EARLY CRETACEOUS TURBIDITIC SEDIMENTATION ALONG THE BETIC–MAGHREBIAN CHAIN: DETRITAL MODES OF THE SANDSTONES, PROVENANCE AND PALAEOGEOGRAPHIC IMPLICATIONS

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Geological setting of the Early Cretaceous flysch of the Betic-Maghrebian Chain, their provenance and palaeogeographic implication

The Betic-Maghrebian Chain, mainly organized in a east-west trending band and extended from the Strait of Gibraltar to the eastern Sicily, is characterized by the superimposition of several nappes related to the following main palaeogeographic realms: Internal, External and Flysch Domains (this last located in an intermediate position).

Typical successions of the Flysch Domain (Early Cretaceous to Early Miocene) form a tectonic edifice, widespread along the Betic-Maghrebian Chain and made up by several tectonic units, piled up and overthrusted onto the external deposits.

These flysch nappes, located between the Internal and the External Zones, to the north and south respectively, reflect the original palaeogeographic position of the flysch basin, which began to form on a transcurrent boundary separating the African and European plates from the Lias and successively was partially oceanized during Dogger (DURAND-DELGA & FONTBOTÉ, 1980; BOUILLIN *et al*. 1988).

In the Betic-Maghrebian Chain, the flysch deposits are commonly subdivided into two palaeogeographic groups: *maurétanien* flysch, with internal provenance and *massylien* flysch, with external provenance. The *maurétanien* flysch are represented by Cretaceous Variegated Clays grading upward to Oligocene-Miocene turbidite successions, tectonically overlain by Early Cretaceous flysch deposits, known as Los Nogales Flysch (Betic Cordillera), Jebel Tisirène Flysch (Rif), Guerrouch Flysch (Algeria) and Monte Soro Flysch (Sicilian Maghrebian Chain).

These Cretaceous successions always overthrust onto Cretaceous to Oligocene-Miocene turbiditic deposits and they are tectonically overlain by the Hercynian crystalline units belonging to the Internal Zones of the different sectors of the Betic-Maghrebian Chain.

The most important problems related to the *maurétanien* Early Cretaceous flysch are (1) the absence of a continuous Jurassic stratigraphic substratum (doubtfully recognized only in few sectors of this chain), (2)

the absence of a Tertiary sedimentary cover and (3) their provenance, difficult to be identified because of the enrichment of detrital quartz, which always characterizes the sandstones of these successions in all the sectors of the chain.

Petrographic characters of the Early Cretaceous flysch of the Betic-Maghrebian Chain

The Early Cretaceous *maurétanien* flysch show an evolution from mainly pelitic and/or marly-calcareous successions to mainly arenaceous turbidites (Figure 1). The base calcareous turbidites can be included in the calclithite group[1], made up by carbonate clasts showing very close petrographic and biostratigraphic similarities with the Mesozoic covers of the Hercynian crystalline massifs[2]. Arenaceous turbidites[3], instead, can be ascribed to the plagioclase subarkoses family (Table I), characterized by abundant quartz, subordinately by plagioclase, by low amounts of fine-grained rock fragments (near always epimetamorphic rocks and, rarely, volcanic clasts). Potassic feldspar is almost absent, cement is not abundant, whereas a siliciclastic matrix is always present and, often, with characteristics of pseudomatrix (*sensu* DICKINSON, 1970). The heavy mineral assemblages, highly mature (zircon, tourmaline and rutile very abundant), always show a low content of chloritoid, staurolite and picotite and, sometimes, also few grains of augitic clinopyroxenes and horneblendes (PUGLISI, 1981; CARMISCIANO & PUGLISI, 1983; PUGLISI & COCCIONI, 1987).

Table I lists mineralogical compositions of the sandstones of early Cretaceous flysch of the Betic-Maghrebian Chain known in literature, also including new petrographic data about the Jebel Tisirène[4] and the Monte Soro Flysch.

These compositional features suggest a provenance from the Hercynian crystalline range rocks and from their Mesozoic carbonate covers, presently deformed into the tectonic edifices of the internal Rif, Kabylides and Calabria-Peloritani Arc. This provenance could also be supported by the paleocurrent distribution (mainly from W and NW in Sicily, and from E, and rarely from NW, in Morocco; CARUSO *et al*., 1999, and BESSON, 1984, respectively). Nevertheless, this hypothesis is not well supported by the following petrographic evidences: (a) absence of K-feldspar within the plagioclase subarkoses, (b) high amounts of quartz, which is not abundant in the source rocks with the only exception of the Verrucano-like

[1] $Q_{14.6}F_{1.2}L_{84.2}$, as average composition calculated on 55 samples belonging to the Jebel Tisirène and to the Monte Soro Flysch (see Table I).

[2] Calclithites are often characterized by the presence of micritic limestone clasts with Calpionellids. *Calpionella alpina* LORENZ, *C. elliptica* CADISH, *Crassicollaria parvula* REMANE, *Cr. intermedia* (DURAND-DELGA) and *Tintinnopsella carpathica* (MURGENAU & FILIPESCU) have been identified, thus suggesting for the clasts an age varying from Tithonian up to Hauterivian, according to the criteria suggested by REÁKOVÁ & MICHALIK (1997).

[3] $Q_{82.8}F_{12.4}L_{4.8}$, as average composition calculated on 92 analysis of sandstones sampled in all the equivalent flysch along the Betic-Maghrebian Chain.

[4] The samples have been collected from the Jebel Tisirène Mountain (near the village of Bab Berret) and from a stratigraphic section of about 400 m thick, measured at the outcrop of Punta Ceres (W of Ceuta).

quartzose sandstones (Early Lias), (c) presence of few grains of augitic clinopyroxenes and horneblendes in the heavy mineral assemblages, probably linked to volcanic sources, but volcanic rock fragments are very rare and never fresh in the sandstones, (d) occurrence of picotite within the heavy mineral assemblages, typical accessory mineral of ophiolitic rocks, never found in the hypothesized source rocks.

Discussion and conclusive remarks

Petrographic characters of the sandstones of all the Early Cretaceous *maurétanien* flysch widespread along the Betic and Maghrebian Chains are very much alike, thus demonstrating the large longitudinal dimensions of their basin, perhaps similar to those of the Ligurian Tethys.

This sedimentary basin originated during Late Jurassic times as the product of large lateral trascurrent faults separating the European and African plates (CASSOLA *et al*., 1990), before the deposition of the Early Cretaceous flysch, as testified by the remnants of the substratum of these flysch found in Morocco, Algeria and Sicily and aged to Tithonian (ANDRIEUX, 1971; BOUILLIN, 1979; EL KADIRI *et al*., 1989; BOUILLIN *et al*., 1995).

The petrographic data of the analyzed flysch could justify a provenance from sources (i) made up by Hercynian crystalline massifs and by their Mesozoic covers, (ii) originally located on the European palaeomargin (AlKaPeCa block, *sensu* BOUILLIN *et al*., 1986; i. e. Alboran + Kabylides + Calabria + Peloritani) and probably (iii) characterized by low topographic gradients, responsible for prolonged transports of materials, as testified by the increasing maturity observed in the analyzed sandstones. Petrography of these flysch also point to emphasize the longitudinal extent of isopic turbiditic facies in the Maghrebian Tethys at Early Cretaceous times, not excluding the possibility of extend this correlation also in other sectors of the alpine chains as, for example, along the Carpathian-Balkan segment. Some Early Cretaceous flysch deposits cropping out in this last sector, in fact, perhaps could be successfully compared with that of the Betic-Maghrebian chain, showing the same geological setting and the same petrographic characteristics linked to a very similar provenance.

Finally, the absence of Tertiary covers could point for an early segmentation and deformation of these Cretaceous *maurétanien* flysch with local underthrusting beneath the crystalline units (CASSOLA *et al*., 1990), thus admitting also in the Maghrebian sectors the existence of compressive tectonic phases aged to Late Cretaceous times.

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Table I - Modal point counts of the sandstones of the Early Cretaceous maurétanien flysch of the Betic-Maghrebian Chain.

Figure 1 - Geological sketch map of the Betic-Maghrebian Chain. 1- Internal units with Hercynian crystalline basement and Mesozoic-Cenozoic sedimentary covers; 2- Maurétanien flysch; 3- Maghrebian flysch units; 4- external units; gently deformed foreland; 6- undeformed foreland. The schematic lithologic columns show the Early Cretaceous Maurétanien flysch with the stratigraphic location of their mainly arenaceous (7) and calcareous (8) intervals.

Tab. 1.

	Jebel Tisirène Flysch (Rif, Morocco, new data)						Los Nogales Flysch[1]		Guerrouch Flysch[2]		Monte Soro Flysch (new data)				Monte Soro Flysch[3]	
	Jebel Tisirène Section				Punta Ceres Section		Betic Cordillera (Spain)		Algeria		Sicilian Maghrebian Chain					
	Calclithites (n= 5)		Siliciclastic turbidites (n= 7)		Siliciclastic turbidites (n= 8)		Siliciclastic turbidites (n= 11)		Siliciclastic turbidites (n= 16)		Calclithites (n= 50)		Siliciclastic turbidites (n= 17)		Siliciclastic turbidites (n= 33)	
	x	σ	x	σ	x	σ	x	σ		x σ		x	σ	x	σ	x	σ
Qm	13.4	8.09	63.9	7.99	73.7	6.25	61.5	9.15			**Qm**	9.5	3.78	61.0	6.69	60.8	8.56
Qp	0.9	0.65	6.4	1.70	4.1	2.30	5.6	1.40	**Q**	73.9 13.8	**Qp**	0.2	0.29	4.9	1.18	5.2	1.22
Qr	-		-		-		0.5	0.49			**Qr**	-		4.8	1.37	0.8	0.37
Ch	0.5	0.48	0.5	0.56	0.4	0.48	0.4	0.44			**Ch**	0.6	0.50	1.2	0.43	0.6	0.51
P	1.9	1.24	5.5	2.12	8.5	4.11	15.0	3.13	**P**	11.6 6.22	**P**	0.2	0.27	11.2	3.11	11.7	4.12
K	-		-		0.2	0.20	0.1	0.26	**K**	-	**K**	-		0.1	0.29	0.1	0.20
Ls	64.0	8.56	7.5	1.82	-		-				**Ls**	70.8	6.55	0.4	0.27	0.2	0.30
Fo	0.5	0.37	0.2	0.24	-		-				**Fo**	-		-		-	
Lm	0.5	0.53	4.5	2.71	1.4	0.74	2.9	1.89	**L**	2.7 2.31	**Lm**	1.4	0.23	0.4	0.34	3.0	1.57
Lv	-		-		-		0.5	0.52			**Lv**	0.4	0.21	0.2	0.27	0.3	0.26
M	0.3	0.26	1.8	1.05	2.7	1.81	2.0	1.22			**M**	0.2	0.31	3.5	1.11	2.1	1.83
Al	-		-		0.2	0.28	0.5	0.58			**Al**	2.3	0.99	0.3	0.21	0.3	0.42
Cm	17.9	4.04	7.9	1.12	1.6	1.13	1.9	2.62	**M**	11.8 9.11	**Cm**	4.3	1.25	9.8	2.40	9.5	5.51
Mt	-		1.8	2.55	7.2	2.30	9.1	5.20			**Mt**	10.1	3.51	2.1	1.75	6.4	3.18
	100.0		**100.0**		**100.0**		**100.0**			**100.0**		**100.0**		**100.0**		**100.0**	
Q	17.5	4.95	79.3	6.98	88.1	6.24	78.6	7.23	**Q**	83.8 13.8	**Q**	11.7	3.55	85.0	4.23	82.2	5.61
F	2.3	1.37	6.2	1.84	9.9	2.69	17.5	5.71	**F**	13.1 6.22	**F**	0.2	0.27	13.7	3.06	13.8	4.15
L	80.3	9.53	14.5	5.13	2.0	1.23	3.9	2.75	**L**	3.1 2.31	**L**	88.1	7.38	1.3	0.35	4.0	2.12
	100.0		**100.0**		**100.0**		**100.0**			**100.0**		**100.0**		**100.0**		**100.0**	

x and σ = average and standard deviation; n= number of analyzed samples. **1** - Los Nogales Flysch (Betic Cordillera): analyses from PUGLISI & COCCIONI (1987); **2** – Guerrouch Flysch (Algeria): analyses from RAOULT *et al*. (1982); **3** – Monte Soro Flysch (Sicilian Maghrebian Chain): analyses from PUGLISI (1981) and from CARMISCIANO & PUGLISI (1983).

Gross composition: symbols of the parameters adopted for modal analysis

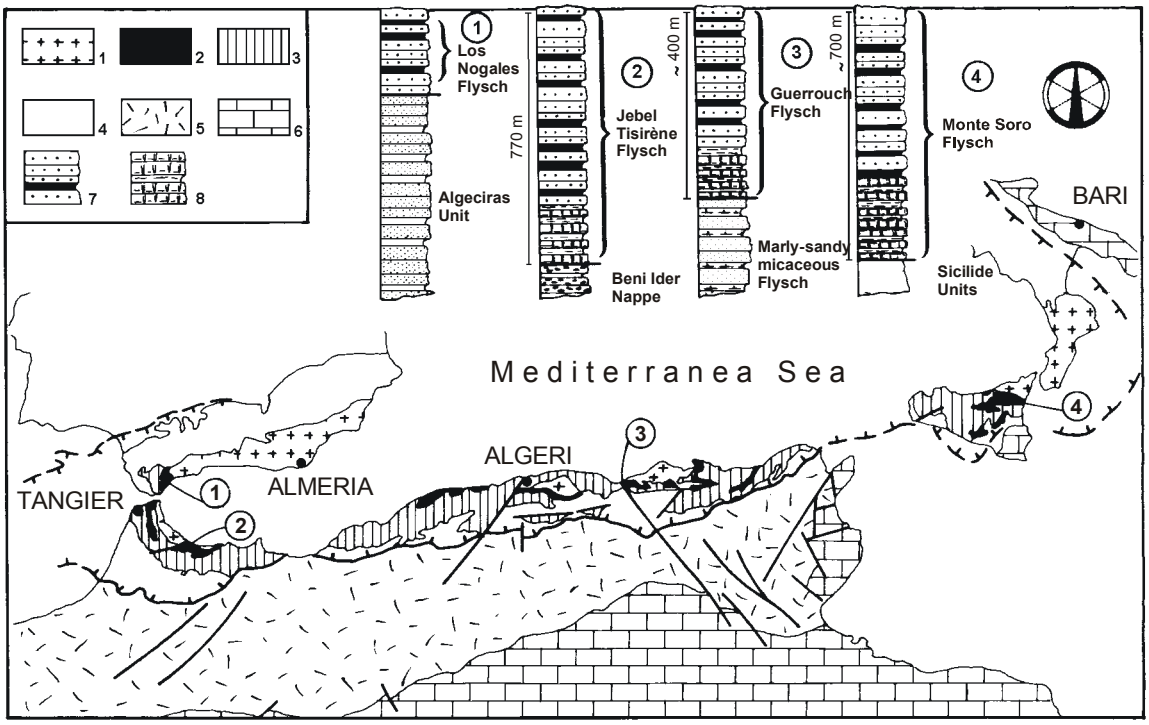
Q = **Qm** + **Qp**, where: **Q** = total quartzose grains, **Qm** = monocrystalline quartzose grains (including **Qr** = quartz in coarse-grained rock fragments, i. e. > 0.06 mm), **Qp** = polycrystalline quartzose grains (including **Ch** = chert);

F = **P** + **K**, where: **F** = total feldspar grains, **P** and **K** = plagioclase and potassium feldspar single grains;

L = **Ls** + **Lm** + **Lv** + **Fo**, where: **L** = unstable fine-grained rock fragments (< 0.06 mm, i. e.: **Ls** = sedimentary, mainly carbonate, **Lv** = volcanic and **Lm** = epimetamorphic lithic fragments), **Fo** = fossils.

M = micas and/or chlorites, **Al** = other mineral in grains, **Mt** = siliciclastic matrix, **Cm** = carbonate cement.

Fig. 1.


1
2
3
4
5
6
7
8
1
Los Nogales Flysch
770 m
Algeciras Unit
2
Jebel Tisirène Flysch
Beni Ider Nappe
~ 400 m
3
Guerrouch Flysch
Marly-sandy micaceous Flysch
~ 700 m
4
Monte Soro Flysch
Sicilide Units
BARI
Mediterranea Sea
ALGERI
ALMERIA
TANGIER