2 – ukształtowaniem się antyestuariowego typu cyrkulacji,
3 – subewaporacyjnymi warunkami,
4 – rozwojem nannoplanktonu wapiennego,
5 – obniżeniem poziomu kompensacji kalcytu w wyniku działania wyżej wymienionych czynników.

Okresem maksymalnego rozprzestrzenienia facji maiolica jest najpóźniejszy tyton i berias, ale w wielu basenach maiolica dopiero pod koniec barremu (lokalnie później) zastępowana jest innymi facjami – ciemnymi łupkami, marglami lub turbidytami. Te zmiany facjalne są odbiciem zmian cyrkulacji (bardzo słaba w środkowej kredzie) oraz zmian paloegeograficznych wyrażających się zamykaniem „oceanicznych” stref medyterańskiej Tetydy.

EXPLANATIONS OF PLATES

Plate I

1 – Bedded limestones of maiolica facies. Pieniny Limestone Formation, Branisko succession, Kapuśnica, Pieniny Klippen Belt
2 – Bedding distorted by slumping in Cismon section, Belluno Trench, Southern Alps

Plate II

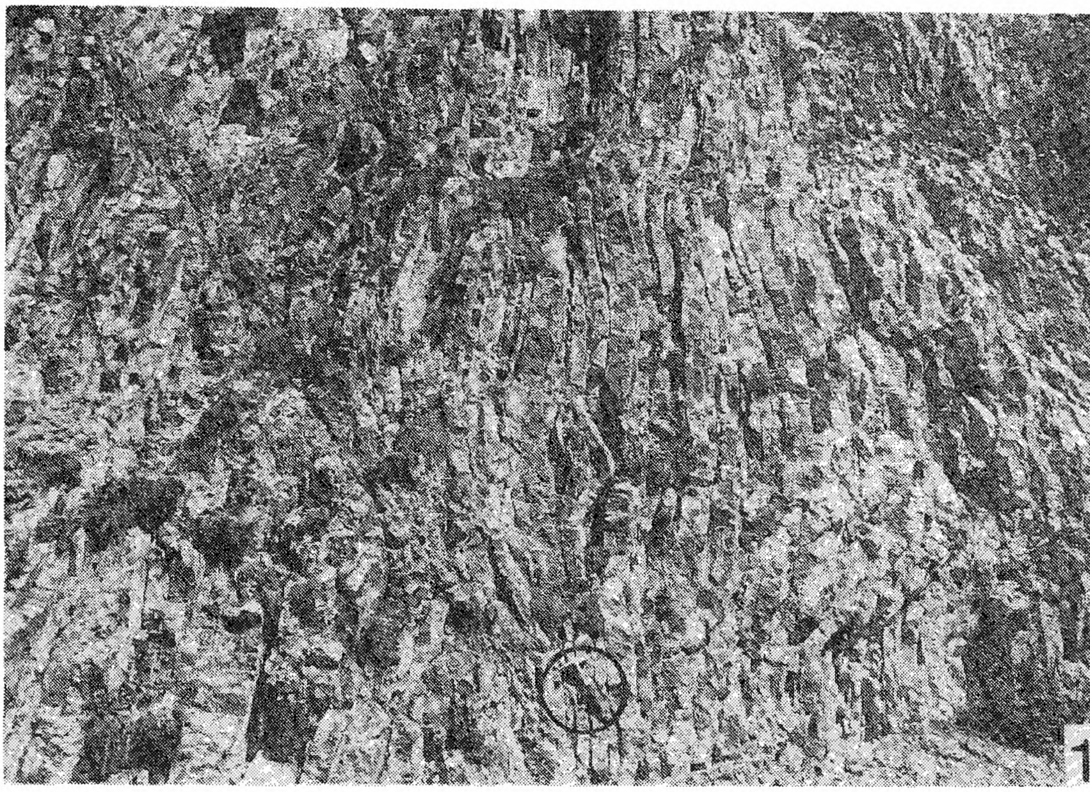
1 – Trace fossils *Teichichnus* and *Chondrites*. Dark band ca. 1 cm thick is a siliceous layer. Pieniny Limestone Formation, Kapuśnica. Vertical section, natural size
2 – Trace fossils *Chondrites* and vertical traces. Pieniny Limestone Formation, Kapuśnica. Vertical section, natural size

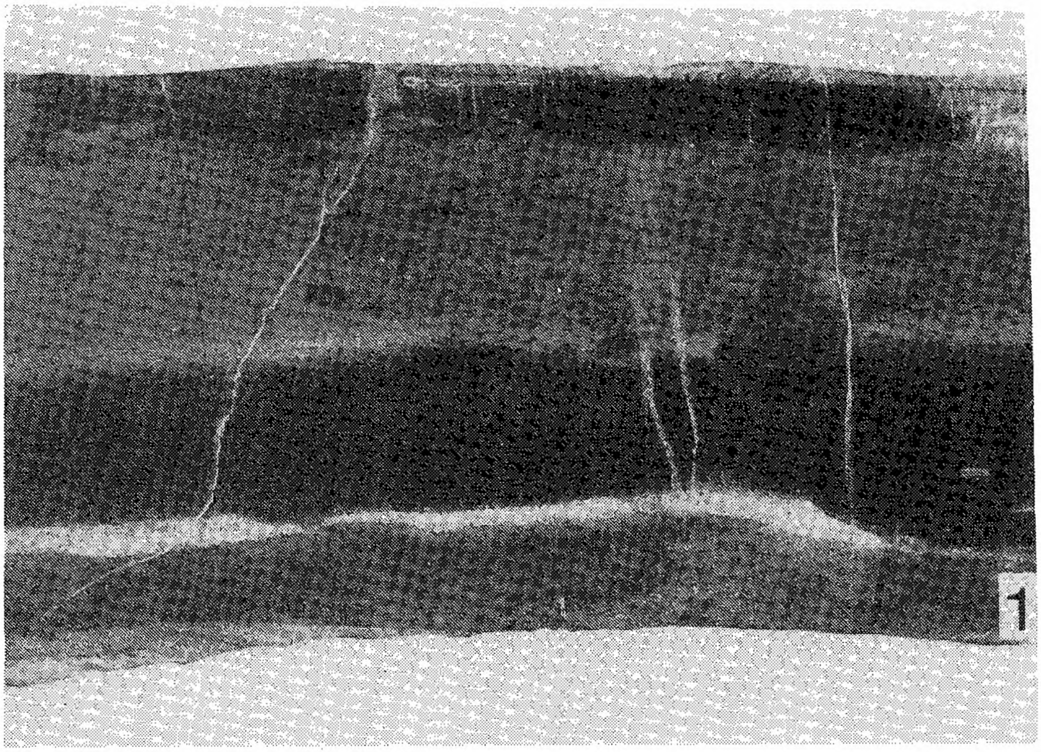
Plate III

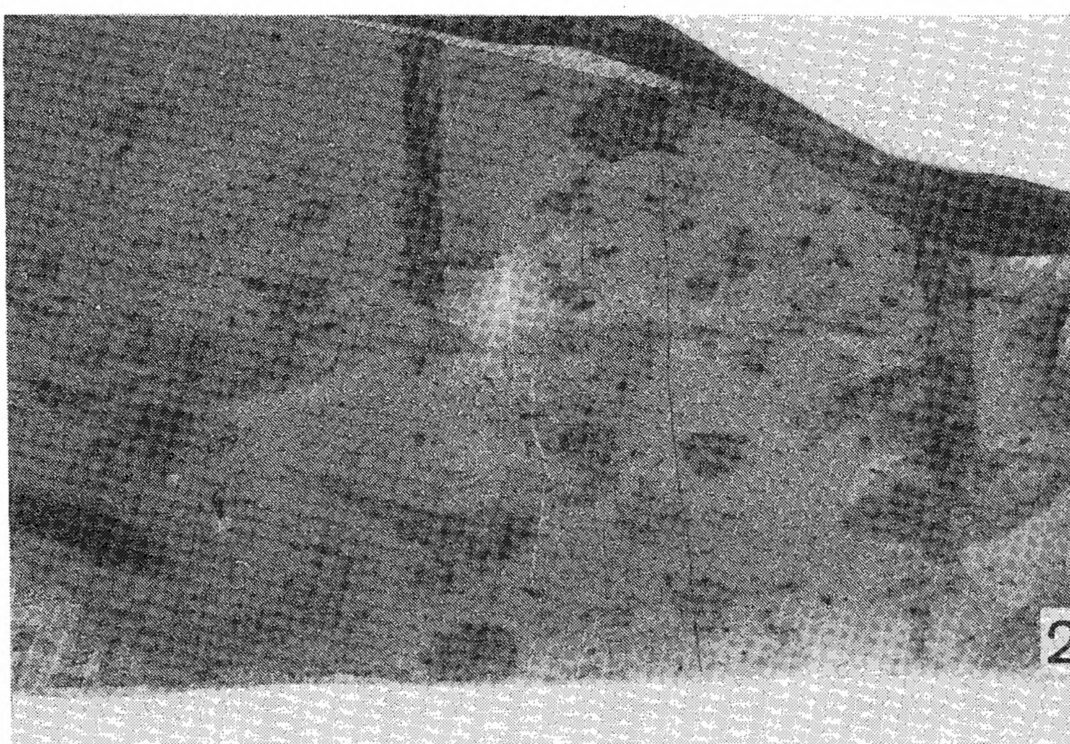
Numerous trace fossils visible in limestone as well as in chert (dark). Pieniny Limestone Formation, Kapuśnica. Vertical section, natural size

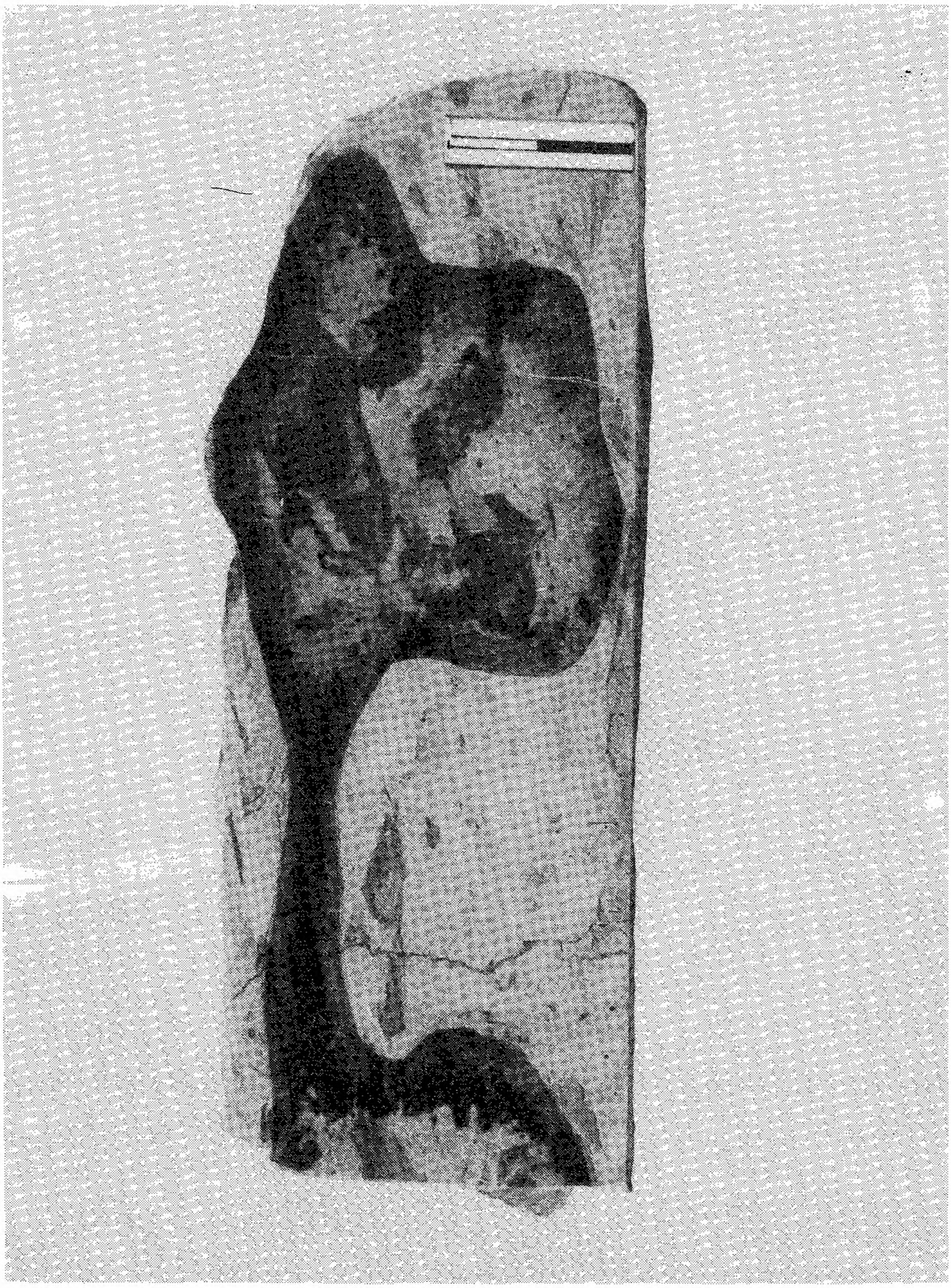
Plate IV

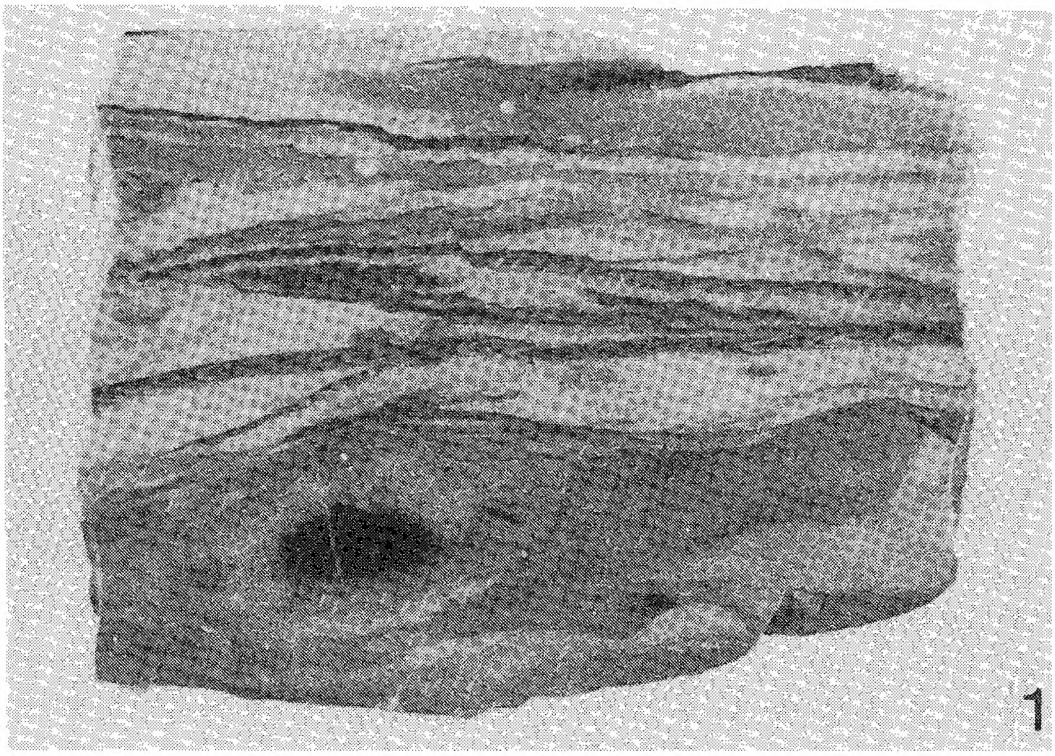
1 – Layer with *Zoophycos* traces, Maiolica, Belluno Trench, Southern Alps. Vertical section, natural size
2 – *Zoophycos* traces and thin layer including limestone clasts and flow deformations above. Cismon section, Southern Alps. Vertical section, natural size
3 – Large indetermined trace of burrowing organism and small *Chondrites* traces. Kryta Valley, Tatra Mts. Vertical section, natural size











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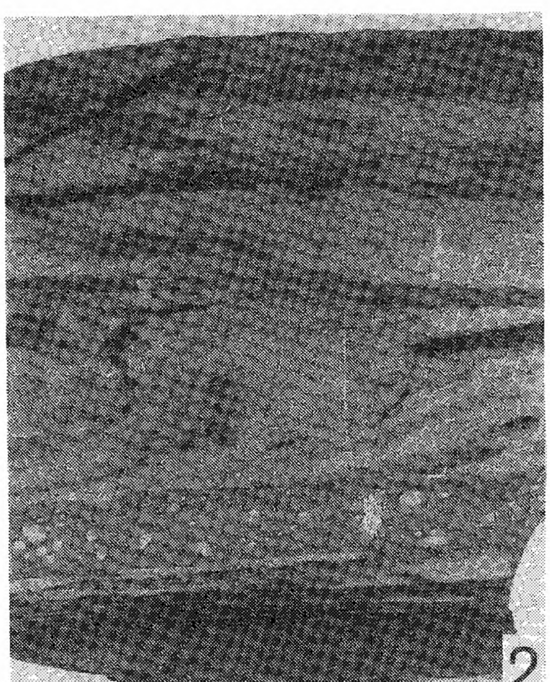

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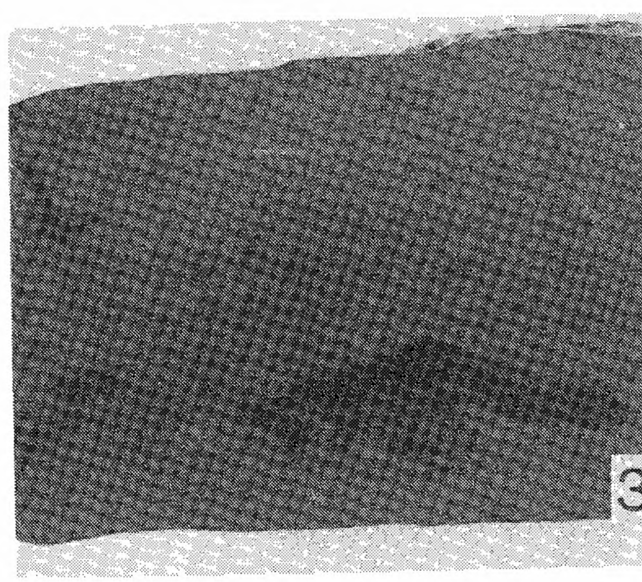

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