

SEDIMENT-PETROGRAPHY OF MALAGUIDE ROCKS FROM THE SIERRA DE ESPUÑA (BETIC CORDILLERAS, SPAIN): COMPARISON OF RESULTS FROM A DESCRIPTIVE AND A QUANTITATIVE ANALYSIS¹

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ABSTRACT

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The sediment petrography of Malaguide sequences from the Sierra de Espuña has been studied with an 'intuitive and descriptive' method for the analysis of sediments in thin sections. This method comprises an initial intuitive grouping based on a few characteristics of the sediment and a subsequent detailed description of the thin section.

Differences between specific members of the Malaguide sequences, that were found with this method, are confirmed by a quantitative analysis based on point count data. It is concluded that the intuitive and descriptive method is an adequate tool for the study of the sediment petrographical aspects of a sedimentary sequence and that it produces results in a relatively short time.

INTRODUCTION

The Sierra de Espuña is situated in the Internal or Betic Zone of the Betic Cordilleras, the alpine foldbelt of southern Spain. In the eastern part of the Betic zone, four tectonic complexes (in ascending order: Nevado-Filabride complex, Ballabona-Cucharón complex, Alpujarride complex and Malaguide complex) have been distinguished (RONDEEL & SIMON, 1974). The Malaguide complex is composed of essentially non-metamorphic sediments ranging in age from Silurian to Tertiary. The youngest are dated as Early Miocene (MACGILLAVRY ET AL., 1963; GEEL, 1973). Prior to the deposition of Middle Miocene sediments, the rock sequences of the Betic Zone underwent considerable deformation (RONDEEL & SIMON, 1974).

In his description of Malaguide sequences in the Velez Rubio area, ROEP (1972) concluded that there are characteristic differences in detrital content between specific Permo-Triassic members and suggested that the study of these

aspects can be used to unravel the structural history of complex tectonic sequences.

In the Sierra de Espuña, where Malaguide rocks are extensively exposed, the study of the stratigraphic framework and the detrital contents was essential for the distinction of tectonic units and for the description of the structural evolution of the rock sequences in this area (MÄKEL & RONDEEL, 1979; MÄKEL, 1981).

Sediment-petrographical studies are usually based on point count data, subsequently analysed with statistical methods. An alternative to such a quantitative analysis is a method for the study of sediments in thin sections, developed by DE BOOY (1966). It combines the results of a rapid 'intuitive grouping', based on a few sediment characteristics, with a subsequent thin section description. The analysis of Quaternary sediments in The Netherlands, showed that this method can provide a thorough description of the detrital contents in a relatively short time (ROEP & REMMELZWAAL, 1977).

In this paper we present the results of an intuitive and descriptive analysis of Malaguide rocks from the Sierra de Espuña. In addition some aspects are analysed numerically with the aid of point count data. Comparison of the results of these two methods allows us to discuss the sediment-petrographical aspects of the Malaguide stratigraphy as well as the advantage of the intuitive and descriptive method.

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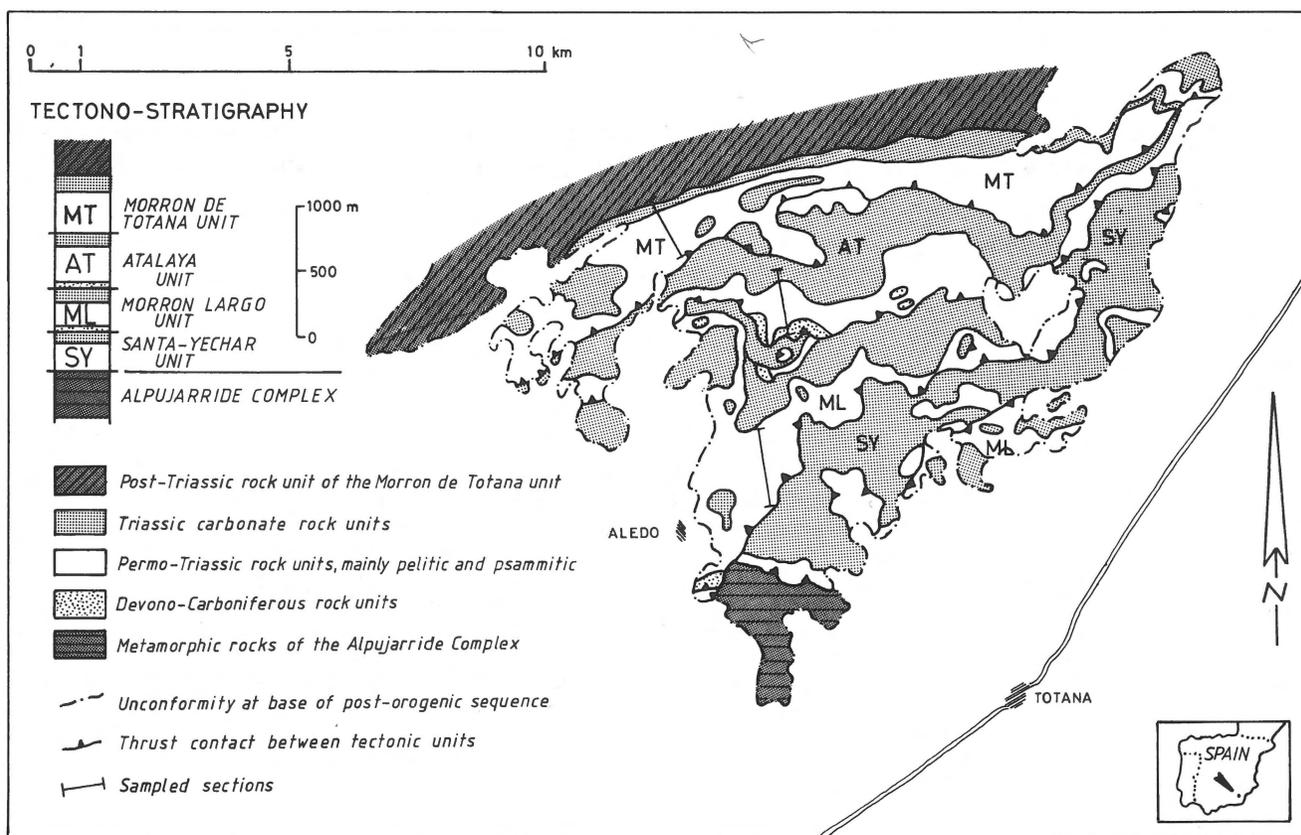


Fig. 1
Geological sketchmap of the Sierra de Espuña.

GEOLOGY OF THE MALAGUIDE SEQUENCES IN THE SIERRA DE ESPUÑA

In the Sierra de Espuña, four Malaguide tectonic units have been distinguished (Fig. 1). A general stratigraphy for the Permo-Triassic and Upper Triassic (Fig. 2) has been recognised in all units (MÄKEL & RONDEEL, 1979). In both the Atalaya unit and the Morrón Largo unit (Fig. 1), the Permo-Triassic sequences overlie the graywacke member of inferred Devonian-Carboniferous age. This member is comparable to the Piar Formation of the Velez Rubio area (GEEL, 1973). In the Morrón de Totana unit, the top dolomite member is stratigraphically overlain by a sequence of carbonates, marls and gypsum of inferred Upper Triassic and younger age (IGME, 1974).

The emplacement of the Malaguide units in the Sierra de Espuña involved two phases of folding and thrusting which caused a considerable disturbance of the stratigraphic order within the units (MÄKEL, 1981). As a result of this deformation, a continuous section of the Malaguide stratigraphy is not found in any of the units. The section described here is a composite one which gives a general representation of the Malaguide stratigraphy. The sections sampled for the analysis described here are indicated in Figure 1.

INTUITIVE AND DESCRIPTIVE ANALYSIS

DE BOUY (1966) developed this method for the study of sediments in thin sections and ROEP & REMMELZWAAL (1977) give an example of its application. A short explanation of the steps to follow for the analysis is given here.

- 1) All thin sections are coded to avoid any possible bias in subsequent steps.
- 2) The coded thin sections are rapidly compared with each other under the microscope and grouped into type categories which are based on a few sediment characteristics. Repetition of this process acts as a check on the consistency of the grouping.
- 3) From each intuitive group a 'leader' is selected and described in detail.
- 4) With these descriptions, a table is prepared and all thin sections are systematically analysed according to this table.
- 5) The thin sections are decoded and their descriptions arranged in the correct stratigraphic order.

The results of the intuitive and descriptive analyses of 82 thin sections, representing the general stratigraphy of the Malaguide sequences in the Sierra de Espuña, are given in Table I.

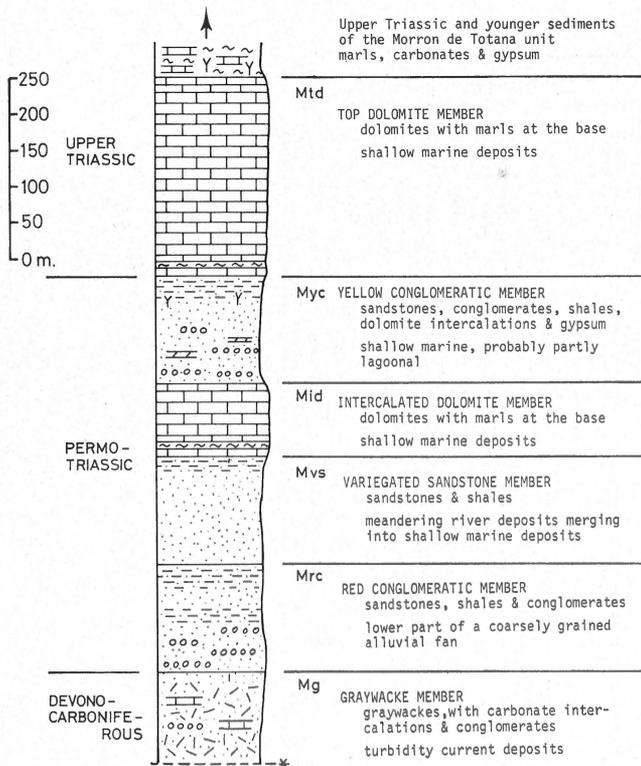


Fig. 2 Schematic composite columnar section of the Malaguide stratigraphy in the Sierra de Espuña.

The first columns contain the results of the intuitive grouping, obtained in three hours by the second author. Thirteen sediment types, listed in Table I, were distinguished. Intuitive grouping done by the first author and repeated by Mr. H. K. H. Holst did not show any significant departure from that presented in Table I. The remainder of the Table contains the descriptive results, showing the relative abundance of detrital constituents arranged into five groups.

The intuitive grouping shows clear differences between the clastic members. Type 1 sandstones and type 6 conglomerates occur almost exclusively in the Myc member. Type 3 sandstones are only found in the Mg member. The Mvs member shows four types of sandstones whereas type 5 sandstones and type 7 & 8 conglomerates are mainly restricted to the Mrc member. Differences between the two carbonate members are not readily apparent.

The grain size distribution for the sandstone type sediments is indicated by the modal class following the Wentworth scale (PETTJOHN, 1975). The Permo-Triassic members show a mixture of fine and very fine grain sizes whereas in the Mg member only the grain sized sediments are found. Medium grain sizes are occasionally found in the Mvs member.

The grain roundness distribution, based on roundness classes given by PETTJOHN (1975), shows a predominance of subrounded grains in the Mg member. Subrounded and rounded grains occur in the other clastic members.

Comparison of the four clastic members is possible by considering the data presented in the five groups of detrital components. The contents of the quartz group and heavy mineral group are rather similar for all clastic members, both in general aspect as well as in detail.

Feldspars are abundant and varied in the Mg member contrary to the Mrc member which has a relative low feldspar content of mainly K-feldspar and altered feldspar. The Myc and Mvs members are intermediate in this respect although the content of the former is more varied. The frequent occurrence of K-feldspar (partly optically uniaxial to small biaxial negative, most likely representing sanidine) in the Myc member is significant. Compared to the other members, the Mrc member is almost devoid of microcline.

Micas are abundant and varied in the Mg member. In the other clastic members colourless micas are predominant, especially in the Mrc member.

The content in rock fragments of the Mg member is very variable. Carbonate fragments occur very frequently in the Myc member. The composition of these fragments varies but (recrystallised) mudstones are predominant. In the three lower clastic members, fragments of clastic and (low-)metamorphic rocks are common. Schist fragments however are not found in the Mvs member. Carbonate concretions (type 8 conglomerates) are almost exclusively found in the Mrc member. Volcanic rock fragments are occasionally encountered in the Mg member but are almost completely lacking in the others.

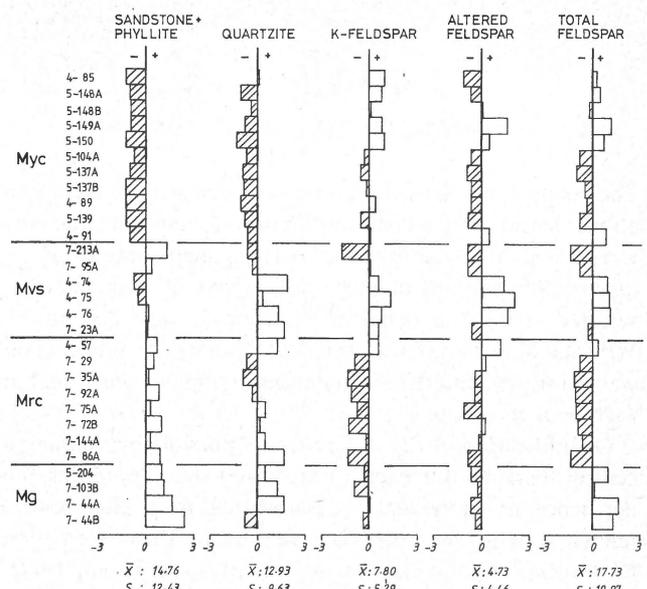


Fig. 3

Central tendency diagrams showing the departure from the mean for specific (combination of) detrital components calculated with a Z-transformation. Mean and standard deviation are calculated for each variable using the point count data for specific components per thin section as listed in Table II.

Table II
Point count data and grain size statistics used for quantitative analysis.

	SANDSTONE TYPE	FELDSPAR				ROCK FRAGMENTS					GROUP PERCENTAGES			GRAIN SIZE STATISTICS						
		K-feldspar	Polysynthetic	Microcline	Karlsb./Albite	Sandstone	Shale	Quartzite	Phyllite	Schist	Carbonate	QUARTZ	FELDSPAR	MICA + ROCK FRAGM.	mean grain size (phi)					
															a ₁	a ₂	a ₃	a ₄		
Myc	4-85	1	13	2	6		4	14		14	70.3	11.4	18.3		2.42	.58	.69	4.56		
	5-148A	1	12	8	2			3	3	23	70.9	11.4	16.3		3.30	.67	.25	2.15		
	5-148B	5	8							5	74.1	7.9	18.0		2.88	.83	.34	2.51		
	5-149A	1	12	4	3	12		5	4		63.9	16.0	20.1		2.74	.61	.54	2.99		
	5-150	1	13	3	3	7					72.5	13.8	13.7		2.75	.53	.67	3.73		
	5-104A	1	6	1		2		3	3	6	3	75.6	4.7	19.7		2.14	.81	.29	3.01	
	5-137A	5	5		1	1				4	3	63.0	4.8	32.2		3.82	.56	-.38	2.66	
	5-137B	1	7	2	2	2			5		30	72.7	7.1	20.2		2.51	.63	.02	2.52	
	4-89	1	10	2	2	2		2	3		22	73.6	8.8	17.6		3.13	.68	.24	3.24	
	5-139	1	5	2		1	1		3	5	34	70.4	6.1	23.5		2.51	.54	-.05	3.24	
4-91	1	8	5	7	7		7	3		23	66.0	14.5	19.5		2.71	.66	.96	5.63		
Mvs	7-213A	2		1		1	15	7	15		54.3	.9	44.8		1.75	.66	1.21	6.14		
	7-95A	4	8			1		3	10	20	65.2	5.8	29.0		3.45	.62	-.06	2.62		
	4-74	2	11	6	11			6	31	6	66.3	11.7	22.0		2.16	.50	.04	2.74		
	4-75	2	15		14			8	5	16	5	65.4	13.4	21.2		2.38	.57	.06	2.77	
	4-76	2	12	3	2	12		9	7	25	8	61.0	13.0	26.0		1.81	.56	.93	4.86	
	7-23A	2	11		2	2		7	15	30	8	64.4	6.9	28.7		2.06	.50	.28	2.93	
Mrc	4-57	5	11		10			25	23	5	65.2	9.5	25.3		2.88	.55	-.14	2.66		
	7-29A	5	3		6		4	6	7	17	3	58.6	7.0	34.4		3.42	.60	.30	2.19	
	7-35A	4	1	1	3			4	4	17	3	73.6	3.6	22.8		3.34	.67	.18	2.25	
	7-92A	5	2	1	3			4	10	25		77.9	2.4	19.7		2.68	.53	.53	4.11	
	7-75A	5	4		1	1	1	1	2	18	17	2	75.4	2.9	21.7		2.59	.56	1.11	5.06
	7-72B	5	1		6			1	15	22		50.8	5.4	43.8		3.82	.62	-.58	2.71	
	7-144A	5	7		4		1	2	18	12		57.1	9.8	33.1		3.40	.81	-.56	2.85	
	7-86A	2	1		1		7	29	26	5		65.1	1.0	34.0		2.25	.65	.63	3.33	
Mg	5-204	3	6	17	3	2	6	7	18	21	4	1	42.5	15.1	42.4		2.68	.93	-.38	3.44
	7-103B	3	8	2	1	4	2	5	25	27	6		48.4	10.9	40.7		2.82	.92	.30	2.25
	7-44A	3	8	17	7	2	3	1	29	33	7		40.1	17.8	42.1		2.45	.84	-.13	2.33
	7-44B	5	6	19	4	3	2	7	5	43	8	6	40.9	17.2	41.9		2.05	1.14	-.24	3.89

a₁ = mean in phi-units; a₂ = standard deviation of mean or sorting coefficient; a₃ = skewness; a₄ = kurtosis.

feldspar values for the Mg member reflect the abundance and variety of feldspars in this member. The greater variety in the Myc member relative to the Mvs member, indicated by the descriptive analysis, is not apparent from the diagram. The scarcity of feldspar components in the Mrc member is however clearly indicated.

The maximum dimension of 100 grains measured per thin section, has been used to calculate statistics following the moments method (AGTERBERG, 1974), after a phi-conversion (PETTJOHN, 1975) was applied. The bargraphs in Table II show the mean values with their 95% confidence interval. In general the mean values are in agreement with the model classes recorded during the descriptive analysis. Low values (medium to fine) are found for the type 2 sandstones of the Mvs member. Fine to very fine grain sizes are found in the Myc and Mrc member and fine grain sizes in the Mg member.

Following FRIEDMAN (1961), the skewness is plotted against the standard deviation or sorting coefficient (Fig. 4A). Samples of the Mg member plot significantly different compared to the majority of the other samples. The sorting coefficients for this member are higher - i.e. sorting is poorer - and have a wider range than the other members. For the other members the sorting range is relatively narrow, but they show a wider range of, mostly positive skewness values. Sorting in the Mg member is moderate to poor, the other members are moderately well sorted.

The numerical data (Table II) have been used to classify the sandstones. In the diagram of Figure 4B, the percentages of the point count data for the quartz group, feldspar group and the combined micas plus rock fragment groups have been plotted. Again the sandstones of the Mg members group significantly different.

DISCUSSION OF THE SEDIMENT PETROGRAPHICAL ASPECTS

We can summarise the sediment petrographical aspects of the Malaguide sequences by combining the results of both analyses. The most characteristic aspects for the individual members are listed in Table III.

The sandstones of the graywacke member show a more variable detrital content when compared with the other clastic members. Their sorting is moderate to poor and the fine sand grades are subrounded. The yellow conglomeratic member differs from the other Permo-Triassic members in the large amounts of carbonate fragments, carbonate cement and K-feldspar. The latter also occurs regularly in the sandstones of the variegated sandstone member. A relatively high amount of low-metamorphic rock fragments, especially phyllite, is found in the red conglomeratic member. The sandstones of the Permo-Triassic members contain subrounded to rounded grains in the fine to very fine grades and they are

Table III
 Characteristics aspects of the detrital contents of the members of the Malaguide stratigraphy in the Sierra de España.

SANDSTONES		CONGLOMERATES	CARBONATES	
			recrystallised mudstones algal limestones	TOP DOLOMITE MEMBER
carbonate fragments K-feldspar (sanidine) colourless micas carbonate cement	fine-very fine grained sorting: moderately well - moderate subrounded - rounded	carbonate fragments		YELLOW CONGLO- MERATIC MEMBER
		carbonate fragments	recrystallised mudstones algal limestones	INTERCALATED DOLOMITE MEMBER
clastic & low-metamor- phic fragments K-feldspar & altered feldspar, colourless micas quartz & carbonate cement	medium-very fine grained sorting: moderately well subrounded-rounded			VARIEGATED SAND- STONE MEMBER
clastic & low-metamor- phic fragments colourless micas quartz & FeO cement	fine-very fine grained sorting: moderately well subrounded-rounded	carbonate concretions in shales quartz fragments		RED CONGLOMERATIC MEMBER
clastic, metamorphic & volcanic fragments varied feldspars & micas matrix of clay and decom- posed feldspar	fine grained sorting: moderate-poor subrounded	carbonate, quartz & metamorphic fragments	recrystallised mudstones	GRAYWACKE MEMBER

moderately sorted. In the variegated sandstone member medium grain sizes are sometimes found.

As to the conglomerates, the occurrence of carbonate pebbles is significant for the yellow conglomeratic member. Carbonate concretions are found in calcretic soils in the upper part and quartz pebble conglomerates in the lower part of the red conglomeratic member.

There are two carbonate members in the sequence and both are characterised by (recrystallised) mudstones and algal limestones.

Considering the detrital contents of the two lower Permo-Triassic members, it can be concluded that the source area consisted of sediments and (epi-)metamorphic sediments; quartzites and phyllites were most probably predominant. The shift towards a higher feldspar content in the variegated sandstone and yellow conglomeratic members possibly indicates the denudation of a higher metamorphic terrain. The relative abundance of tourmaline and zircon indicates sediment recycling (GREENSMITH, 1971). The same arguments also hold for the graywacke member, although the large amount of feldspar and high metamorphic fragments (schists) points to a source area with higher-grade metamorphic rocks. A similar contrast was found in the Velez Rubio area (ROEP, 1972; GEEL, 1973).

Intraformational reworking of the intercalated dolomite member is probably responsible for the large amount of carbonate fragments in the overlying yellow conglomeratic member (ROEP, 1972; MÄKEL & RONDEEL, 1979). This assumption is not contradicted by the composition of the fragments which compares reasonably well with the carbonates of the intercalated dolomite member.

Sanidine, especially in the yellow conglomeratic member indicates volcanic activity in the source area. In the Velez Rubio area, volcanic activity was probably more pronounced (ROEP, 1972). The large amount of phyllitic and schist fragments in the lower part and carbonate fragments in the

higher parts of the Permo-Triassic sequences indicates a small distance from source area to depositional environment. For the Velez Rubio area this distance was estimated as several tens of kilometres (ROEP, 1974).

The analysis of paleocurrent measurements indicated that the source of the red conglomeratic and variegated sandstone member, was situated S to SE of the Malaguide depositional realm (MÄKEL, 1982). Whether the source area consisted of rocks of the graywacke member is questionable since fragments of this member have not been identified in the Permo-Triassic members. There is a considerable difference between the graywacke member and the much more mature Permo-Triassic sequence. This contrast has been used as an argument for a mild Hercynian diastrophism in the Malaguide sequences (ROEP, 1974).

CONCLUSIONS

The intuitive and descriptive analysis gave a complete overview of the detrital contents of all sediments of the Malaguide sequence. Combination of the data in a table makes visual comparison of parts of the sequence mutually possible. Differences can, however, only be discussed in relative terms.

The descriptive part is preceded by an intuitive grouping based on the selection of a few characteristic sediment attributes and subsequent grouping of the thin sections accordingly. The intuitive part of the analysis can be performed in a relatively short time (three hours for this analysis), but already indicates significant differences between specific members.

Quantitative analysis, using numerically analysed point count data, is often used for the description and classification of clastic sediments. The combination of numerical data from different sediment types is however difficult. The application

of statistical techniques furthermore requires the gathering of a large amount of data which, even with the use of sophisticated point count techniques, is time-consuming.

Comparing the results of the different methods here we have seen that they agree at large. Differences between the clastic members which are apparent in Table I, are in general confirmed by the quantitative analysis.

We conclude that, next to quantitative analysis, the intuitive and descriptive method is a useful tool for the description of a sedimentary sequence. The fact that an intuitive analysis takes little time makes it very appropriate for regional surveys, since it permits a rapid comparison of core data or of a stratigraphic section with a detailed standard section. For the study of the Betic Cordilleras this implies that, using the standard section of a specific area (i.e. the Sierra de Espuña or the Velez Rubio area), Malaguide sequences from other areas can be compared easily and quickly.

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