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STRIKE-SLIP FAULTS IN THE SOUTHERN BORDER OF THE VERA BASIN (ALMERIA, BETIC CORDILLERAS)

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ABSTRACT

The Southern border of the Vera basin is affected by a dextral fault (Cortijo Grande fault) trending N70E. This is crossed by other faults trending NNE-SSW, and particulary at the Eastern end where it is severely bent by the Palomares fault.

The movements of the Cortijo Grande fault started at the latest during the Serravallian with compression trending from N80W to N60W wich steadily turned to N20W during the Messinian-Pliocene. Fault displacements affect Quaternary deposits in many occasions. Neogene sediments clearly show deformations contemporary to the deposit.

Key words: *Strike-slip faults, Neogene, Betic Cordilleras.*

RESUMEN

El borde sur de la depresión de Vera está afectado por una falla dextrorsa (falla de Cortijo Grande) de dirección N70E. Esta ha sido cortada por otras fallas de dirección NNE-SSW, en especial en su terminación oriental donde está fuertemente flexionada por la falla de Palomares.

Los movimientos de la falla de Cortijo Grande se han producido al menos desde el Serravalliense con compresiones según la dirección N80W a N60W que progresivamente rotaron a N20W en el Messiniense - Plioceno. Los desplazamientos de las fallas llegan a afectar en muchos casos a sedimentos cuaternarios. Los del Neógeno muestran claramente estas deformaciones coetáneas con el depósito.

Palabras clave: *Fallas de desgarre, Neógeno, Cordilleras Béticas.*

Introduction

On the SE part of the Iberian Peninsula, within the Betic Cordilleras, there are important strike-slip faults. Some of these are trending NE-SW to NNE-SSW and have been described on many occasions: Bousquet and Philip (1976), Ott d'Estevou and Montenat (1985), Rutter et al (1986), Weijermars et al (1985) or cited in the context of the Betic Cordilleras: Groupe de Recherche Néotectonique (1977), Sanz de Galdeano (1983), Boccaletti et al (1985), Sanz de Galdeano et al (1985), etc. However, fractures trending N60E to E-W on the northern flanks of the Sierras Cabrera and Alhamilla have not been studied or have at most been described as faults without any other specification or as reverse faults with local strike-slip components: Durand-Delga and Fontbote (1963). Nevertheless, they are large strike-slip faults which belong to the most important system of the Betic Cordilleras. (Sanz de Galdeano, 1983).

Here, features of these fractures in the north of Sierra Cabrera and their relationship with those trending NE-SW are described.

From a geological point of view this sector is situated to the east and south of the Sorbas and Vera basins respectively, within the internal zones of the Betic Cordilleras (fig. 1).

In the basement of the Sierra Cabrera the Nevado-Filabride is mainly constituted by dark schists and micaschists with garnet, quartzites and only in very few places by carbonate rocks and tourmaline gneises. However, in the Sierra de Bedar (fig. 2), carbonate rocks, gneisses and metabasites are much more common, although micaschists are also present.

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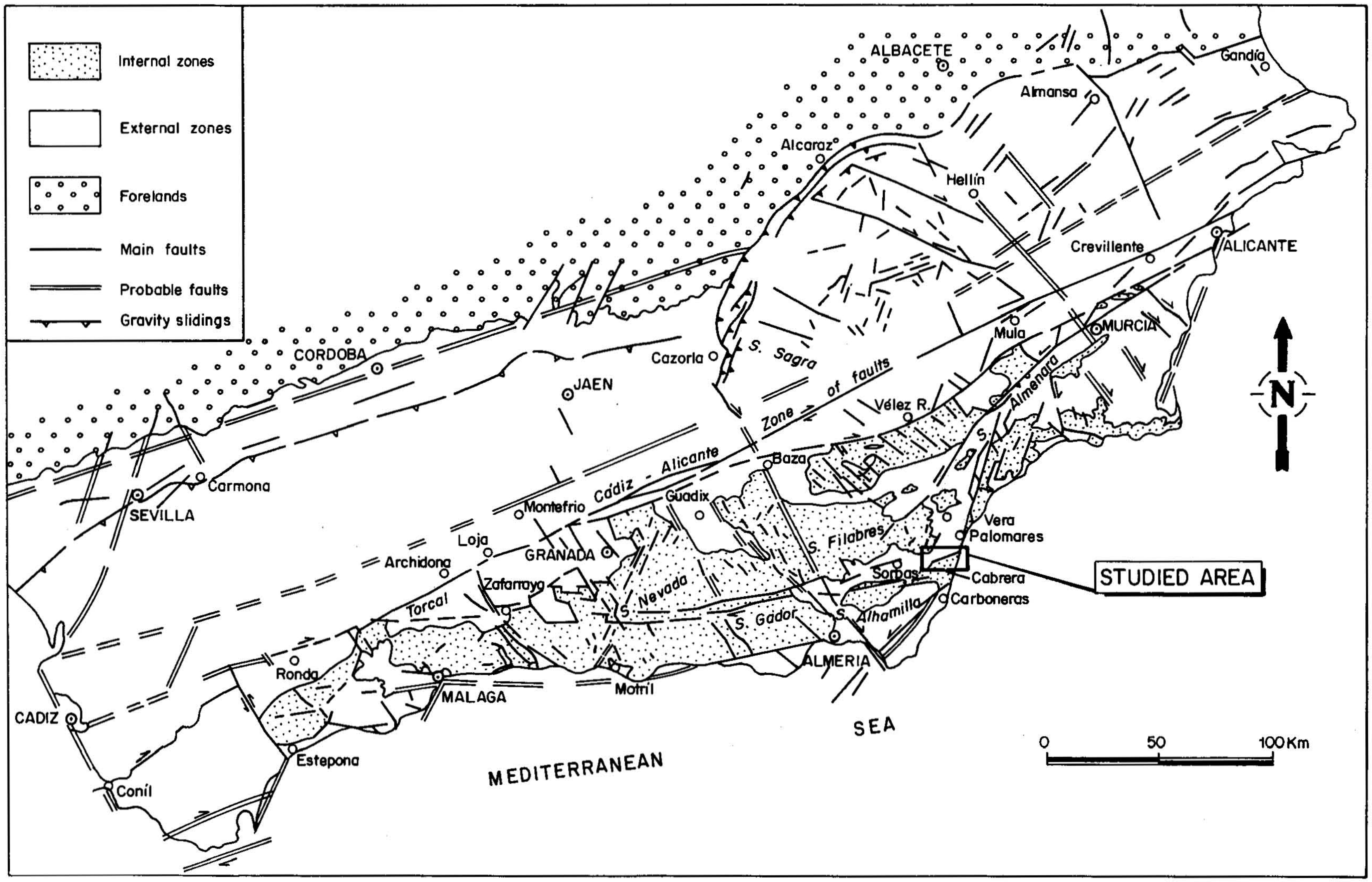

Fig. 1.—The faults of the Betic Cordilera.

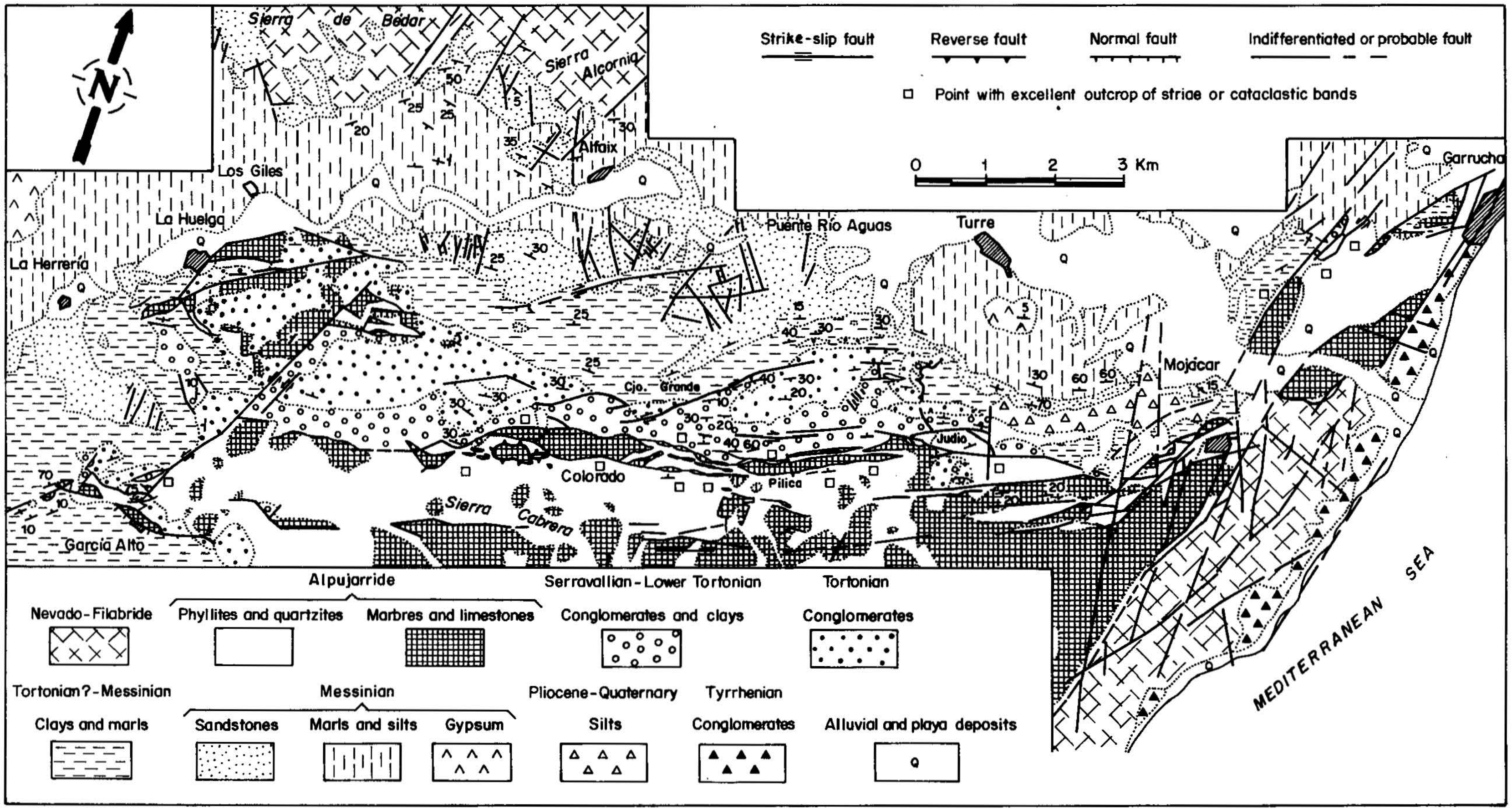

Fig. 2.—Geological map of the are investigated.

The Alpujarride complex, overlies the Nevado-Filabride and is formed by triassic bluish grey phyllites (although in other areas there are schits under them) and quartzites with some metabasits and, over them, some carbonate rocks, here with very little metamorphism. The Malaguide appear in very small outcrops, whose description can be seen in Rondeel (1965) and Garcia-Monzon et al (1974), included in this article together with the Alpujarride complex.

The oldest neogene sediments apart the Burdigalian that form very little outcroops, are those of the Serravallian-Lower Tortonian. They are formed by marine conglomerates, sands and silts several hundred meters thick. One of their characteristics is that they do not have boulders from the Nevado-Filabride but from the Alpujarride and the Malaguide.

Clearly discordant, some marine conglomerates are deposited, with boulders of up to several cubic metres, containing thin beds of sanstones and in some places silts and clays. The boulders are mostly formed by the Nevado-Filabride rocks, and of particular interest is the great amount of tourmaline gneisses and metabasites. The thickness of this sediments varies very much, ranging from 300-400 m thick near Cerro Colorado to almost nil to the East near the sea. Their age is Upper Tortonian-Messinian?. Their characteristics and age closely resemble those of the Block-Formation of the Granada basin (Viennot, 1930).

Over this, gradually, and at times laterally, appear silts, clays and marls. Their thickness varies greatly, reaching here about 300 m Their age is Upper Tortonian?-Messinian.

Above this sediments and slightly discordant, there are sandstones, sandly limestones and marine conglomerates of varying thickness: 80-100 m in this sector and towards Mojacar much less. On top of these, there are marls and silts. They are about 100 m thick, although laterally they also decrease considerably. Their age is Messinian.

To the SW of Mojacar, SE and SSE of Turre, there are sediments formed by porous silts with scattered gypsum, with structures which resemble small pipes, perhaps algae. They may correspond to the Pliocene or Lower Quaternary.

There are also deposits to the Tyrrhenian age near to, or even on, the coast and other Quaternary sediments such alluvial and colluvial deposits.

Tectonics

An important fault, the Cortijo Grande fault, on the Northern border of Sierra Cabrera (figs. 1 to 4) passes through the Colorado and Pilica hills south of Turre.

This fault is a set of almost parallel fracture lines affecting the Alpujarride and Neogene sediments within a zone 100 m to 1.500 m thick (fig. 3). This zone is characterized by bands of intense cataclasis of a few metres to over 30 m of thickness, to be observed particularly within the Alpujarride phyllites. These bands show incipient vertical foliation. Furthermore, phyllites, quartzites and, sometimes even carbonate beds suddenly appear in vertical position with their edges parallel to the direction of the bands. Also, there are many tectonic fragments specially formed by carbonate and quartzite materials and by Miocene rocks included within the phyllites or vice versa. These fragments range from less than 1 m to more than 1 or 2 km in length (e.g. the Colorado and Pilica hills). The edges of this tectonic fragments, generally totally cleancut, are striated. The striae are in general subhorizontal and parallel to foliation bands and are interpreted as indicators of movement directions. They are very spectacular in some places, as in the Judio hill, however they are present throughout the fault, from the vicinity of Mojacar to the village of La Huelga. In general, striae are parallel to the direction of the fault because the tectonic fragments themselves are elongated in this direction and only two class of deviation are found: at the ends of the fragments where faces are not parallel to the direction of the fault and in very small fragments. In the first case, striae may have very different directions. However, pianes associated to the faults, even if not vertical, usually maintain the direction of the striae. Very small tectonic fragments can be rotated and the striae are adapted surrounding the surfaces of the boulder.

It has to be stressed that some large surfaces, sometimes of over 150 m, contain different sets, of subhorizontal as well as locally subvertical striae. The striae, calcite and gypsum fibers and lunate tectoglyphs, indicate that the Cortijo Grande faults is dextral. This interpretation is also supported by the great number of small tectonic fragments with sigmoidal tails. Furthermore, there are fractures oblique to the bands of cataclastic rocks with dextral displacements, with could be considered as Riedel fractures (R).

Miocene sediments, especially older ones, and even those considered as Pliocene or Quaternary, are also affected by these bands. Cataclasis in Miocene sediments is less intense, but the beds are vertical in places and severe fracturing, rather than foliation, is frequent.

The Cortijo Grande fault is limited to both E

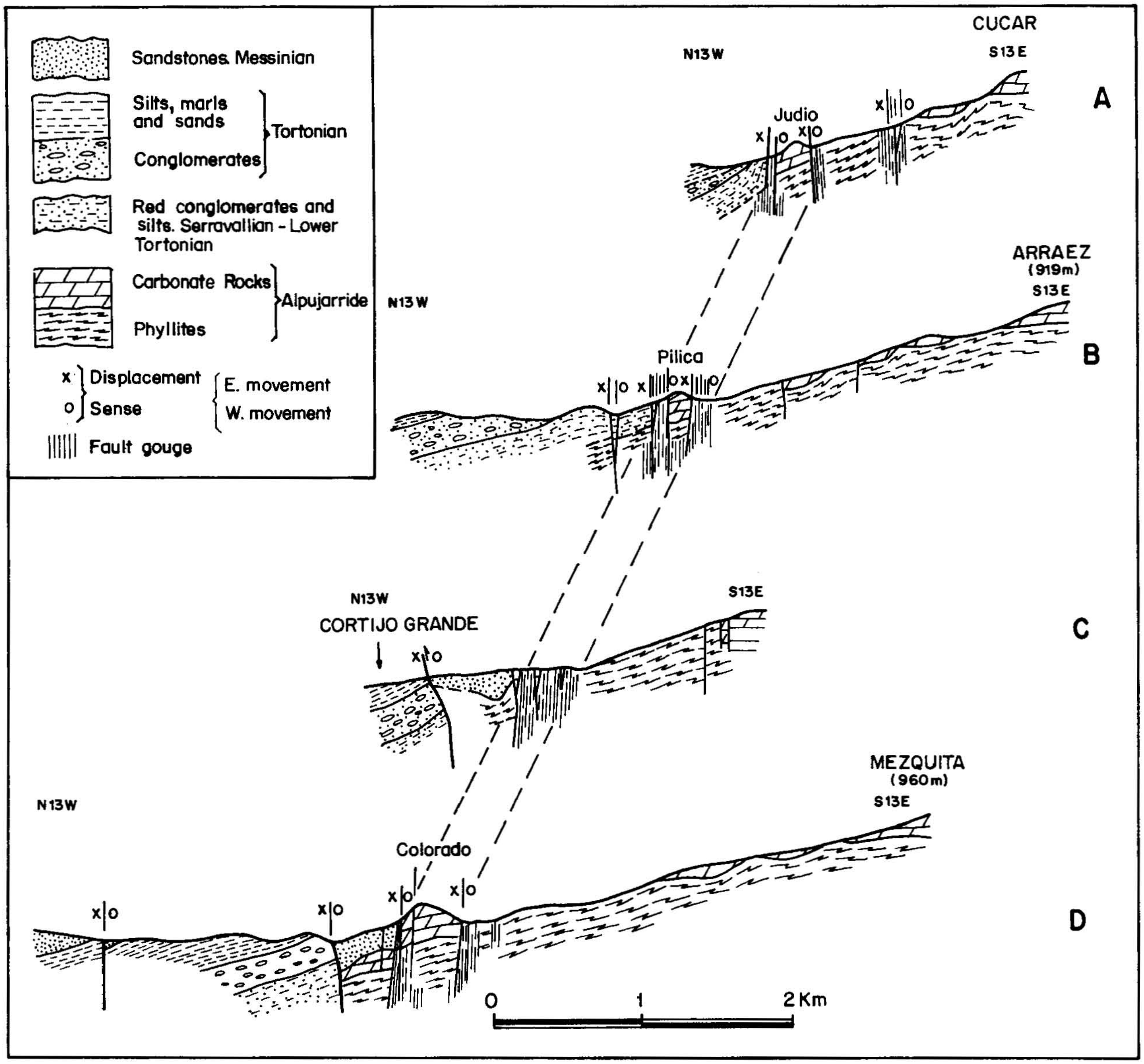

Fig. 3.—Geological cross-sections of Cortijo Grande fault.

and W by faults trending NNE. To the East, the Palomares fault, complex and diversified, is particularly important. Geological and photogeological studies show that it is formed by a set of faults and not by a single surface. A description is given by Bousquet and Philip (1976) and Weijermars et al (1985).

Of particular interest are the effects of this fault on the Cortijo Grande fault: the latter turns into parallelism with the NNE direction of the Palomares fault. Also, Alpujarride and Neogene rocks have been turned forming a vertical drag fold. The Cortijo Grande fault reappears to the east of the Palomares fault, which is crossed by E-W trending fault. This situation is interpreted as two active cross-cutting systems.

To the West, the NNE trending faults which pass through La Huelga and to the East of the Sierra de Alcornia (East of Sierra de Bedar) have clearly sinistral components and a vertical component of over 200 m. These faults cut the Cortijo Grande fault and represent its western termination.

A third system of fractures is trending NW-SE, and unlike other sectors in the Betics, does not from large fractures but are present at micro and mesotectonic levels.

The Cortijo Grande fault also presents vertical or subvertical striae and other intermediate ones but those with rakes between 0 and 20 are much more common. Therefore it can be deduced that the throw is not very important with regard to the heave. However, the latter cannot be calculated directly, although the Cortijo Grande accident may reach easily tens of km while that of Palomares, taking into account the displacement existing between the sierras Cabrera and Almenara, reaches 60 km approximately.

Microtectonics

More than a thousand of measurements of faults and joints were carried out. Many of this faults appear in well defined conjugated sets, 379 had strie and in 178 of these the direction of movement could be deduced.

Measurements cover the whole area, which could be subdivided into 12 sectors. The results are shown in figs. 4 and 5.

It has to be pointed out that fractures trending NW-SE have displaced both dextrally and sinistrally depending on whether σ_1 was closer to N-S or to E-W. Similarly, the whole set of fractures has not been formed by only one system of stresses, but at least two systems are necessary to explain its movements and the conjugated sets which are clearly observed.

In the Alpujarride rocks we have obtained the approximate direction of N80W-N50W, depending the sector, as predominat for σ_1. A direction close to N20W is also deduced (fig. 5, diagrams 1 to 4).

In the Serravallian-Tortonian sediments the direccion of N80W is deduced to the North of the Pilica and Colorado hillocks and in the Cortijo Grande sectors. The direction N50W is deduced to the south of Judio hillock. The direction N20W, approximately, is also deduced in this sediments with small changes from sector to sector (fig. 5, diagrams 5 to 8).

The direction N20W is the only one obtained in the Messinian outcrops at the bridge over the river Aguas and in the Alfaix sector (N27W and N15W respectively) (fig. 5, diagrams 9 and 10), were there are also numerous normal faults almost parallel to the deduced direction of σ_1. This fact is particularly evident in the river Aguas where there are a great number of normal conjugated faults with N27W as their average strike. So, it is possible to think that the formation of strike-slip and normal faults is almost contemporary, with a clear tension perpendicular to the direction of σ_1.

In Mojacar, at the Western road, the directions obtained in the Messinian sediments for σ_1 are N24 E, N5E and N25W (fig. 5, disgram 11). Two of these, N24E and N5E, without any real significance or somehow unreliable, since this is a sector in which materials have rotated more that 50° due to the drag effect of the Palomares lines of faults. The direction N25W coincides with other mentioned previously.

In Pliocene-Quaternary (?) deposits there are joints which would be compatible with N20W and N70E compressions (fig. 4).

Directions of tensional fractures in conglomerate pebbles (in Serravallian-Lower Tortonian sediments outcropping near Cortijo Grande) have also been measured (121 measures). Their poles have one maximum in the direction N58E and another less important one in N35E (fig. 5, diagram 12).

Cronology of deformations

During the Serravallian and Lower Tortonian there was not important erosion, since in their sediments there is not any detrital material inherited from the Nevado-Filabride.

Without any doubt, after the deposit of the Serravallian-Lower Tortonian sediments and before the upper Tortonian, a strong pulsation took place, as is shown by the fact that the Upper Tortonian-Messinian sediments are clearly discordant even over the Alpujarride. There are detrital materials from the Nevado-Filabride, in large boulders in many places, but apparently they come from the Sierra de los Filabres (in this case, its Southeastern spur which is called Sierra de Bedar and Sierra Alcornia) and apparently before Sierra Cabrera had risen sufficiently.

On the whole, it seems that the predominant direction of σ_1 ranged from N80W to N55W for the Serravallian (and earlier) and Tortonian ages. These stresses seem to have continued during the Messinian, although a turn in the direction of σ_1, which steadily becomes N30W-N20W, can be deduced. At the same time, NNE-SSW faults must have moved a great deal, whilst in this sector NW-SE faults are not very important, although quite numerous at meso and microstructural level. The NNE-SSW faults may have had an older history, although movements older that the Messinian, when they already had vertical displacements of at least 200, are not observed. On the SE edge of the Sierra Alcornia they formed a cliff on the base of which beach-like Messinian materials were deposited.

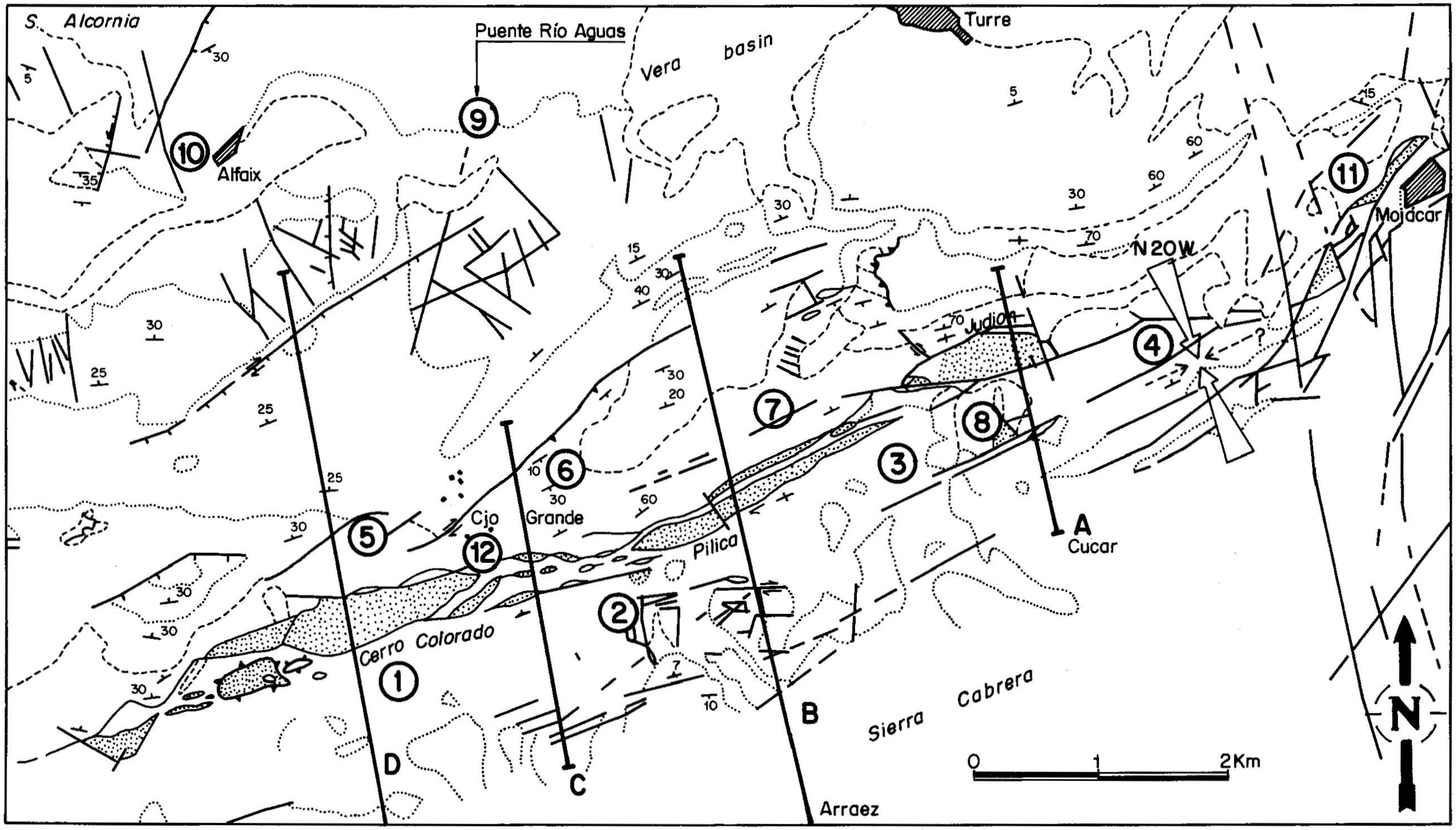

Fig. 4.—The Cortijo Grande fault. In points are marked carbonate tectonic fragments in cataclastic bands within the Alpujarride. Letters and numbers show the positions of the cross-sections and the sectors of the diagrams of figs. 3 and 5 respectively. The arrows show directions of σ_1 deduced from joints in Pliocene-Quaternary? sediments.

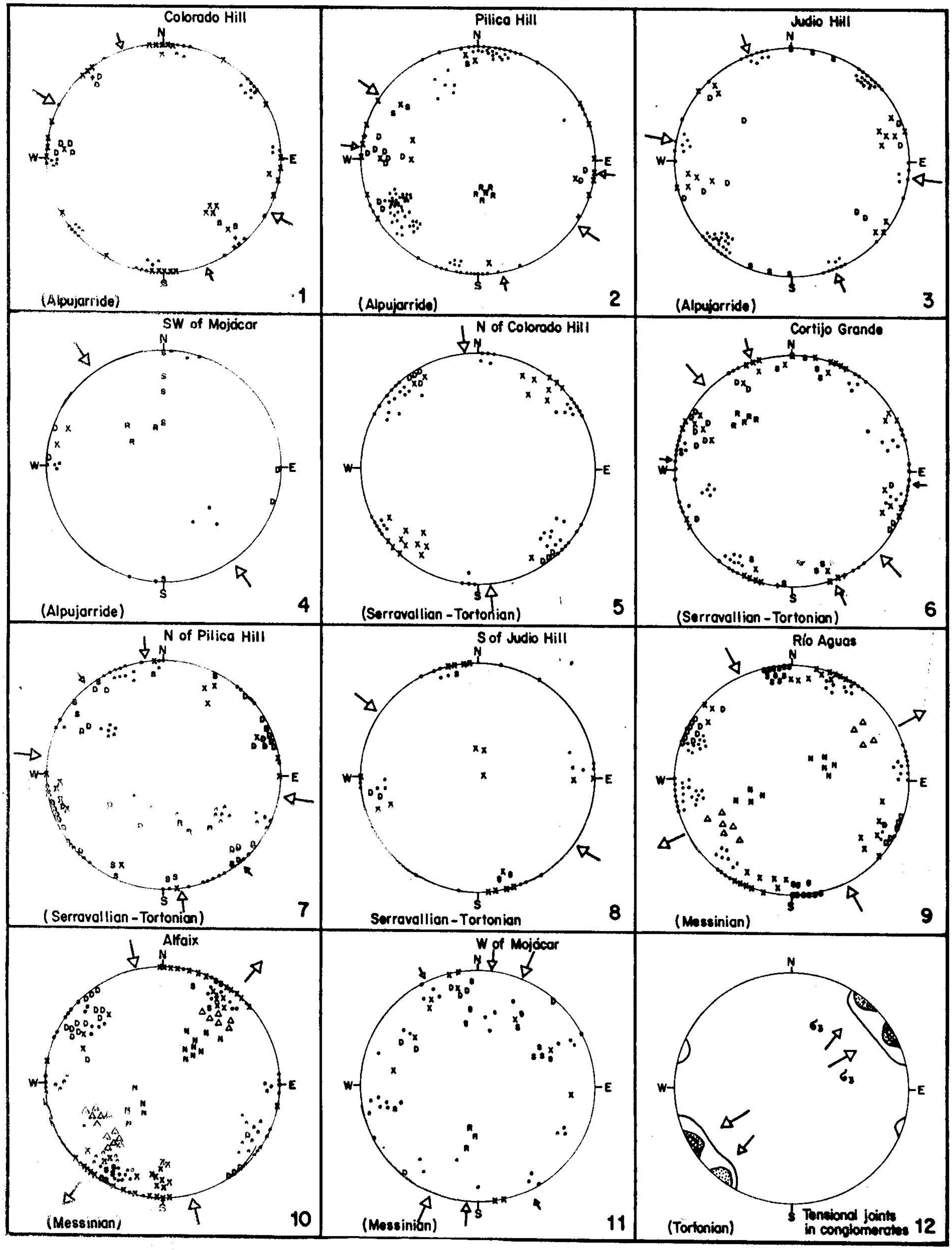

Fig. 5.—Diagrams of tectonic measures. Points: Poles of strike-slip and reverse faults. Triangles: Poles of normal faults. Crosses: Indifferentiated striae. D, S, R and N: Striae of dextral, sinistral, reverse and normal faults respectively. In many cases several measures are coincident in a determinated point. The arrows show the directions of σ_1 deduced, and their size is proportional to the importance of the directions obtained. Diagram 12: measures of poles of tensional joints in Lower Tortonian conglomerates.

The strong drags (over 2 km) and the flexure caused by the Palomares faults on the Cortijo Grande fault clearly affect Upper Messinian sediments which proves that the movements are quite modern. Furthemore, to the North in the Vera basin, in outcrops which are almost kilometrical in size, sediments, possibly from the Lower Quaternary and affected by wrench faults trending NNE-SSW are observed. One of these faults clearly affects tyrrhenian deposits in the village of Garrucha. Also in the interior of Sierra Cabrera some colluvial deposits are affected by strike movements (clearly seen due to the presence of gypsum fibers), but on this occasion the fault trends N70E.

Even fault planes it the Cortijo Grande fault are clearly affected at several points, such as the Judio hillock, where they are cut by NNE-SSW faults. It should also be pointed out however that near Mojacar, almost E-W fault planes cut NNE-SSW faults with decimetrical, dextral horizontal displacements.

In short, forces running N80W which steadily changed to an average N45W were predominant in this sector during the Serravallian and until the Tortonian-Messinian. σ_1 rotation continued during the Messinian-Pliocene until the approximate direction of N20W became predominant, as can be observed in the river Aguas. This compression direction extends into the Quaternary, if not until present. However, E-W movements still continue somehow, as is shown by the existence of deformations and sets of faults in Neogene and Quaternary sediments compatible with WNW-ESE compressions.

Conclusions

1. The Northern border of Sierra Cabrera is affected by a large dextral accident trending approximately N70E: the Cortijo Grande fault. The rocks adjacent to the fault contain cataclasite bands and striations.

2. The Cortijo Grande faults is cut both to the East (Palomares fault) and to the West, by NNE-SSW faults. The Palomares faults provoked the flexion and dragging of the Cortijo Grande fault with a displacement of over 2 km.

3. The σ_1 direction steadily rotates in time from N80W-N60W, in the Serravallian or even earlier, to N20W in the Messinian. This last predominant direction seems to have continued up to the present, although are some very modern movements which prove the existence of compressions, at least of a local and momentary nature, with WNW-ESE directions.

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