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DIFFERENCES IN TECTONIC EVOLUTION OF SUPERPOSED MALAGUIDE AND ALPUJARRIDE TECTONIC UNITS IN THE ESPUÑA AREA (BETIC CORDILLERAS, SPAIN)[1]

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ABSTRACT

Mäkel, G. H. 1981 Differences in tectonic evolution of superposed Malaguide and Alpujarride tectonic units in the Espuña area (Betic Cordilleras, Spain) – Geol. Mijnbouw 60: 203-208.

A description is given of the tectonic evolution of rock sequences of the Malaguide and Alpujarride complexes in the Espuña area. Two phases of folding and thrusting, the first accompanied by metamorphism, affected the Alpujarride sequences. Subsequently Malaguide rocks were folded and thrust over the Alpujarride rocks and Malaguide tectonic units were formed. Afterwards folding and thrusting to the south affected the pile of units. Subsequent Tortonian and younger faulting took place alongh E-W and N-S trending, subvertical faults.

In the Espuña area there exists, besides marked differences in stratigraphy and degree of metamorphism, a clear distinction between the tectonic evolution of the Malaguide and Alpujarride sequences. Therefore it is concluded that intermediate tectonic units do not exist in the Espuña area where they were originally defined. As a consequence of these data, arguments in support of a close palaeogeographic relation between the Malaguide and Alpujarride complexes cannot be founded on the existence of intermediate units.

INTRODUCTION

The Espuña area is situated in the Internal or Betic Zone of the Betic Cordilleras, the Alpine fold belt of southern Spain. In the eastern part of the Betic Zone, four tectonic overthrust complexes (i.e. Nevado-Filabride complex, Ballabona-Cucharón complex, Alpujarride complex and Malaguide complex), mainly comprising Permo-Triassic and Triassic sediments, are distinguished (EGELER & SIMON, 1969). The grouping of units within these complexes is based on differences in lithostratigraphy and tectono-metamorphic evolution (EGELER ET AL. 1971).

The direction of thrusting, i.e. southward or northward, leading to the empilement of the tectonic units has been a matter of considerable debate and several conflicting models of the palaeogeographic arrangement of the thrust masses have been proposed (EGELER & SIMON, 1969; KAMPSCHUUR & RONDEEL, 1975; SIMON ET AL., 1976; TORRES-ROLDAN, 1979; DURAND DELGA, 1966, 1980). In all reconstructions of the palaeogeography and tectonic evolution of the Betic Zone, the affinity between overthrust units of the Malaguide and the Alpujarride complexes plays an important role. The affinity is largely based on observations made by PAQUET (1969) who introduced the Intermediate units of the Sierra de Espuña. These units of intermediate structural position are said to have an intermediate stratigraphic and metamorphic character between 'typically Malaguide' and 'typically Alpujarride' elements. In view of the importance of these Intermediate units, the Espuña area has been reinvestigated by the present author.

In the Espuña area non or very low-grade metamorphic Malaguide tectonic units overlie low-grade metamorphic Alpujarride rock sequences (Fig. 1). The names of the units correspond with those of the 1 : 50,000 geological map of Spain (IGME, 1974). The stratigraphy and metamorphic grade of these units, mainly comprising Permo-Triassic and Triassic sediments, have been described by MÄKEL & RONDEEL (1979). The units are unconformably overlain by Tertiary rocks of Late Miocene (Tortonian) and younger age (GEEL, 1977). This paper summarizes the deformation history and metamorphic evolution of the Malaguide and Alpujarride sequences. No reference will be made to literature on the area published before 1969. For older literature the reader is referred to the thesis of PAQUET (1969).

[1] Manuscript received: 1981-02-25.
Revised manuscript received and accepted: 1981-04-04.
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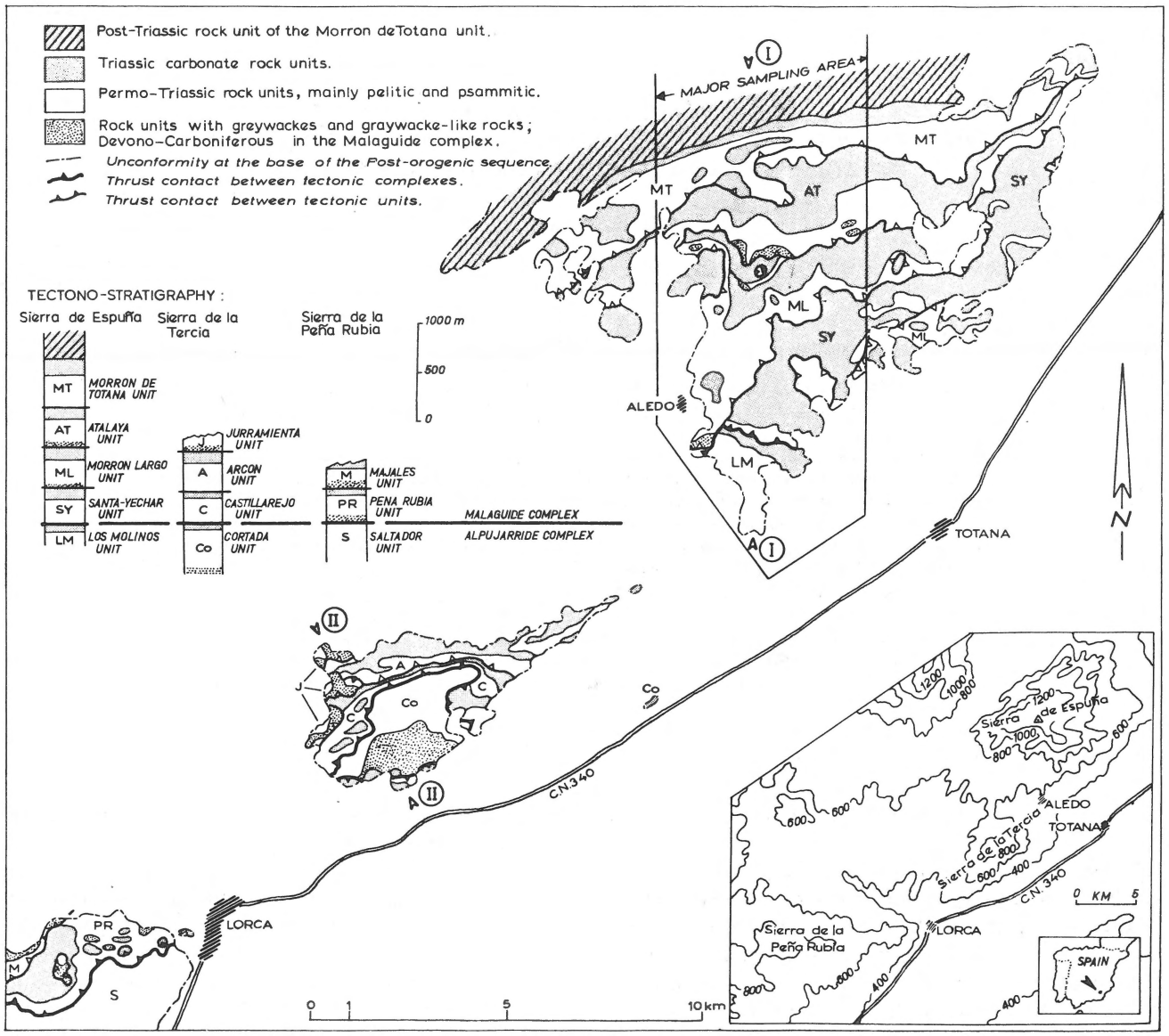

Fig. 1
Geological sketch map of the Espuña area.

DEFORMATION

The sequence of deformational events, which affected the Malaguide and Alpujarride units respectively, will be described. Later deformation phases, which took place after the deposition of post-nappe deposits and affected Malaguide and Alpujarride rocks alike, will be discussed afterwards.

Malaguide complex

During the first phase of deformation in the Malaguide sequences (D_1^M) isoclinal, recumbent folds were formed on a mesoscopic scale. Fold axes are horizontal and trend E-W. An axial-planar, slaty cleavage has locally been developed. Subsequent thrusting of the Malaguide sequences led to the formation of a number of Malaguide units (Fig. 2) and disrupted the stratigraphy within these units. Thrust planes are generally dipping north; the direction of thrusting, however, could not be established. Strongly tectonized zones, occasionally with rauhwackes, are found in the lower Malaguide units, especially in the Santa-Yechar unit and the Peña Rubia unit.

The second phase of deformation (D_2^M) led to the refolding of existing cleavages and folds and to the formation of open to close folds on a microscopic to macroscopic scale with horizontal E-W trendings axes. An axial-planar crenulation cleavage is only found very locally. Subsequently north-dipping thrust planes developed (Fig. 2). Thrusting severely disrupted the existing configuration of the tectonic units. The asymmetry of the folds, which are overturned to the south, suggests a direction of thrusting to the south. Folds related to this phase are the most conspicuous feature in all the Mala-

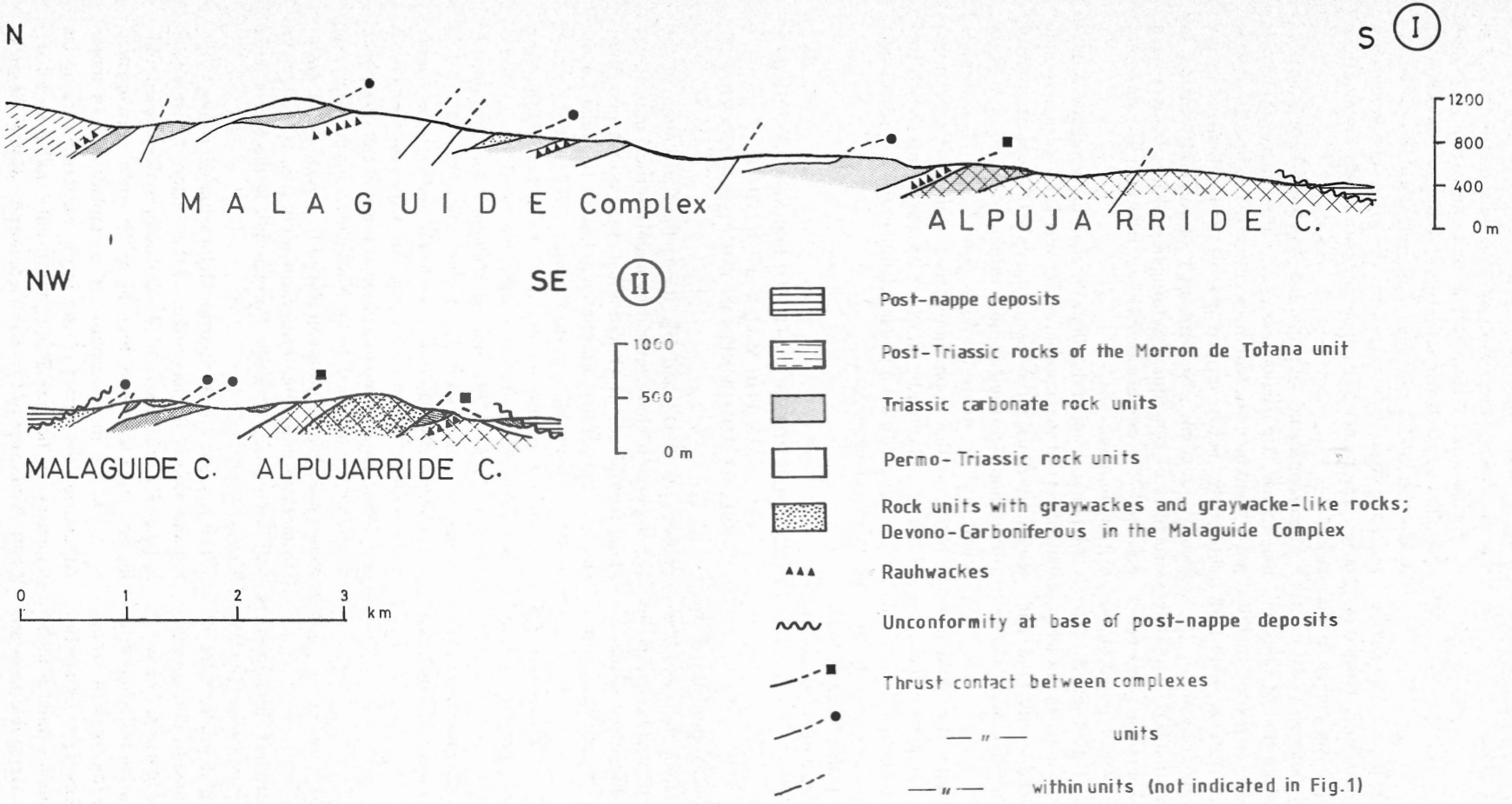

Fig. 2
Schematic cross sections of the Sierra de Espuña (I) and the Sierra de la Tercia (II). The orientation of the sections is indicated in figure 1.

guide units.

Alpujarride complex

During the first phase of deformation in the Alpujarride rocks (D_1^A) tight to isoclinal, reclined folds were formed on a microscopic and mesoscopic scale. Fold axes plunge to the north-northeast. An axial-planar, slaty cleavage is the most conspicuous feature of the rocks. In some thin sections an older foliation has been observed. Folding related to this structure has not been observed, leaving the exact nature of the foliation (sedimentary and/or tectonic) obscure.

Effects of the second phase of deformation (D_2^A) have only been found in the lower parts of the Alpujarride sequences. Since these lower parts are only extensively exposed in the Cortada unit in the Sierra de la Tercia (Figs. 1 and 2), D_2^A-thrust planes are only observed in this unit. Rauhwackes, associated with the thrust planes are found locally. Folds and cleavages related to this phase have not been found and the direction of thrusting is unknown.

The third phase of deformation (D_3^A) led to the refolding of existing structures and the formation of an axial-planar crenulation cleavage. Open to close folds on a microscopic and mesoscopic scale are numerous. Fold axes are mostly horizontal and trend E-W. Locally thrust planes were formed. The asymmetry of the folds suggests thrusting to the south.

Later deformation phases

The next phase of deformation ($D_3^M = D_4^A$) produced E-W striking, vertical normal faults in all tectonic units and Miocene post-nappe deposits. Slickenside striae indicate dip-slip movement. In phyllitic rocks of the Alpujarride sequences sets of kinkbands are found. Kinkband boundaries are parallel to the fault planes.

The last phase of deformation ($D_4^M = D_5^A$) caused N-S striking, steep dipping normal faults in all tectonic units and all post-nappe deposits.

Faults related to these last phases are numerous. The throw of the faults is mostly in the order of several metres or less.

METAMORPHISM

The degree of metamorphism has been studied on samples of pelitic rocks from the indicated sampling area in the Sierra de Espuña (Fig. 1). The overall metamorphic grade of the respective tectonic units has been determined by illite crystallinity measurements made in x-ray diffractograms. The use of illite crystallinity is based on the increasing ordering of the illite lattice with increasing temperature (DUNOYER DE SEGONZAC, 1975). It was concluded that the rocks of the Alpujarride Los Molinos unit of the Sierra de Espuña exhibit a higher illite crystallinity than the rocks of the Malaguide units and that the rocks of the lowermost Malaguide unit in the Sierra de Espuña, the Santa-Yechar unit, have a higher illite crystallinity than those of the higher Malaguide units (MÄKEL & RONDEEL, 1979). The degree of metamorphism of the Alpujarride rocks never surpasses the lowermost greenschist facies. The higher Malaguide units are hardly metamorphic at all.

Microscopic study of pelitic and psammitic, Permo-Triassic and Triassic Alpujarride rocks showed that metamorphism is pre- to synkinematic with respect to D_1^A. The first cleavage is defined by newly formed chlorite and colourless micas, mostly muscovite. Neoformation of minerals related to structures of subsequent deformation phases has not been observed. The crenulation cleavage is formed by rotation of existing minerals.

Metamorphism in the Santa-Yechar unit is related to D_1^M. The effects of metamorphism are restricted to the strongly tectonized zones at the base of the unit. D_1^M -structures, such as folds and cleavages together with quartz veins, have been found in these zones. Neoformation of minerals comprises only chlorite that occurs in the quartz veins. Transformation of illites is indicated by the X-ray measurements. Newly formed minerals are not found in relation to the second cleavage in the Malaguide rocks.

RELATION BETWEEN THE DEFORMATION PHASES IN THE MALAGUIDE AND ALPUJARRIDE UNITS IN THE ESPUÑA AREA

Subsequent to D_2^M and D_3^A, the tectonic evolution of the Espuña area is characterized by mainly vertical movements along fault planes which also affected the post-nappe deposits. This part of the deformational history is similar for the Malaguide and Alpujarride sequences. D_2^M and D_3^A structures are comparable in style and orientation. Differences which exist are attributed to differences in lithology and it therefore seems likely that the Malaguide and Alpujarride sequences were deformed as a whole after D_1^M - D_2^A.

The deformational events prior to D_2^M and D_3^A show considerable differences. In the Alpujarride sequences two phases of deformation coupled to a phase of regional metamorphism have been distinguished. In the Malaguide sequences only one phase of deformation, accompanied by a local, weak dynamo-metamorphism, has been recognised. Effects of D_2^A have only been observed in the Cortada unit in the Sierra de la Tercia.

The sequence of Alpujarride deformational events in the Espuña area is similar to that of the western Sierra de las Estancias. Here the second phase of deformation caused folding and large-scale overthrusting to the north, accompanied by retrograde metamorphism. The emplacement of major Alpujarride overthrust masses in the western Sierra de las Estancias has been related to this event (AKKERMAN ET AL., 1980). As a result of D_1^M, non-metamorphic Malaguide rocks

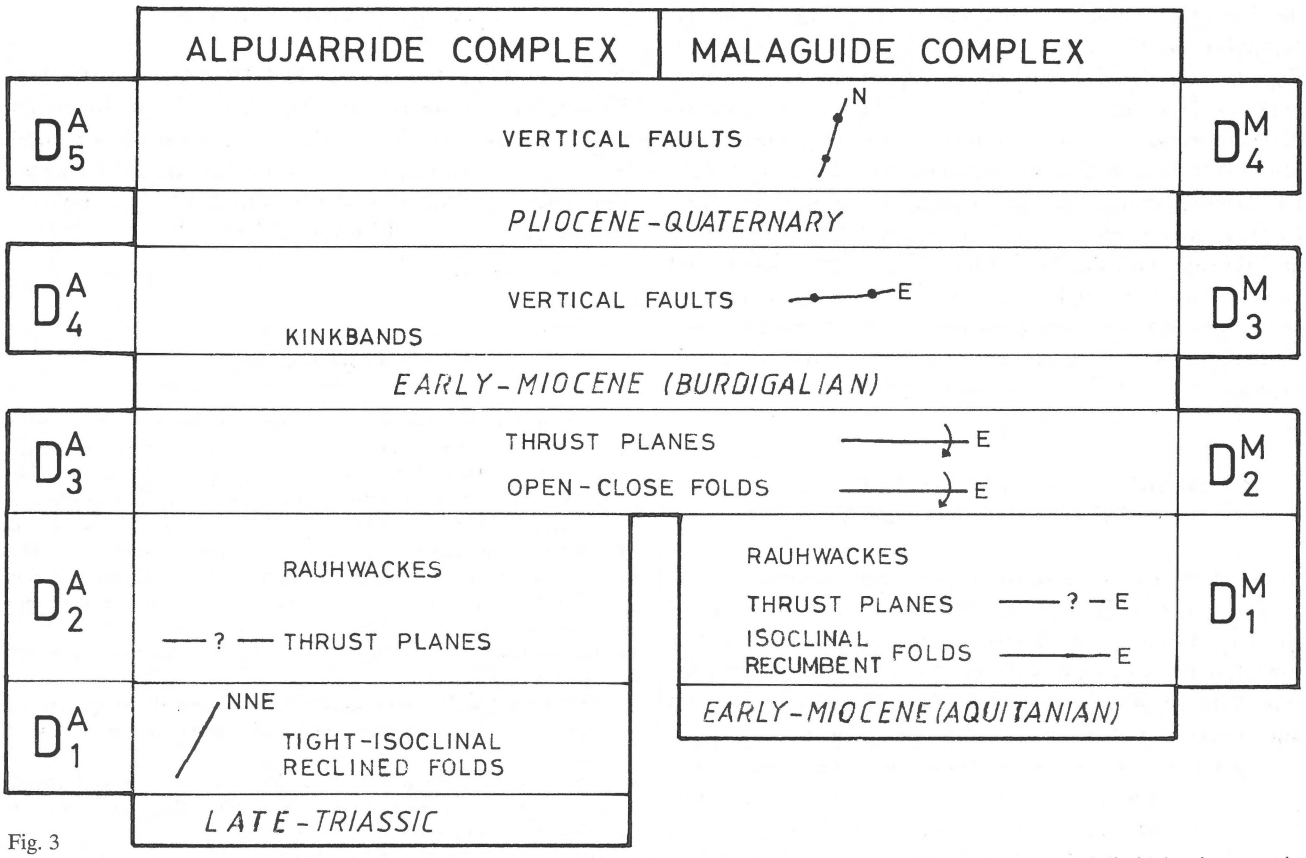

Fig. 3
Scheme of deformation phases of the Alpujarride and Malaguide sequences in the Espuña area. The geologic ages delimit the timespan in which respective deformational events have taken place, based on stratigraphic arguments discussed in the text.

are now overlying low-grade metamorphic Alpujarride rocks, which are found in a tectonic sequence related to D_1^A and D_2^A. It is therefore obvious that the first deformation phase of the Malaguide sequences took place after D_2^A.

DISCUSSION

In their study on the origin of the Betic Orogen of southern Spain, KAMPSCHUUR & RONDEEL (1975) presented a generalized description of the sequence of Alpine deformational events of the Betic Zone. According to these authors this sequence can be divided into two periods. First an older period of folding and thrusting leading to the empilement of tectonic units, accompanied by metamorphism, and a second period of folding and small-scale thrusting, locally accompanied by retrograde metamorphism. After these two periods, movement along steep fault planes caused differential vertical movement of large blocks. The Malaguide complex, with its markedly lower metamorphic grade, is not excluded from this generalized deformational history.

The youngest rocks affected by D_1^A, D_2^A and D_3^A in the Espuña area are the Alpujarride carbonate rocks of Middle Triassic age (MÄKEL & RONDEEL, 1979). The oldest post-nappe deposits, not affected by these deformation events are of Late Miocene (Tortonian) age. This leaves a large timespan for these events to have taken place. The first period of Alpine deformation and metamorphism of the Alpujarride sequences is thought to have started in the Late Cretaceous or Palaeocene and finished before the Eocene (KAMPSCHUUR & RONDEEL, 1975).

The youngest rocks affected by D_1^M and D_2^M are Oligocene deposits found in the Morron de Totana unit in the northern part of the Sierra de Espuña. According to PAQUET (1969) post-Lutetian deposits are separated from the underlying deposits by an angular unconformity of Late Eocene (Auversian) age. However, HERMES & KUHRY (1969) argued convincingly against this; the whole sequence is continuous from the Permo-Triassic into the Oligocene. Discussing data on Miocene deformation events in the Velez Rubio area, HERMES (1977, 1978) concluded that the youngest Malaguide rocks are of Early Miocene (Aquitanian) age. The oldest deposits discordantly overlying Malaguide deposits are of Early Miocene (Burdigalian) age. Although there are some differences in development of the post-Lutetian deposits in the Velez Rubio area and in the northern part of the Sierra de Espuña, Hermes extended his conclusion to the latter area also. D_1^M and D_2^M must therefore have taken place in the Early Miocene, considerably later than the first period of deformation of the Alpujarride complex which probably took place in

the Late Cretaceous or Palaeocene. This supports the assumption that D_1^M affected the Malaguide sequences in the Espuña area after D_2^A affected the Alpujarride sequences.

D_3^M (= D_4^A) faults affected all but the Pliocene post-nappe deposits, hence the last movement along these faults must have taken place before the beginning of the Pliocene. D_4^M (= D_5^A) faulting affected all rock sequences present in the area. Because post-nappe deposits continue well into the Pliocene and possibly into the Quaternary (GEEL, 1977), movement along these faults might have taken place in the Late Pliocene and Quaternary (cf. BOUSQUET, 1979). These faults are thought to be related to the updoming of the respective Sierras.

SUMMARY OF THE TECTONIC EVOLUTION OF THE ESPUÑA AREA

The tectonic evolution of the Espuña area can be summarized as follows (Fig. 3). During D_1^A the Alpujarride rocks of the Espuña area were deformed and metamorphosed, followed by D_2^A with supposedly northward directed overthrusting. Subsequently during D_1^M, Malaguide rocks were folded and thrust over these deformed and metamorphosed Alpujarride rocks. The direction of thrusting of this phase cannot be established with certainty. The malaguide tectonic units were formed and the stratigraphy within these units has been severely disrupted by the overthrusting. The effects of deformation and the dynamo-metamorphism can best be observed in tectonized zones at the base of the lowermost units.

A subsequent phase of deformation (D_2^M = D_3^A) caused refolding of existing structures. It is thought that the Alpujarride and Malaguide rocks were thrust to the south. Afterwards the Malaguide, Alpujarride and post-nappe deposits were affected by two phases of faulting.

CONCLUSIONS

The similar tectonic evolution as supposed by KAMPSCHUUR & RONDEEL (1975), combined with the claimed existence of Intermediate units in the sense of PAQUET (1969) in the Sierra de Espuña, made most authors assume a close palaeogeographic relationship between the Alpujarride and Malaguide complexes. However, MÄKEL & RONDEEL (1979) concluded that there are clear distinctions between the stratigraphy and between the degree of metamorphism of Malaguide and Alpujarride sequences in the Espuña area. From the present study it has become evident that there is also a difference in tectonic evolution between the two complexes in the area.

These differences imply that Intermediate units do not exist in the area where they were defined by PAQUET. Thus arguments in support of a close palaeogeographic relationship between the Alpujarride and Malaguide complexes cannot be based on the existence of these Intermediate units.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. H. E. Rondeel and Dr. O. J. Simon for their support in the field. They, Dr. C. Biermann and Dr. J. Grocott, also of the Department of Structural Geology of the University of Amsterdam, read the manuscript. Their constructive criticism, and that of two anonymous referees, is gratefully acknowledged.

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