Mineral Composition of the Jurassic Sediments in the Subbetic Zone, Betic Cordillera, SE Spain

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ABSTRACT — In this paper we present the mineralogical results of our study of the External Subbetic sequences (Betic Cordillera, Spain) and establish an initial comparative analysis with regard to the geological environment of these deposits and the paleogeography of the Jurassic basin in both the Median and External Subbetic realms.
The mineralogy consists of calcite, dolomite, quartz, K-feldspar, illite, chlorite, kaolinite, smectite and mixed-layer illite-smectite.
In both realms the stratigraphic sequences are transgressive moving towards the top and the most internal zones. From our study of all of the sequences we have been able to conclude that no relationship exists between any particular lithological facies and any one mineral association.

Introduction

The Betic Cordillera forms the westernmost part of the Alpine Mediterranean chains. Two main geological realms can be distinguished (Fig. 1): (i) the Internal Zones, which consist mainly of overthrust units of Triassic and Palaeozoic materials, although in some units, Mesozoic, Tertiary and probably Precambrian terrains can also be found, and (ii) External Zones called Prebetic and Subbetic Zones (BLUMENTHAL, 1927; FALLOT, 1948). In the Subbetic Zones it is possible to identify three sedimentary realms through the facies and the thickness of the Jurassic materials: External Subbetic, Median Subbetic and Internal Subbetic (GARCIA DUEÑAS, 1967; FONTBOTE, 1970). In the External Zones, Palaeozoic materials are not exposed. The cover consists mainly of Mesozoic and Lower Miocene materials.

Since 1980 the Authors have been carrying out mineralogical research within the grey marls and marly limestone facies which make up part of the Jurassic sequences of the Median Subbetic Zone (PALOMO DELGADO *et al.*, 1981, 1985). The geological and mineralogical importance of this facies has been pointed out in the above mentioned works.

In this paper we present the results

of our mineralogical study of the External Subbetic sequences and establish an initial comparative analysis between the geological environment of this deposit and the palaeogeogra phy of the Jurassic basin in both, th Median and External Subbeti realms.

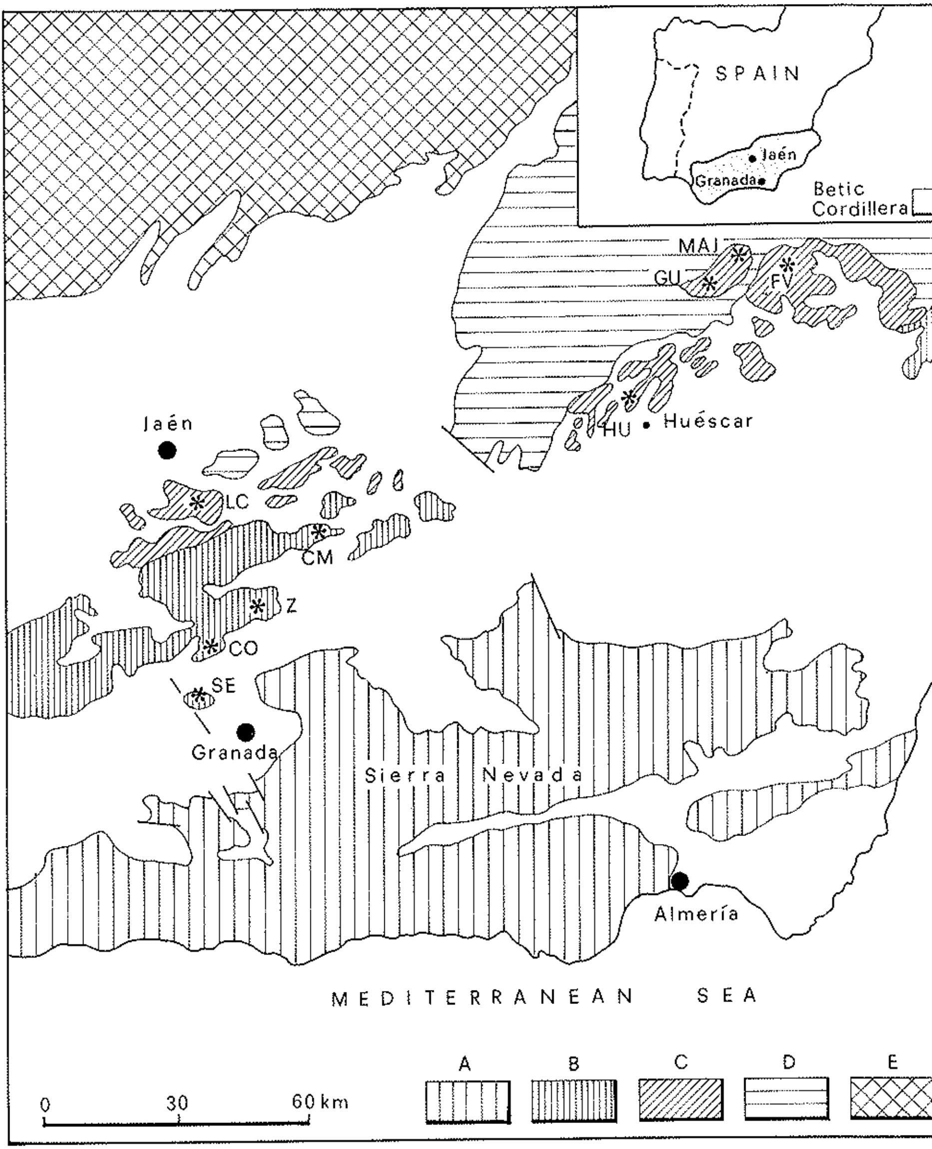

Fig. 1 - Geological setting of the material studied (scheme of LOPEZ GARRIDO & VERA, 197 A: Internal Zones of Betic Cordillera; B: Median Subbetic. Stratigraphic sequences: SE = Sie Elvira, CO = Colomera, Z = Zegrí, CM = Cerro Méndez; C: External Subbetic. Stratigrap sequences: LC = La Cerradura, HU = Huéscar, GU = Guarrumbre, MAJ = Majarazán, FV = Fue Vidriera; D: Prebetic Zone; E: Variscan Massif of the Meseta (Spanish Plain).

Geological setting, lithological facies and age of the materials studied

A scheme of the geological aspects of greatest interest, such as the location of the stratigraphic these sequences, together with those of the Median Subbetic, can be seen in Fig. 1.

The spatial and temporal distribution of the types of lithological facies studied and their geological context appear in Fig. 2. As can be deduced from this figure we have not always been able to collect specimens of marly limestone and marls in the field. The greater part of older materials, below those which we have studied, are non-detrital facies and carbonate platform facies (bioclastic wackestone, crinoidal grainstone, mudstone with chert). In places,

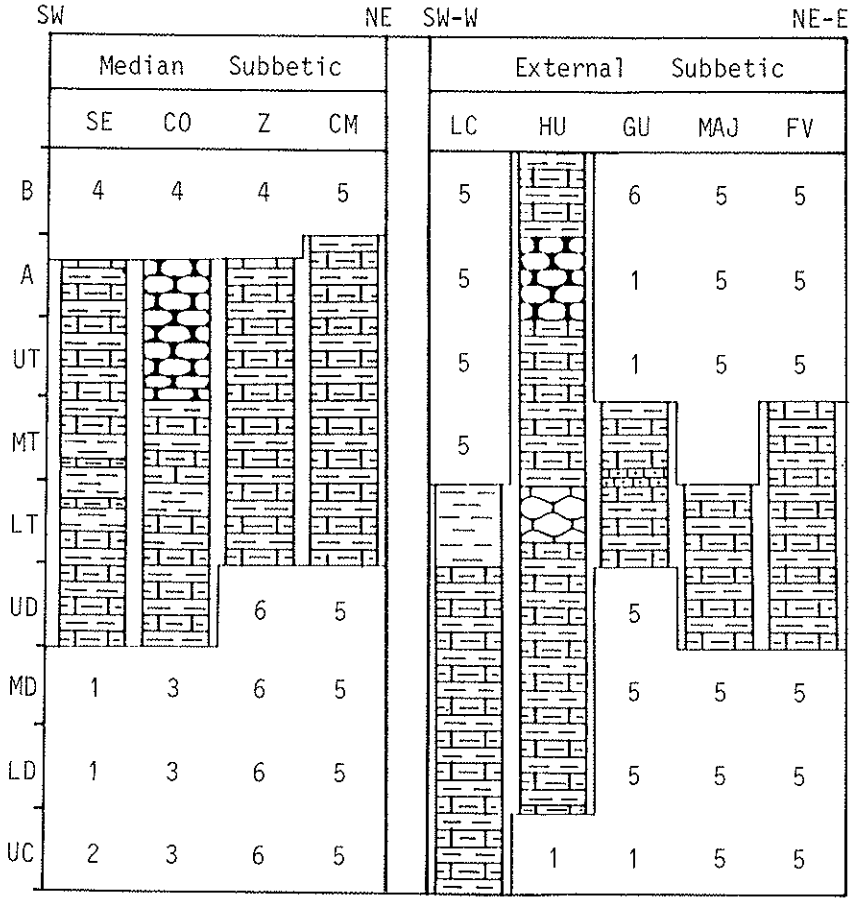

Fig. 2 - Spatial and temporal distribution of the types of lithological facies studied. B: Bajocian; A: Aalenian; UT: Upper Toarcian; MT: Middle Toarcian; LT: Lower Toarcian; UD: Upper Domerian; MD: Middle Domerian; LD: Lower Domerian; UC: Upper Carixian; 1: Bioclastic wackestone; 2: Crinoidal grainstone; 3: Hiatus; 4: Radiolarites; 5: No outcrops; 6: Mudstone with chert.

either a hiatus exists or the materials of these ages do not outcrop. The upper limit of our sampling is determined by the disappearance of the detrital facies (presence of radiolarites, bioclastic wackestone, «ammonitico rosso», etc.) or by the lack of the more modern material outcrops. Nevertheless, we have been able to collect sufficient mineralogical, stratigraphic and paleontological data from a sufficiently representative area of the detrital facies in the Subbetic Zone to present an initial hypothesis concerning the palaeogeography of this Jurassic basin.

Methods and results

We analyzed the samples by X-ray diffraction using a Philips diffractometer, PW-1710, under the following experimental conditions: CuKα radiation, Ni filter and a speed of 2° 2θ per minute. We prepared several classes of samples: a) untreated dry powder specimens, b) oriented specimens, c) ethylene-glycol and dimethyl-sulphoxide saturated oriented specimens, and d) heated to 550 °C oriented specimens.

For the oriented samples we cho to use clay (<2μm) and silt (2-20μr fractions obtained by sedimentatio

Quantitative analysis was carrie out based on the intensity factors er ployed by SCHULTZ (1964) ar BARAHONA (1974).

Mineralogy of the bulk sample

The bulk sample consists of calcit dolomite, quartz, potassium feldsp and clay minerals (illite, chlorit kaolinite, smectite, and mixed-lay illite-smectite). Table 1 shows t average proportions and in Fig. 3 ar Figs 4 to 8 the mineralogical cor position of each of the sequences stu ied can be seen.

As can be seen in Fig. 3 the dispe sion of the mineral composition the samples is greater in the out sequences («FV» and «MAJ»), that those lying furthest to the NE-E. all cases the appreciable variatio correspond to the calcite+dolom and clay minerals, while the var tion in the proportions of quartz+ feldspar remains between 5% a 10%. The average composition each sequence indicates a similar between «LC», «MAJ» and «FV»

TABLE 1
Average (%) mineralogical composition of the sequences studied

Sequence	Calcite+Dolomite	Quartz+Feldspars	Clay Minerals
«La Cerradura»	10	52	38
«Huéscar»	7	60	33
«Guarrumbre»	7	59	34
«Majarazán»	10	50	40
«Fuente Vidriera»	11	50	39

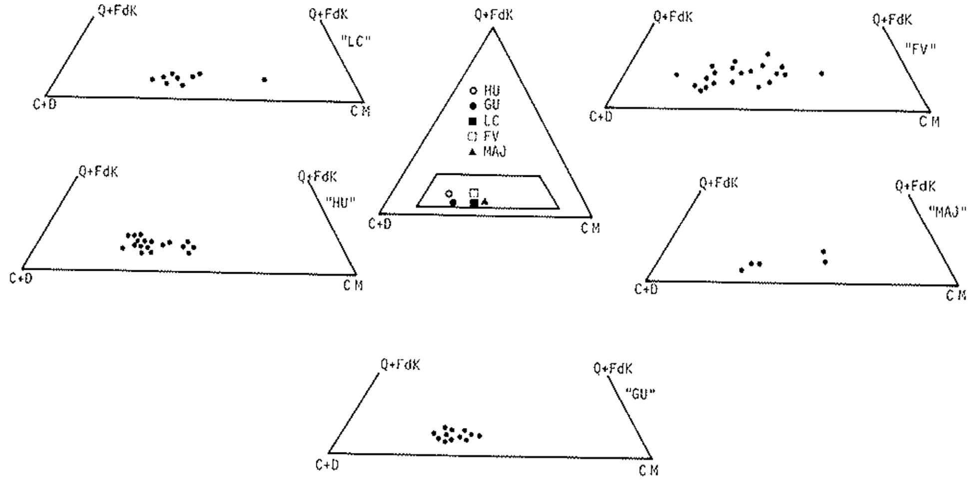

Fig. 3 - Triangular diagrams showing the mineral composition. The average composition of the stratigraphical sequences is plotted in the central triangle. C: Calcite; D: Dolomite; Q: Quartz; FdK: Potassium feldspar; CM: Clay minerals.

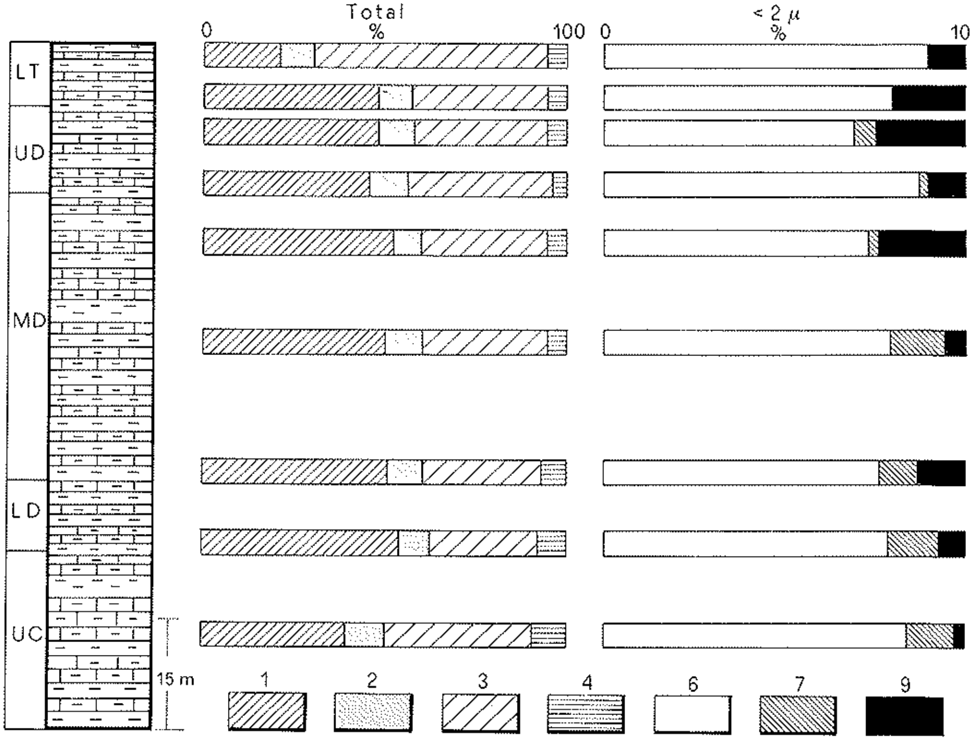

Fig. 4 - Mineralogical composition of the «La Cerradura» sequence. 1: Calcite; 2: Quartz; 3: Clay minerals; 4: Dolomite; 5: Potassium feldspar; 6: Illite; 7: Chlorite; 8: Kaolinite; 9: Smectite; 10: Mixed-layer illite-smectite; B: Bajocian; A: Aalenian; UT: Upper Toarcian; MT: Middle Toarcian; LT: Lower Toarcian; UD: Upper Domerian; MD: Middle Domerian; LD: Lower Domerian; UC: Upper Carixian.

opposed to «HU» and «GU». It is thus possible to deduce that the external sequences probably received mineral contributions from several sources.

Clay minerals (<2μm and 2-20μm fraction)

The clay minerals present are illite (I), chlorite (Chl), kaolinite (K), smectite (Sm) and mixed-layer illit smectite (I-Sm). Figures 4 to 8 shov the quantitative variations from th bottom to the top in the stratigraphi sequences studied.

Starting from the criteria pre sented in an earlier work on Jurassi sediments (PALOMO DELGADO e *al.*, 1985) we have established severa

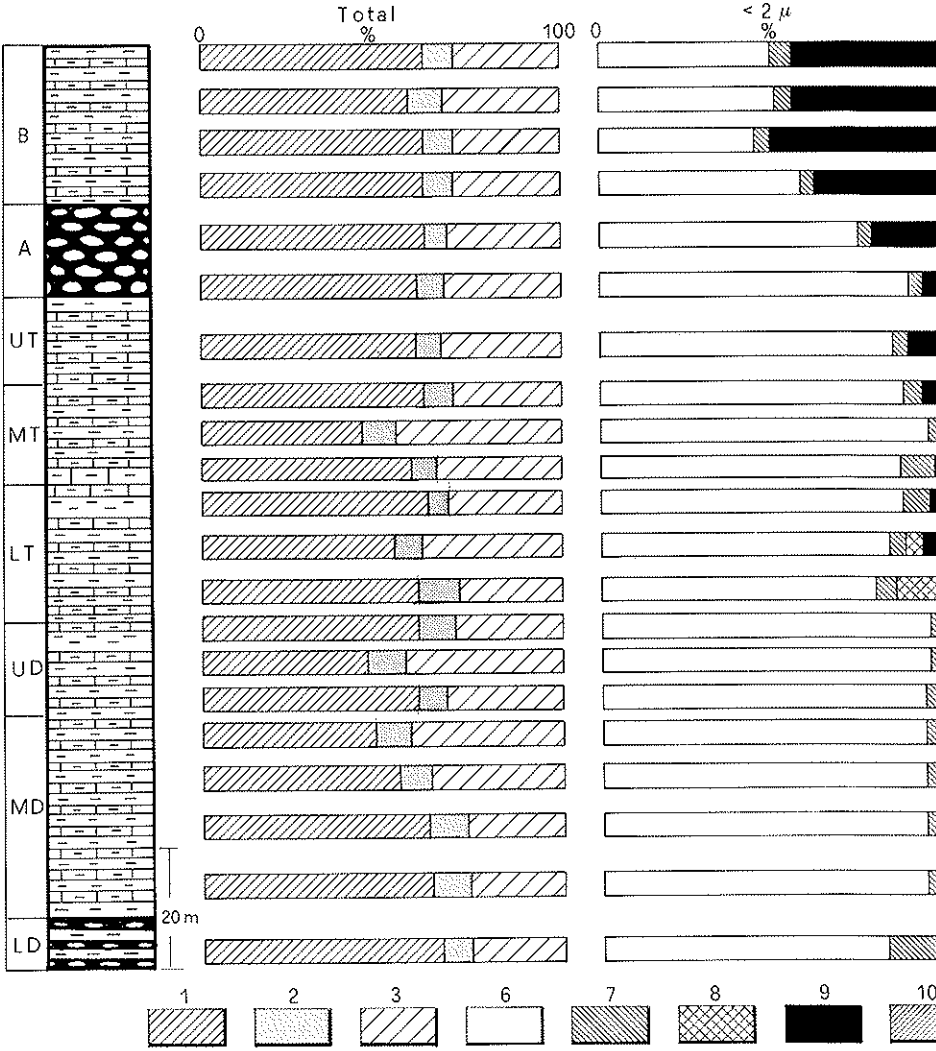

Fig. 5 - Mineralogical composition of the «Huéscar» sequence. Legend as in Fig. 4.

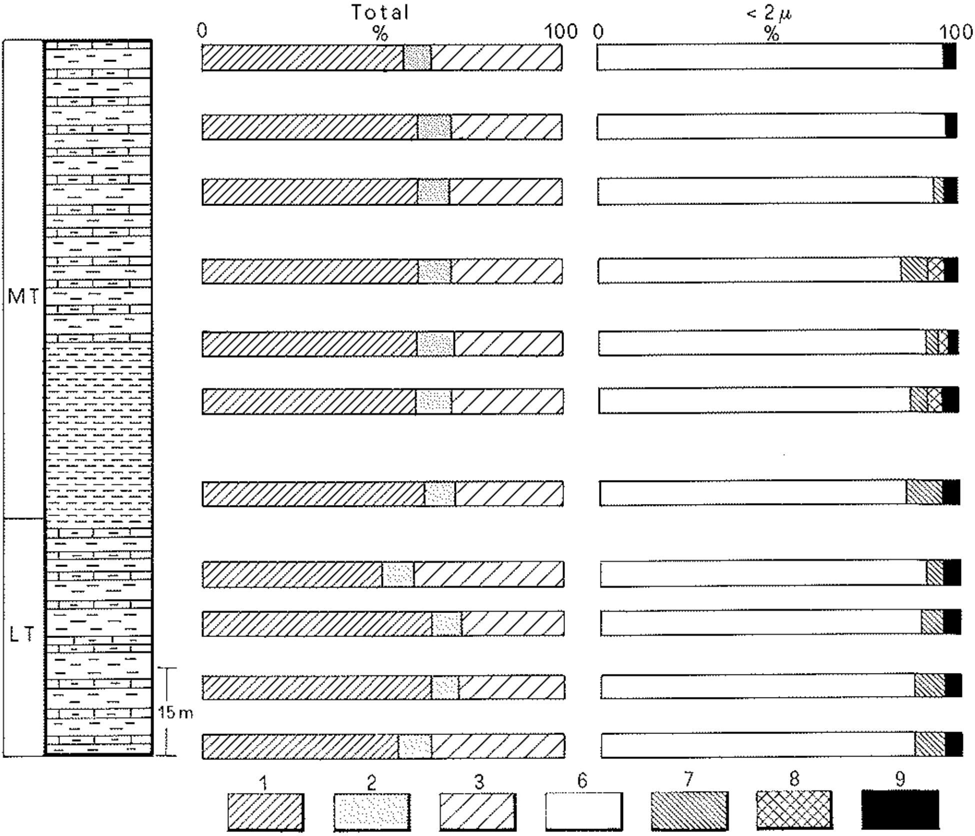

Fig. 6 - Mineralogical composition of the «Guarrumbre» sequence. Legend as in Fig. 4.

associations of clay minerals according to whether or not they occur and, if so, their relative abundance. Thus, the following associations can be distinguished:

Association A: I, Chl, *K*

Association B: I, Chl, *(Sm)*

Association C: I, Chl, *Sm*

Association D: I, Chl, *I-Sm* (only present in the Median Subbetic)

Association E: *I*, *Chl*

The italics indicate the presence of certain minerals considered to be indicative and the brackets indicate that, although the presence of a mineral is constant through the sequence, it is only present in small proportions.

Spatial and temporal distributions of these associations and their relationship with the lithology of the various sequences are shown in Fig. 9.

Comparative study of the sedimentation in the Median and External Subbetic

The bulk mineral composition at both palaeogeographical realms is

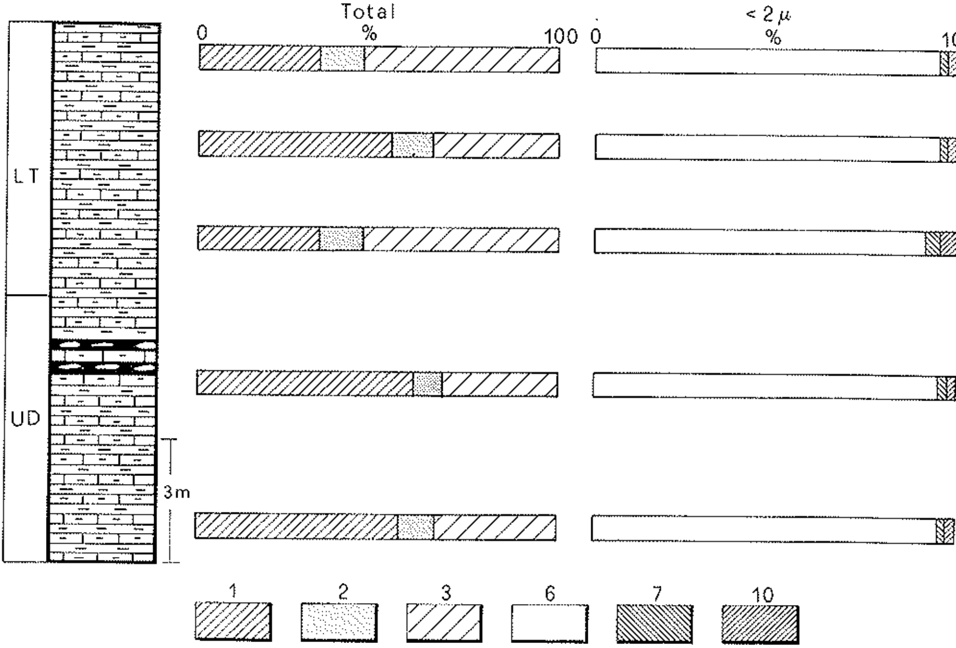

Fig. 7 - Mineralogical composition of the «Majarazán» sequence. Legend as in Fig. 4.

very similar: calcite, quartz, dolomite, K-feldspar and clay minerals (illite, chlorite, kaolinite, smectite and mixed-layer illite-smectite). Nevertheless, the quantitative study of the bulk mineralogy reveals significant differences, which are expressed graphically in Fig. 10. Figure 10a shows clearly that the standard deviation of percentage for any of the minerals under discussion is greater in the Median Subbetic sequences. In fact, the coefficients of variation (V) for quartz+K-feldspar reach values of between 30 and 43 in the Median Subbetic, while in the External Subbetic they range between 10 and 21. Similarly the values of V for the carbonates (calcite+dolomite) range from 4 to 32 and 7 to 17, and for the clay minerals from 7 to 34 and from 11 to 19 in the Median and External Subbetic sequences, respectively.

According to our data, the stratigraphic sequence which registers the largest quantitative variations in the three mineral groups is «Zegrí», in the Median Subbetic, with V=43 (quartz+K-feldspar), V=32 (calcite+dolomite) and V=34 (clay minerals). In the External Subbetic the maximum values are to be found in the «Huéscar» sequence, where V=22 (quartz+K-feldspar) and in the «Majarazán» sequence, where V=17 (calcite+dolomite) and V=19 (clay minerals).

It is logical to surmise, therefore, that the sedimentation in the Median Subbetic took place under notably

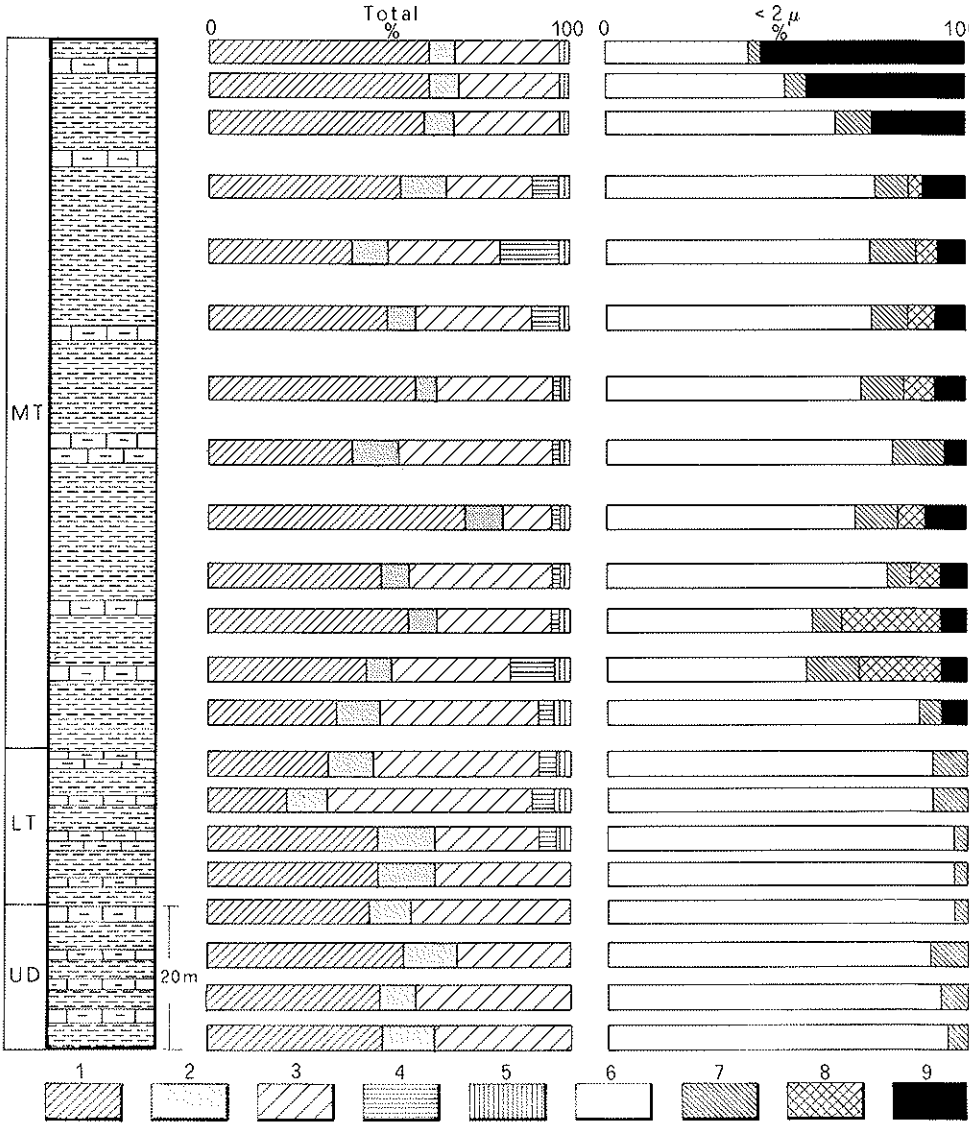

Fig. 8 - Mineralogical composition of the «Fuente Vidriera» sequence. Legend as in Fig. 4.

different conditions, above all with regard to the quantity and periodicity of the detritus, than those of the External Subbetic, where conditions appear to have been more constant. This agrees with the hypothesis that the Liassic-carbonate-platform break-down began in the most external area (GARCIA HERNANDEZ *et al.*, 1980) and that the mineral association in these first detritic deposits is relatively homogeneous. On the

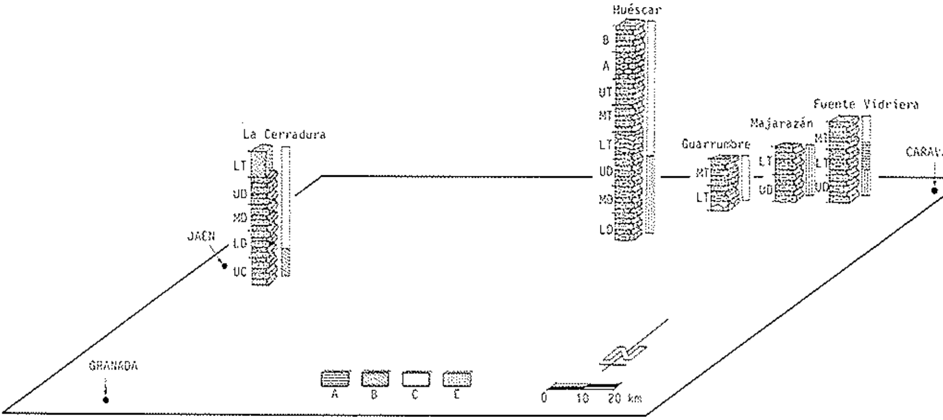

Fig. 9 - Spatial and temperal distribution of mineralogical associations and their relationship with the lithology of the various sequences. A: I, Chl, *K*; B: I, Chl, (*Sm*); C: I, Chl, *Sm*; E: *I*, *Chl*. Ages as in Fig. 2.

other hand, the deepening of the basin and/or a distancing of the internal zones from the continent, with a corresponding variability in sedimentation, and furthermore, the possible existence of emerging areas («Dorsal Medio-Subbética», BUSNARDO, 1979) all go towards explaining the high values for the coefficients of variation which we have encountered. An especially revealing example of this occurs as we have mentioned above, in the «Zegrí» sequence. We shall return to this palaeogeographical swell site later on.

When we relate the different ages of the materials studied to the coefficients of variation (Fig. 10b) it is clear that much greater variability is to be found in the Median Subbetic sequences than in the External ones. In the latter sequences the highest values of V (quartz+K-feldspar

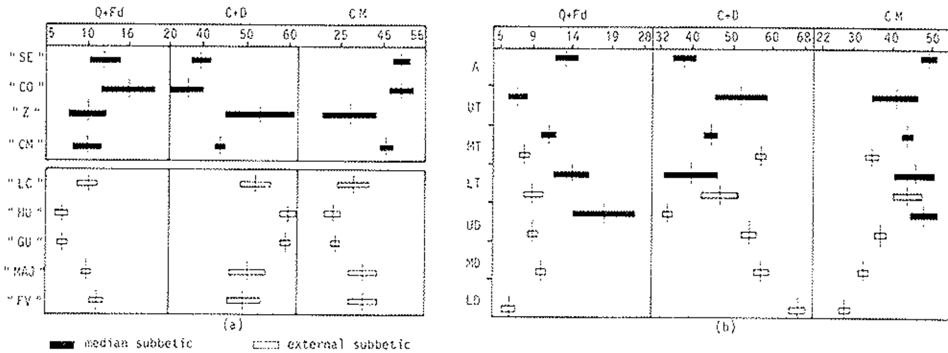

Fig. 10 - Mineralogical composition. (a): in relation with the sequences studied; (b): in relation with the age of the materials. The standard deviation is indicated by the bar and the arithmetic average by the cross-bar. Legend as in Fig. 4.

=26, calcite+dolomite=20, clay minerals=17) correspond to the Lower Toarcian, while in the Median Subbetic we have been unable to unequivocally assign the materials to a period with any precision. In any case the Domerian-Toarcian limit is a moment in geological history characterized by a crisis in the development of the fauna, with a disappearance of benthonic organisms, evidence of predominantly juvenile forms and the existence of euxinic conditions (BRAGA *et al.*, 1982). All these facts could be related to the mineral characteristics described above, such a variation in the mineral content and a decrease in the proportion of carbonate materials present.

The study of clay minerals and the establishment of various mineral associations (PALOMO DELGADO *et al.*, 1985) has enabled us to carry out a comparative study of the geological environment of the deposits in the Median and External Subbetic (Fig. 11). Our conclusions concerning its temporal and spatial evolution appear below.

We have found similar mineral associations in the External Subbetic and in the Median Subbetic. In the External Subbetic, however, we have

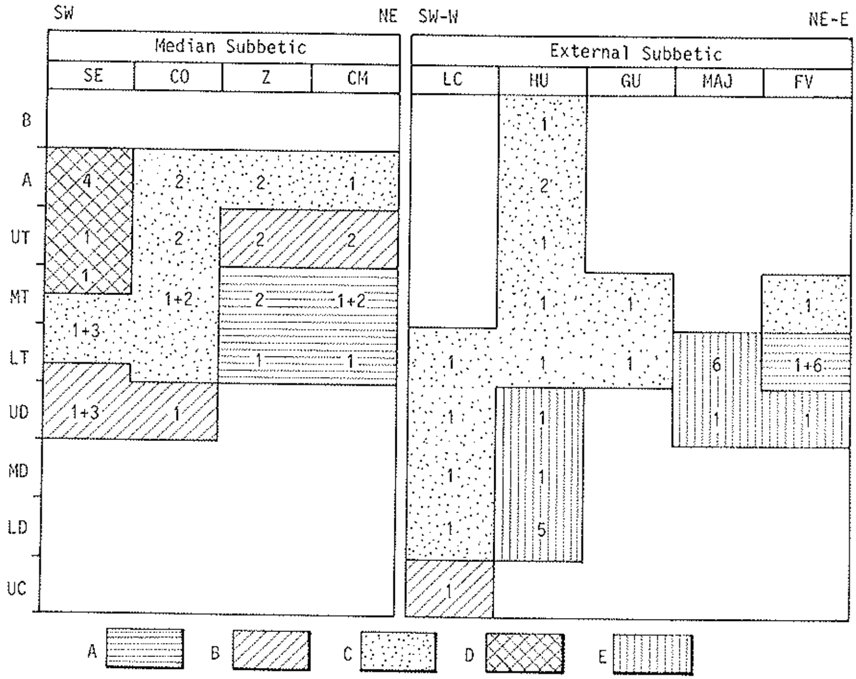

Fig. 11 - Relationship between the lithology of the sequences and the mineral associations. Lithology: 1, Grey marls and marly limestone; 2, «Ammonitico Rosso» facies; 3, Red and pinky limestones, sandy marls and grey marls; 4, Limestones and marls with chert nodules; 5, Nodular limestones; 6, Brown marls. Clay mineral associations: A: I, Chl, *K*; B: I, Chl, (*Sm*); C: I, Chl, *Sm*; D: I, Chl, *I-Sm*; E: *I*, *Chl*. Ages as in Fig. 2.

identified a new association E, made up of illite+chlorite.

In both realms the stratigraphic sequences are transgresive moving towards the top. This might correspond to the transgression which began, according to HALLAM (1978), at the Carixian-Domerian limit of the global curve of transgression-regression during the Jurassic.

It is clear that, in any specific age, the sequences are also transgressive towards the most internal zones, that is to say, towards the SW. Thus the «Sierra Elvira» sequence is the most pelagic and/or deepest from the end of the Middle Toarcian. This overall picture does not however apply to the «Cerro Méndez» and «Zegrí» sequences, which, in the Lower and Middle Toarcian, represent shallow-water deposits and probably correspond to swell zones.

After the Liassic-carbonate-platform break-down (GARCIA HERNANDEZ *et al.*, 1980; PALOMO DELGADO *et al.*, 1985), a non-uniform compartition of the basin occurred, resulting in the formation of troughs, as in «LC», for example, and swells, as in «Z» and «CM». Nevertheless, the sequence of the mineral associations and their relationship with the various ages suggests that the palaeogeography of the basin was more homogeneous in the External Subbetic.

From our study of all the sequences we are able to conclude that no relationship exists between any particular lithological facies and any one mineral association. Thus, for example, the grey marls and marly lin stone facies appear together w associations A, B, C and E, and fr this we conclude that the lithologi facies we have investigated were posited under different conditio depending on their location in basin.

We approached the problem of source rock for these sediments studying the crystallochemical para eters of micas and chlorites in Median Subbetic (PALOMO DELC DO *et al.*, 1985) and in the Extern Subbetic. The charactheristics these minerals in the both realms identical, which corroborates idea that the source rocks are igneous and metamorphic rocks the Variscan Massif of the Mes (Spanish Plain) (op. cit.).

Nevertheless, the local appearar in the External Subbetic of illite+chlorite association introdu a new factor into the overall pictu This association is typical of the P betic, Triassic sediments, to be fou to the north of the Subbetic (Fig. as pointed out by CABALLERO LOPEZ AGUAYO (1973). It is a fac which indicates that the source a underwent intense erosion, giv rise to detrital sediments. Its exc sive appearance in the most exter sequences, and immediately after Liassic-carbonate-platform bre down, supports the theory of shallower-water environment of basin in this area and points to influence of Prebetic sediments, most external areas of which already emerged from the water a were eroded, and which probably also descended from the Variscan Massif of the Meseta.

As a final comment, the presence of kaolinite in the sequence lying a long way from the probable source rocks («Z» and «CM» of the Median Subbetic and only in the Lower Toarcian of the sequence «HU» of the External Subbetic) suggests the possibility of the existence of BUSNARDO's «Dorsal Medio Subbética» (1979) situated between the Median Subbetic and the External Subbetic, which may have been above water at some period.

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