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PRESENT GEOMORPHOLOGICAL CHARACTERISTICS OF ALBORAN ISLET AND SURROUNDINGS, SPAIN: A DIAGNOSIS

ABSTRACT: COTILLA RODRÍGUEZ M.O. & CÓRDOBA BARBA D., *Present geomorphological characteristics of Alboran Islet and Surroundings, Spain: a diagnosis*. (IT ISSN 1724-4757, 2004).

Alboran Islet is a contemporary geomorphological structure, located in the plate boundary zone of Africa and Eurasia, and experiences the effects of active exogenous abrasive-denudative processes. The exogenous agents, in order of importance from greatest to least, are: 1) the process of marine abrasion in the Western Mediterranean Sea causing the successive and continuous receding of the shoreline; 2) winds that, as well as providing corrosive salinity through a strong, permanent sea-spray, beat down on the surface of the islet and produce corrosion, deflation and the transportation of sediments to the sea; 3) human activity that has left two formidable marks on the shoreline: a ramp and an inlet on the western side of the islet. This physical weathering and the natural thermal effect produced by a drastic day-night temperature pendulum speed up the fracturing of the ground. Also, the activity of birds, their organic wastes and chemical action must be noted. All these factors modify the shoreline and the denuded surface of the islet. This overall analysis that takes into account the fore-mentioned factors: the cartography of the gully, fracture and cave systems on the islet, certain submarine fractures, and the redoubt's rocky borders. This supports the hypothesis that, if the current geodynamic situation remains unchanged, this small emerged continental structure, just an islet, will disappear into a series of isolated rocks.

KEY WORDS: Alborán, Geomorphology, Spain.

RESUMEN: COTILLA RODRÍGUEZ M.O. & CÓRDOBA BARBA D., *Rasgos geomorphológicos actuales de la Isla de Alboran y zona circundante, España: un diagnóstica*. (IT ISSN 1724-4757, 2004).

La Isla de Alborán es una estructura geomorfológica contemporánea localizada en la zona límite de placas de Europa y África. Ella está afectada por un conjunto de procesos activos de tipo exógeno (abrasivo-denudativo). Los agentes exógenos, en orden de importancia decreciente, son: 1) los procesos de la abrasión marina del Mar Mediterráneo Occidental que favorcen al sucesivo y continuo retroceso de la línea de costa; 2) los vientos, que además de proveer la salinidad del entorno, funcionan como un *spray* permanente que favorecen a la corrosión, y desplazan a los sedimentos hacia el mar; 3) la actividad antrópica que ha producido al menos dos importantes escalones en la línea de costa: una rampa y un muelle. La meteorización física y la influencia térmica solar se perciben con un significativo péndulo térmico entre el día y la noche. Esto favorece, en mucho, a la fracturación del terreno. La actividad de las aves, con sus desechos orgánicos en combinación con los procesos químicos asociados, se perciben muy bien en la isla. Este conjunto de elementos y procesos son factores que funcionan y son suficientes para denudar la superficie de la isla. En el análisis se han considerado la cartografía de las fracturas, las alineaciones, los canales, las cavidades y las cuevas, incluso submarinas, los restos rocosos (promontorios o peñones aislados) y los cantos al pie del talud. Con todo esto es posible formular la hipótesis de que esta pequeña estructura continental, de mantenerse las condiciones actuales, desaparecerá en sucesivos islotes.

PALABRA CLAVE: Alborán, Geomorfología, España.

RESUMÉ: COTILLA RODRÍGUEZ M.O. & CÓRDOBA BARBA D., *Caractéres géomorphologiques actuels de Ile d'Alboran et des environs, Espagne: une analyse*. (IT ISSN 1724-4757, 2004).

L'Ile d'Alboran est une structure géomorphologique récente située dans la région inter-plaque entre l'Europe et l'Afrique. Elle subit les effets des processus exogènes actives avec abrasion et dénudation. Les agents exogènes en ordre d'importance sont: 1) Le processus d'abrasion marine dans la Méditerranée Occidentale, que produit la retraite successive et continue de la ligne de côte; 2) Le vent, couplé avec la salinité qu'il emporte avec la forte et permanente humidité marine, frappe la surface de l'Ile et produit corrosion, déflation et transport de sédiments vers la mer; 3) L'activité humaine qui a laissé deux formidables traces dans la côte: une rampe et une entrée sur le coté ouest de l'Ile. Cet effet de l'environnement s'ajoute à la forte variation journalière de la température qui accélère de façon pendulaire la fracturation du terrain. On peut aussi ajouter l'activité des oiseaux avec ses dépôts organiques et l'action chimique qui s'ensuit. Tous ces facteurs modifient la ligne de côte et la surface exposée de l'Ile. Cette analyse prend en compte les données suivantes: la cartographie des ravins, le système des fractures et les caves dans l'Ile, certaines fractures sous-marines, et les contours des réduits rocheux. L'ensemble des ces données favorise l'hypothèse de que,

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si la situation géodynamique actuelle ne change pas, cette petite structure continentale émergée, l'Ile, va disparaître laissant à sa place une série de roches isolées.

MOT CLES: Alboran, Geomorphologie, Espagne.

INTRODUCTION

Alboran Island (AI) is a geomorphological structure located in the Western Mediterranean approximately in the center of the Alboran Sea (AS) (fig. 1). The shape of this small island (~0,1 km^2) resembles a triangle pointing toward the NE, with sides of differing lengths (~0,6 km and 0,3 km) (fig. 2). Its small surface area would seem to justify its being categorized as an islet rather than an island. For the most part the island has a steep shoreline (height ~10-15 m) except for two small areas on the western edge. The island is very flat and has no trees though patches of shrubby plants less than 30 cm in height do exist.

As an intermediate point between Africa and Europe, AI historically had strategic importance because it was on the route of ships entering and leaving the Mediterranean Sea through the Strait of Gibraltar (SoG). According to a legend the island was named after a «famous» corsair who used it as headquarters though it can be argued that the name is derived from the Arabic term *Al-Borany = of the moors*. Some believe the name comes from the petrological term alboranite. Since the 19th century AI awoke scientific interest. There have been many authoritative studies, including from Davila (1876) to Gaibar-Puertas (1969, 1970). All these scientific contributions have fundamentally concentrated on the geographical and geological context. Meanwhile geophysical investigations, naturally greater in scope than

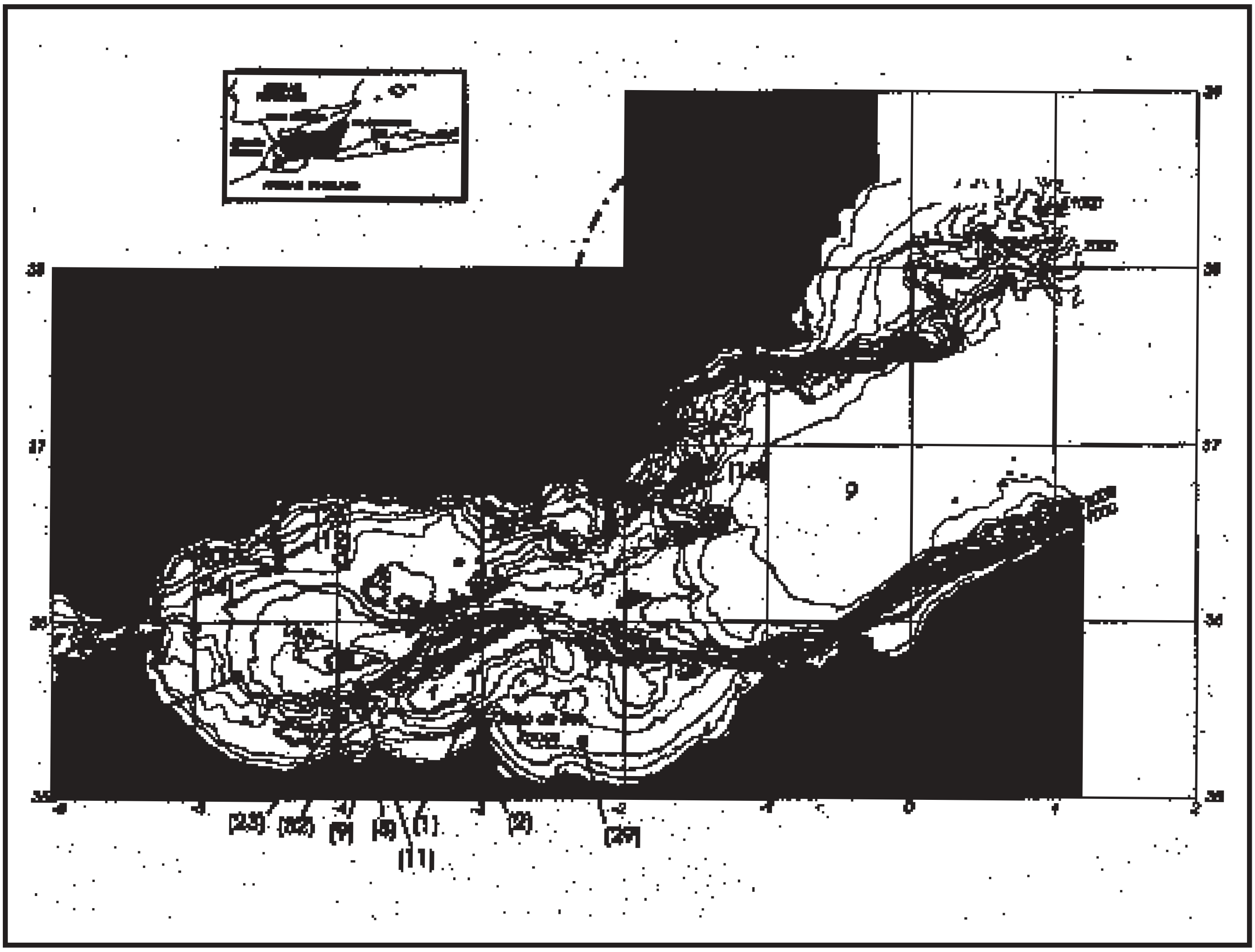


FIG. 1 - General view of the Alborán area and the selected focal mechanism solutions. [See table 5 and fig. 1a] (1. South Alborán Basin, 2. Alborán Ridge, 3. Alborán Channel, 4. Djibouti Bank, 5. Avenzoar Bank, 6. Maimonid Ridge, 7. Alborán Trough, 8. Golfo de Almería, 9. Algero-Provensal Basin, 10. Western Alborán Basin, 11. Xanem Bank, 12. Chella Bank).

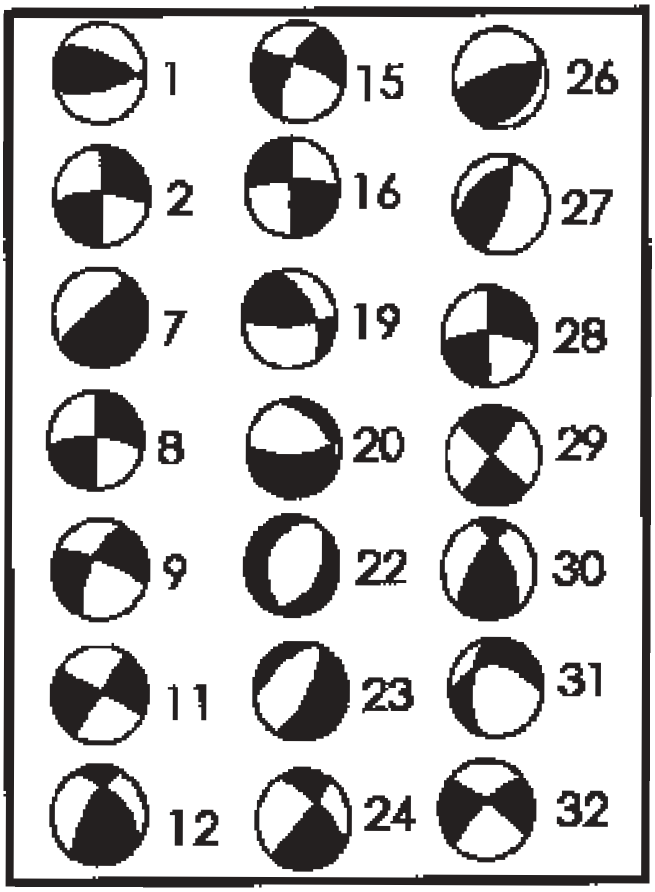


FIG. 1a - Representation of the focal mechanisms (lower hemisphere).

just the area around the island, began in the 70's. Among them are Berry & Knopoff (1967) and Vázquez & Vegas (1999).

The AS, a marine basin (~150 km wide and ~360 km long) of the Western Mediterranean Sea has an approximately latitudinal direction. It can be divided on the basis of isobaths from -500 m to -2.000 m into two differently shaped and sized basins (fig. 1). Both converge in a narrow zone near AI, this zone having a strong relief gradient in the southern part. The first basin (Western Alboran Basin) is on the western side with semicircular shape and extends from the SoG to the north of AI reaching depths of 1,0-1,5 km. The second basin (Algero-Provençal Basin) is much greater in size and volume of sediments and is located to the east of the mentioned island. This basin has an approximately triangular shape and reaches depths of up to –2,5 km. AI emerges in the southern part of the junction of both basins. There the bathymetric values are less than to –500 m over a currently submerged horst type continental sea structure with a marked NE trend.

The study is based on the bibliographical review and data collected during different stays on AI (years: 1978 and 2000) and on the authors' morphotectonic analysis of the Alboran region. The main objectives are to point out the geomorphological processes that, at present, operate on AI and to make a relief diagnosis.

GENERAL OVERVIEW OF THE TECTONIC SETTING AND SEISMICITY

We will first present briefly the most relevant characteristics of the geological and geophysical results of the study region and surroundings. This section is taken principally from the following sources: Álvarez-Marrón (1999), Bezzeghoud & Buforn (1999), Buforn & *alii* (1995), Calvert & *alii* (1997, 2000), Comas & *alii* (1992, 1995, 1999), Esteras & *alii* (2000), Fernández & *alii* (1998), González & *alii* (1994, 1998), Hatzfeld & *alii* (1993), Hayward & *alii* (1998), Keller & *alii* (1995), López-Casado & alii (2001), Meghraoui & *alii* (1996), Mezcua & Rueda (1997), Mezcua & *alii* (1996), Polyak & *alii* (1996), Ramdani & *alii* (1989), Reilly & *alii* (1992), Sanz de Galdeano (1990, 1996), Sousa Moreira & alii (1977), Torné & *alii*

FIG. 2 - Oblique aerial photograph of the Alborán Islet (1978).

(2000), Vissers & *alii* (1995), Watts & *alii* (1993), & Woodside & Maldonado (1992).

The Alpine-Mediterranean region is quite complicated from a geodynamic point of view. It evolved within the framework of convergent motion between the African and Eurasian plates (figs. 3a, b). The Betic and Rif Cordilleras, and the AS are related structures that make up the western end of the alpine orogen (fig. 4a). These cordilleras are the result of an intracontinental collision where thrust belts are characterized by multi-vergent low-angles (south, north and west) tectonic transportation. The Betics (south of the Iberian Peninsula = IP) can be divided into two major zones, the Internal (IZ) to the south and to the north the External, which itself is subdivided into the Subbetic zone and the Prebetic zone bordering the Hercynian Massif of the Iberian Meseta (fig. 4a). Present-day topography is closely linked to surface geology, which shows a clear structural orientation in E-W direction. There are significant altitudinal differences between the western and the eastern Betics, up to ~2,2 km and ~3,5 km, respectively. Analogue topography detects submerged relief in the AS, and the East Basin is found to be deeper than the Western Basin. The geodynamics of the Western Mediterranean region is still a matter of debate because up to now there has been not any good explanation as to why or how extensional basins (namely the AS, the Algero-Provençal Basin, the Tyrrhenian Sea and the Valencia Trough) began and developed during the Miocene within the convergent. Another main geological feature is the Alpine belt Maghrebine (Rifian-Kabyle) Chain in North Africa, which runs approximately E-W (fig. 4a). The Tell-Rif system is an orogen resulting from the opening and closing of an ocean followed by a continent-continent collision.

The AS lies at the westernmost end of the Mediterranean and is surrounded by the Betic, Rif, and Tell orogens, which join up across the Arc of Gibraltar (AoG). The age the oldest sediments indicates the AS probably began its development in the Early Miocene. The sediment infill is of marine type in origin (including up to the Pliocene), while the basement consists of continental type.

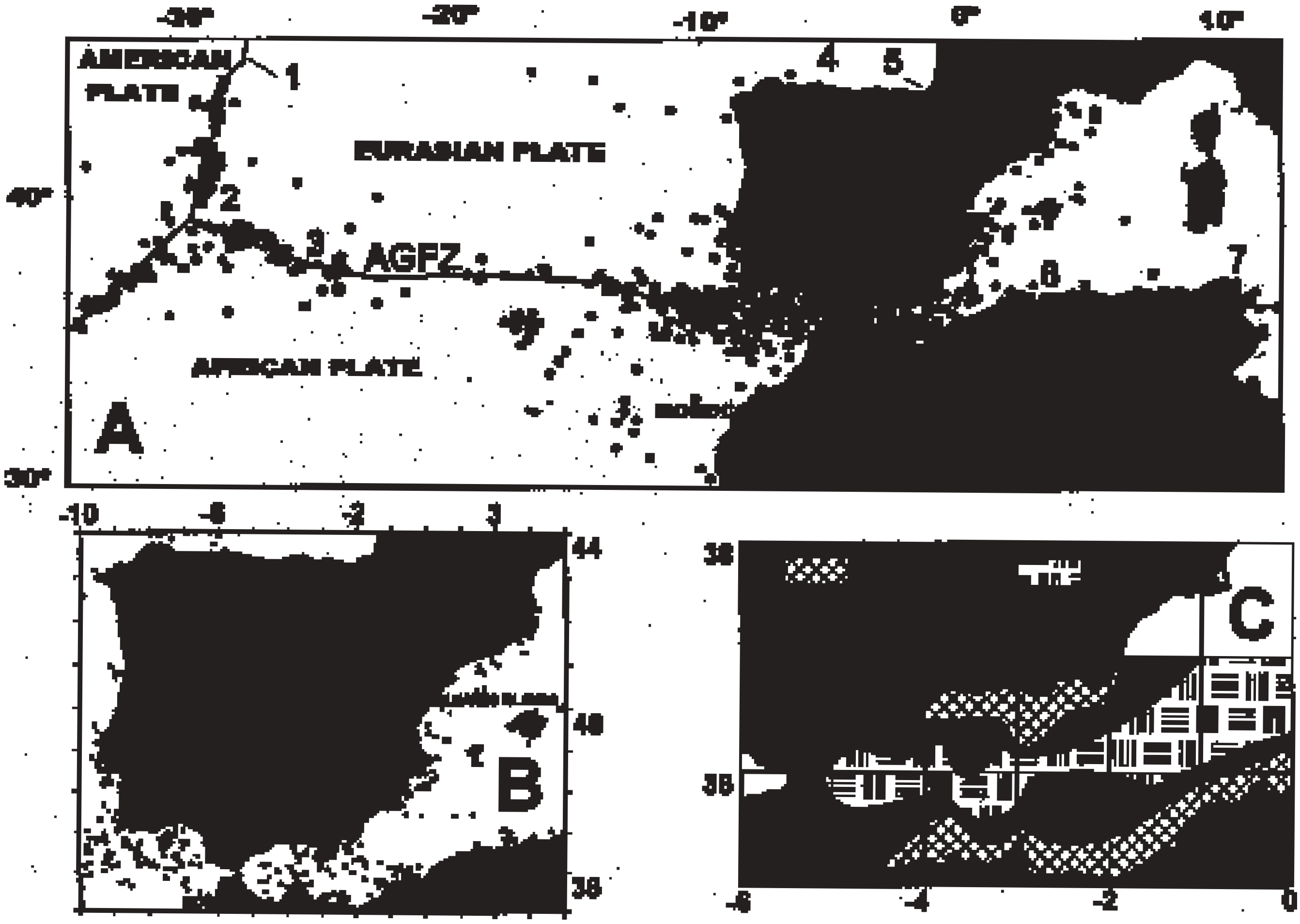
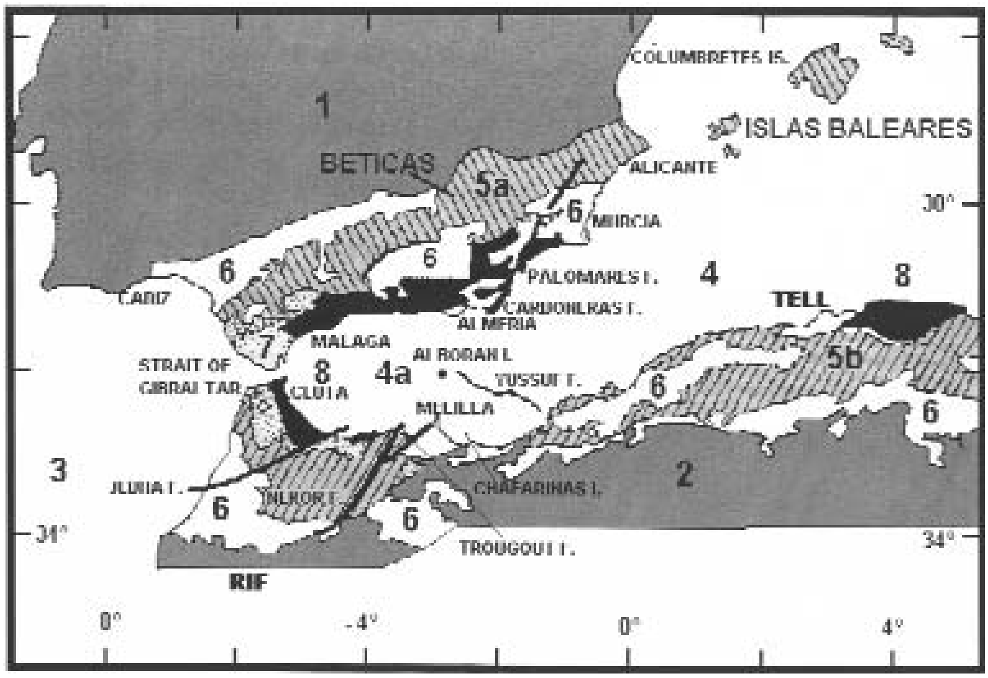


FIG. 3 - A) Scheme of the seismicity (1989-1996) and plates [epicentres = black circles, heavy black line = plate boundary, AGFZ = Azores-Gibraltar Fault Zone, 1 = Mid-Atlantic Ridge, 2 = Azores Triple Junction, 3 = Gloria fault, 4 = North Spanish Trough, 5 = Gulf of Biscay, 6 = Oran, 7 = Tunis]; B) Seismicity of the Iberian Peninsula and surroundings (1980-1996) [epicentres = white circles] ; C) Seismic activity map [A = high, B = middle, C = low].



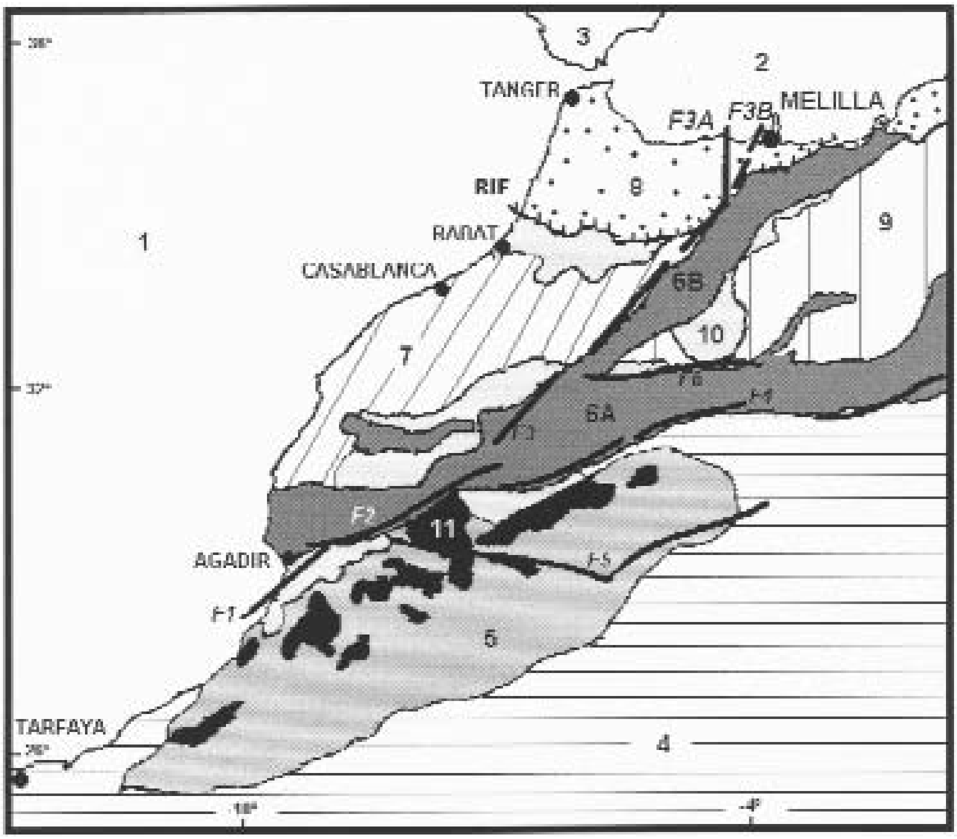


FIG. 4 - A) General geological framework [1. Iberian foreland, 2. African foreland, 3. Atlantic Ocean, 4. Algero-Provensal Basin, 4a. Western Alborán Basin, 5a. Iberian cover, 5b. Maghrebian cover, 6. Tertiary basin, 7. Flyschs trough units, 8. Alborán domain.]; B) Geological sketch of Morocco. [1. Atlantic Ocean, 2. Mediterranean Sea, 3. Iberian Peninsula, 4. Sahara Craton, 5. Anti-Atlas Mountains, 6A. High Atlas Mountains, 6B. Middle Atlas Mountains, 7. Moroccan Meseta, 8. Rif, 9. Orán Meseta, 10. Upper Cenozoic Basin, 11. Precambrian Basament, F1. Tarfaya fault, F2. Tizo n'Test fault, F3. Transalboran fault, F3a. Trougout fault, F3b. Nekor fault, F4. South Atlas fault system, F5. Great Anti-Atlas fault zone, F6. North Atlas fault system. Modified from Comas & *alii* (1999)].

Also, Miocene marine sediments are found in the intermountainous basins of the IZ of the Betic Cordillera. However, continental Plio-Quaternary sediments found in the basins of IZ seem to indicate that the AS and the Betic Cordillera started to split at the end of the Miocene. A thin continental crust up to 30 km thick underlies the Alboran Basin. The sea floor shows a system of horst and graben structures. High heat flow values and an anomalous low velocity mantle characterize the region. These factors create a pronounced West to East decrease in the lithosphere thickness from 60-85 km to 30-40 km, respectively. Up to now, there is no evidence of any oceanic crust. Seismic refraction studies of the Alboran Domain show a crust variation in N-S direction. The crust reaches depths of 38 km beneath the Betic Cordillera, 25 km on the Iberian coast, 15 km in the AS and 40 km under the Rif Cordillera. Offshore southern IP Free-Air gravity data show a structure of positive anomalies, but in the Western AS the data turns out to be negative. An elongated well-defined negative Bouguer gravity anomaly runs approximately along the Betic-Rif Mountains. The heat flow in AS is quite different from that of the IP (up to 80-90 mWm^{-2}) and differences are also noted between the two basins (Western and Eastern) with the values reaching 50-80 mWm^{-2} and 70-130 mWm^{-2}, respectively. This might suggest the existence of a younger oceanic lithosphere to the East according to well established thermal models (e.g., Parsons & Sclater, 1977).

Geochronological data obtained in volcanic rocks of the AI and Columbretes Islands (fig. 4a) suggested to different authors a link between them and the southeastern IP and northern Morocco. The Miocene evolution of the basins of eastern Morocco and southeastern Spain is linked to a SW-NE elongated shear zone across the AS. In the eastern part of the Betic Cordillera a large left-lateral NE-SW shear zone is recognized (i.e., Alhama de Murcia, Palomares, Carboneras, Serrata and Las Morenas) between Alicante and Almería, and in northern Africa the Jebha and Nekor faults are defined (fig. 4a). These faults in northern Morocco of undisputed importance are strike-slip faults. The Jebha fault, which strikes from N60E to N80E, is the southern boundary of the main part of the Rifian internal zone (RIZ). This fault displaces the northern part of the RIZ at least 50 km to the west with respect to the southern part. Geophysical data confirm the importance of the fault and indicate that it may extend WSW to the Atlantic coast (100 km north of Rabat) and ENE along the Alboran Ridge in the Mediterranean. The WSW projection of the Jebha fault does not seem to disrupt the Rifian external zone, which suggests that the final major movement on the Jebha fault affected only the RIZ. The Nekor fault is clearly exposed on the surface only for 100 km in the eastern Rif and separates the Cretaceous rocks of the Ketama unit to the northwest from the Miocene of the Adrar Azani massif to the southeast. Left-lateral, strike-slip displacement across the Nekor fault is estimated to be 50 km. The Nekor fault is a major feature, being nearly 700 km long. In the western Rif the Nekor fault is covered by pre-Rifian thrust sheets while, in the eastern Rif, it offsets the Aknoul thrust sheet.

Woodside & Maldonado (1992) pointed out that the structural and tectonic features in the Alboran Basin could be divided into four principal groups. Two zones of compressional tectonics lying in the north-central and south-central regions are in contact at the sea's midpoint (~36ºN, –03ºW), where the compressional stresses appear to be greatest. Their contact is marked by the intersection of two major fault systems [1) the southwestward extension of the Serrata fault zone and the northeastward prolongation of the Jebha fault system; 2) the west-northwest-east-southeast trending fault along the southern border of the Alboran Trough]. The other two regions split by these fault systems are the Western Alboran Basin and the Eastern Alboran Basin.

The Azores-Gibraltar active fault zone (AzGFZ) marks the western boundary between the African and Eurasian plates (fig. 3a). Many authors assume that these plates have been converging for the past 53 My. At the western end of this plate boundary, the relative plate motion is mainly considered divergent in correspondece to the Azores Triple Junction (AzTJ). At about –17ºW to the east of IP the AzGFZ is quite diffuse and suggests that the Hayes-Atlas fault constitutes the plate boundary (fig. 3a). A well-defined belt of seismic activity is observed between the AzTJ and the Gulf of *Cádiz* but is quite diffuse from the SoG to the east (fig. 3a). The AS and the Betic-Rif thrust belts are seismically active. According to Mezcua & Rueda (1997) there is only superficial seismicity in the area immediately around the AI. The seismicity level in the IP is not exceptional but it is significant in the southeastern localities of *Málaga, Adra* and *Almería* (table 1 and fig. 3b). In Alhoceima area (near of the Morocco coast) was reported an important historic earthquake (1848.07.08, I_0 = 8 {MSK}). Also near *Melilla* was reported an earthquake of the same intensity value in 1792.08.31. The largest earthquakes are in the Tell region [in Mascara area ocurred the two strongest historic earthquakes (I_0 = 10 {MSK}, 1819.03 and 1887.11.29)]. There is a meaningful cluster of instrumental epicenters in Africa to the SW of the AI. In table 2 is presented a selection of the main recent earthquakes occurred in the study region. However, the arrangement of those epicenters does not ensure the existence of faults. In tables 3 and 4, 7 recent seismic events registered by the Instituto Geográfico Nacional

TABLE 1 - Selection of historic earthquakes in the southeastern Iberian Peninsula

No.	Date	Intensity (MSK)	Coordinates Lat	Lon	Locality
1	1522.09.22	9	36,90 N	– 02,50 W	Almería
2	1579.01.30	8	37,70 N	– 01,70 W	Lorca (Murcia)
3	1674.08.28	8	37,70 N	– 01,70 W	Lorca (Murcia)
4	1804.08.25	9	36,80 N	– 02,80 W	Dalias (Almería)
5	1819.12.20	7	37,70 N	– 01,60 W	Lorca (Murcia)

TABLE 2 - Main earthquakes recently occurred in the study region

No.	Date	Magnitude	Coordinates Lat	Lon	h (km)	Locality
1	1910.06.16	Mb = 6,3	36,70 N	– 03,10 W	10	Adra
2	1964.03.15	Ms = 6,2	36,20 N	– 07,60 W	12	Gulf of Cádiz
3	1969.02.28	Ms = 8,0	36,00 N	– 10,40 W	29	Gorringe Bank
4	1980.10.10	Ms = 7,3	36,20 N	+ 01,30 E	5	El-Asnam
5	1994.05.26	Mw = 5,8	35,30 N	– 04,03 W	7	Alhoceima
6	1994.08.18	Mw = 5,7	35,52 N	– 00,11 W	4,5	Mascara

TABLE 3 - Earthquakes of Cabo de San Antonio - Islas Baleares (Instituto Geográfico Nacional, 2003)

No.	Date	Time	Lat. N	Lon. E	Mb
1	26.02.03	03:32	42,20	+ 02,28	3,8
2		09:30	42,27	+ 02,08	2,3
3		22:55	42,25	+ 02,17	2,7
4	27.02.03	00:16	42,13	+ 02,28	2,9
5		00:26	42,23	+ 02,22	2,4
6		01:31	42,27	+ 02,23	2,5
7		22:08	42,27	+ 02,18	2,3

TABLE 4 - Earthquakes of Western of the Alborán Islet (Instituto Geográfico Nacional, 2003)

No.	Date	Time	Lat. N	Lon. W	m_b
1	18.02.03	13:09	35,84	– 03,53	4,7
2		17:13	35,97	– 03,65	2,2
3		17:51	36,07	– 03,36	2,4
4		18:35	35,87	– 03,56	2,0
5		18:43	35,96	– 03,34	2,2
6		18:54	36,17	– 03,49	1,9
7		20:12	35,85	– 03,54	3,2
8		20:29	35,92	– 03,54	2,3
9		20:40	35,83	– 03,59	2,3
10		23:21	36,00	– 03,55	2,4
11		21:13	36,05	– 03,37	2,2
12	19.02.03	00:33	35,83	– 03,56	3,9
13		01:23	36,03	– 03,18	2,0
14		20:33	35,94	– 03,22	2,3
15	20.02.03	22:42	35,82	– 03,25	2,4
16	21.02.03	00:04	35,89	– 03,50	2,5
17		03:09	35,80	– 03,38	2,0
18	22.02.03	04:31	35,84	– 03,62	2,9
19		01:54	35,91	– 03,49	2,3
20		10:24	35,87	– 03,55	2,9
21		11:07	35,86	– 03,58	3,8
22		11:36	35,88	– 03,41	2,5
23		11:52	35,90	– 03,45	2,6
24	23.02.03	12:26	35,72	– 03,44	2,3
25	26.02.03	16:00	35,70	– 03,52	2,5
26	02.03.03	11:04	35,81	– 03,35	2,9
27	03.03.03	20:55	35,96	– 02,99	2,4

(2003) for the maritime zone of *Cabo de San Antonio-Islas Baleares* and 26 for the west of the AI. Both groups of epicentres are concentrated in circles with diameter inferior to 10 km. The *Cabo de San Antonio-Islas Baleares* group can be associated with a NE lineament (Cotilla & Córdoba, 2003). The group of the west of the AI is in an important submarine relief contrast zone. Using the data from the Instituto Geográfico Nacional (1989-1996) maps of epicentres density and seismic activity have been drawn following the methodology of Riznichenko (1976). On the maps it can be appreciated that the greater activity zones are distributed along the north / south continental edges and the zone of lowest values are in the AI zone (fig. 3c).

Table 5 shows selected solutions of focal mechanisms for the AS. In figs. 1 and 1a the data shows the heterogeneity of focal mechanisms in the region, though there is certain regularity in the deep earthquakes. It is possible to assume there is a certain geodynamic differentiation in each segment. All the focal mechanisms of deep events (h> 60 km), eight in total, are to the west of the AI. There is a cluster (No. 7, 12, 20, 24, 26, 27, 30) near *Málaga.* In Morocco, there are ten events with focal mechanisms with a compressional strike-slip component. In general the P-axes show an N-S (up to NW-SE) orientation according to the plates convergence (African / Iberian) direction but related in the surroundings (AS and Betic-Morocco Mountains) with E-W to NE-SW horizontal tension axis.

GEOMORPHOLOGY

AI forms part of the Alboran Submarine Mountain Chain, which extends along the ocean floor for approximately 200 km and is also known as the Alboran Ridge (fig. 1). This structure emerges at AI. The Alboran Trough is a transversal tectonic depression at the end of the Alboran Ridge. Both structures are the most important linear seafloor relief elements in the area. The Alboran Ridge is situated between three basins: West, East and South. This volcanic structure is characterized by a transpresional fracture system of the Upper Miocene in a range of NE-SW to E-W directions. This distensive process between the Eurasian and African plates created the Alboran Basin. It is an example of Cenozoic volcanism in the Mediterranean region. Evidence of this volcanism, of calcoalkaline and alkaline types, from the Tertiary and of the Quaternary, respectively, is found, as we said before, also in the bordering continental zones, south of the IP and north of Morocco. All results of drilling in the Alboran Basin and on the island find Neogene andesitic rocks made of pyroclastic materials of subaereal emission that are currently organized in monoclinal layers of strike 65°-85° and dipping 20º-45º to the north. On the IP (*Sierra de Gata*) there are materials of the composition and age hitherto mentioned. The current upper marine surface, of the Holocene, is built on volcanic material without differentiation. On top of this material an eolic mantle of the same age is found. As the substrate of the island is of volcanic origin (tuff and andesite) the insertion of pebbles in the tuffs is frequent.

Table 5 - Shocks with focal mechanisms solutions

No.	Date	Time H	Time M	Coordinates Lat	Coordinates Lon	h (km)	mb	Represented in fig. 1	Reference
1	1951.05.19	22	21	35,43 N	– 03,32 W	19	5,4	X	Vidal (1986)
2	1959.08.23	22	21	35,51 N	– 03,23 W	20	5,4	X	Bezzeghoud and Buforn (1999)
3	1960.02.21	23	40	30,45 N	– 02,62 W	–	6,0		UdIas & *alii* (1989)
4	1963.06.20	19	47	34,75 N	– 03,87 W	60	4,5		Vidal (1986)
5	1967.08.28	21	15	31,30 N	– 06,18 W	–	4,6		Medina and Cherkaoui (1992)
6	1968.01.22	07	19	35,14 N	– 05,83 W	40	4,1		Mezcuaand Rueda (1997)
7	1968.02.13	18	57	36,55 N	– 04,59 W	97	4,3	X	Coca and Mom (1994)
8	1968.04.17	09	12	35,29 N	– 03,38 W	22	5,0	X	Vidal (1986)
9	1968.10.30	11	41	35,29 N	– 03,46 W	05	4,6	X	Coca and Mom (1994)
10	1973.04.29	14	37	34,56 N	– 03,99 W	10	4,6		Vidal (1986)
11	1974.07.14	02	55	35,56 N	– 03,76 W	01	4,4	X	Hatzfeldand Frogneux (1980)
12	1975.08.07	15	30	36,48 N	– 04,53 W	104	5,2	X	Grimison and Chen (1986)
13	1979.01.17	17	43	33,40 N	– 05,40 W	–	4,5		Medina and Cherkaoui (1992)
14	1979.06.16	13	51	32,80 N	– 05,30 W	–	4,0		Medina and Cherkaoui (1992)
15	1980.06.22	23	18	36,01 N	– 05,35 W	82	4,7	X	Medina and Cherkaoui (1992)
16	11983.03.20	06	59	36,57 N	– 02,16 W	19	4,4	X	Coca and Mom (1994)
17	1983.11.24	20	55	34,77 N	– 04,46 W	40	4,2		Bezzeghoud and Mom (1999)
18	1985.01.24	17	59	36,18 N	– 03,01 W	16	3,5		Vidal (1986)
19	1986.01.28	20	01	32,12 N	– 05,43 W	05	4,9	X	Medina and Cherkaoui (1992)
20	1986.05.13	00	19	36,67 N	– 04,48 W	84	4,3	X	Bufornet & *alii* (1988)
21	1987.07.23	11	57	35,30 N	– 05,91 W	100	3,9		Mom & *alii* (1991a)
22	1987.12.09	15	40	35,42 N	– 03,88 W	10	4,3		Instituto Geográfico Nacional (1990)
23	1988.10.05	00	41	35,47 N	– 03,99 W	11	4,0	X	Instituto Geográfico Nacional (1991)
24	1988.12.12	06	40	36,34 N	– 04,62 W	82	4,5	X	Instituto Geográfico Nacional (1991)
25	1990.04.13	22	17	35,65 N	– 04,83 W	75	3,9		Instituto Geográfico Nacional (1992)
26	1990.05.02	16	40	36,54 N	– 04,53 W	85	4,2	X	Instituto Geográfico Nacional (1992)
27	1992.12.21	11	10	36,60 N	– 04,51 W	39	3,4	X	Instituto Geográfico Nacional (1995)
28	1993.01.04	09	19	36,58 N	– 02,60 W	04	3,7	X	Mezcuaand Rueda (1997)
29	1993.05.23	07	41	35,27 N	– 02,43 W	06	5,4	X	Mezcuaand Rueda (1997)
30	1993.11.09	00	22	36,35 N	– 04,48 W	59	3,8	X	Mezcuaand Rueda (1997)
31	1994.01.04	08	03	36,56 N	– 02,80 W	02	4,9	X	Rueda & *alii* (1996)
32	1994.05.26	08	27	35,30 N	– 04,03 W	03	5,7	X	Mezcua and Rueda (1997)
33	1994.12.25	12	04	36,06 N	– 03,06 W	02	3,3		Herraiz & *alii* (1998)

The *Isla de las Nubes* (fig. 5a) lies just 100 m east of AI, and is separated from AI by the *Canal de las Morenas* (fig. 5a). The rocky outcrop has an approximate altitude of 8-10 m. Shelf that surrounds both islands is very narrow (12-22 m) and is much wider in the northern part. The highest point is in the area around the lighthouse (*«El Faro»*). The slopes vary from 0° to 3° on the surface and from 75° to 90° in the edges. The southern half of the island is higher ground. On AI there are some man-made elements, such as a lighthouse, a heliport, two piers (*Muelle de Poniente* and *Muelle de Levante*), a cemetery, and three small houses. The very large influence of the combined activity of the wind and the salt water can be appreciated on all of these structures. There is no aquifer with drinkable water in the subsurface.

It is recognized that morphostructural and hydrodynamic factors influence the shape, size and evolution of a continental platform. On this basis, the south of the IP has no relation with AI. In the other hand, it would most appropriate to call Alboran Island an «isle» (Alboran Islet = Ai) (Bates & Jackson, 1987).

Morphotectonic analysis

It is well known that the AzGFZ can be divided into at least four sectors. It is highly seismic, but its seismicity is of a moderate magnitude and a relatively low slip rate. In the first sector (Azores) the predominant focal mechanism is normal-transform faulting. The second sector (Gloria fault [approximately from –24ºW to –20ºW]) has an approximately E-W strike and a very low level of seismicity. The third, which is shorter than sectors one and two, has a more irregular E-W orientation. In this sector some strong earthquakes have occurred, and the focal mechanisms are right lateral strike-slip. The fourth sector alternatively changes orientation from NW-SE to NE-SW and is clearly associated with some significant fractures and faults in the IP. The geometric and seismic characteristics of this sector support the hypothesis that oblique plate convergence exists here. It has been proposed that the 01.11.1755 Lisbon earthquake occurred in this sector (Zitellini & *alii*, 2001). The predominant focal mechanisms are reverse faulting. A wide transpression zone begins at the edge of this sector

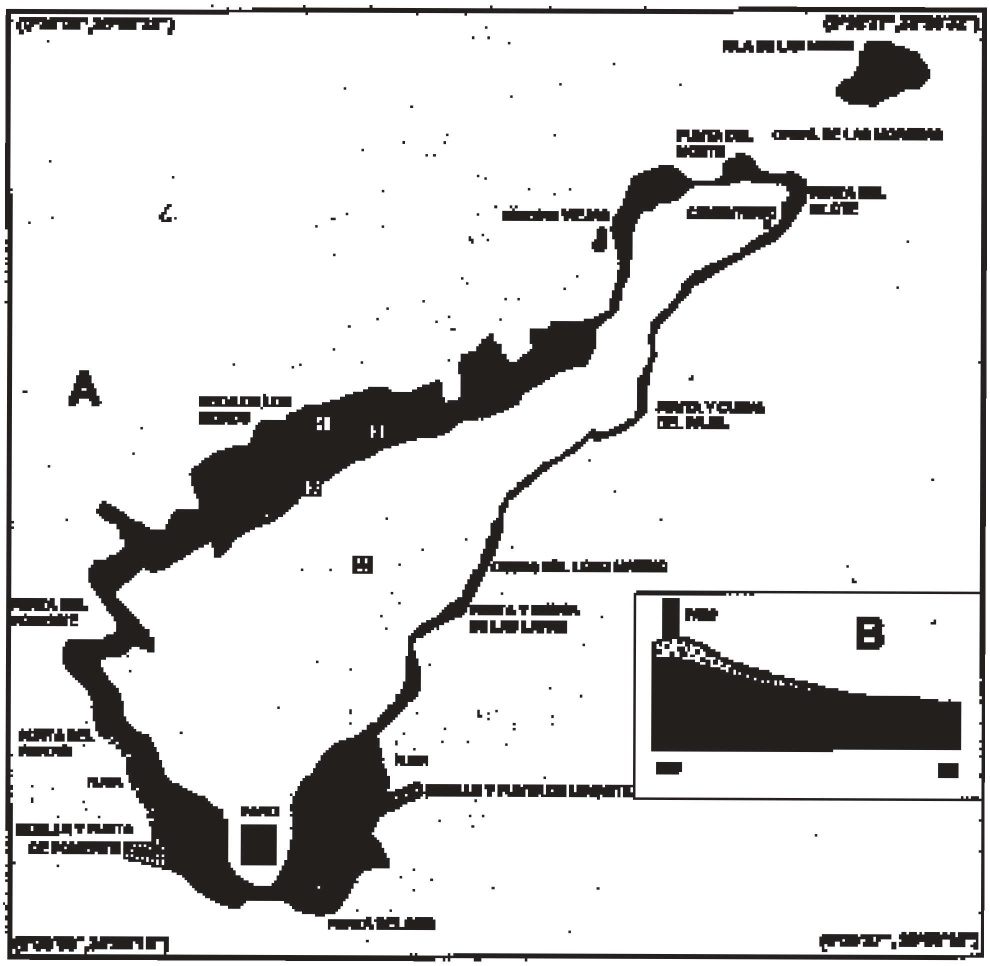


FIG. 5 - A) Schematic geological framework of the Alborán Islet. [1. current marine surface developed over undifferentiated volcanic (Holocene); 2. volcanic rocks; 3. marine terrace (Pleistocene); 4. eolic mantle; 5. pyroclatic materials (and andesitic basalt)]; B) Diagrammatic section through the coasts of the Alborán Islet [1. sand, 2. volcanic conglomerate, 3. tuff with andesite].

and continues to the east to the Tell Atlas Mountains. The associated tectonic regime includes a combination of strike-slip and normal faulting in the AS and Betic-Rif Mountains and reverse faulting in the Tell Atlas System. From this perspective, taking into account the proposal of Rantsman (1979), we can develop a morphotectonic differentiation of the region. From the neotectonic point of view, this is essential in order to establish a foundation for geophysical research (Aleksevskaya & *alii*, 1977).

Morphostructural study and its methods (Guerasimov, 1946; Rantsman, 1979) differ according to the type of region, continental or marine, where research is carried out. In Cotilla & *alii* (1991) and Cotilla & Córdoba (2003) there is an exhaustive discussion of this topic. An analysis of its application to marine research can be found in Cotilla & *alii* (1991) and Hernández & *alii* (1988). The methodology permits to differentiate morphostructures in terms of structures in the Earth's crust (or its upper part) that are expressed in the present day topographic releif. Under this perspective we are able to define three main categories of morphostructures: 1) territorial units (megablock, macroblock, mesoblock, block, microblock and nanoblock); 2) morpholineaments (linear mobile-active limits between the territorial units); 3) knots (intersections) of lineaments. As a rule the knots are wider than the lineaments. Megablock is the largest tectonic unit of a region with the same geodynamic behaviour in the current stage of geological development. Macroblocks inside the megablock are differentiated by the type of orogenesis and/or by large tectonic features. Mesoblocks inside macroblocks differ either by the dominant type of relief or by the average parameters of the relief (such as height of peaks, dominant strikes, relative area occupied by basins and ranges, etc.) or by the pattern of the main elements of the relief. Blocks inside mesoblocks differ in neotectonic history. In Alekseevskaya & *alii* (1977) there is a description of these concepts. Cotilla & Córdoba (2003) applied it to the IP.

The SoG possesses an important oceanographic singularity due to its location in the water confluence zone of the Atlantic Ocean (from the west) and of the Mediterranean Sea (from the east). The results of the geological and geophysical research have determined that with the exception of the Spanish platform, the marine floor in the SoG presents a very rough and irregular topography. The outcroppings of flysch and their structure have been found on both sides of the SoG. The submarine platforms of the north coast of Africa and of the southern IP are wider to the west of the SoG than to the east. The *Islas Chafarinas* are found on the northern African platform and on the platform of the southern and southeastern IP we find the *Islas de Nueva Tabarca* and the *Islas Columbretes*, respectively. Evidently they have a direct structural relationship with Africa and the IP that does not exist in the case of the Ai. The strongest gradients of the submarine relief are only evident in connection with the Western Alboran Basin. Taking into account the results of González & *alii* (1998) it is possible to assert that to the west of the SoG the morphotectonic contrasts found in the zone of Alboran do not exist, despite the greater depth.

The AoG is the result of the westward migration of the Alboran block in the *Subibérico* and *Magrebí* Domains in the Lower-Middle Miocene. The so-called *Umbral de Camarinal* has been interpreted as a residual relief of the acretional prism of the complex of flyschs. The *Umbral de Camarinal* of the SoG connects the Spanish and Moroccan platforms with an approximately N-S strike. It represents a topographic high point in relationship to the adjacent areas. To both flanks of the *Umbral* strong banks have developed that descend toward the depressions of the *Hoyas de Levante* and *de Poniente*. The depths are of more than –500 m in the eastern zone (*Hoya de Levante*) and –630 m to the west (*Hoya de Poniente*). At greater distance the depths are greater. The shallowest bottoms of the *Umbral de Camarinal* are –90 m (*Monte de Seco*) in the north sector, –150 m (*Monte Tartesos*) in the central part and –250 m (*Cresta de* Kmara) in the southern part. In the central part the deepest values are more than –300 m. *Monte Hércules* is located in the *Cresta Central* of the Strait with depths of –450 m to –650 m found along an E-W strike. Also in the Gulf of *Cádiz* exists a recent uplifted structural zone (related with a reverse fault) (Gracia & *alii,* 2000). Then, this region is quite different of Western Alboran Basin.

In regional cartography it can be appreciated that the principal axis of *the Islas Baleares* has approximately the same orientation as the axis of the Alboran Ridge. However, the principal faults of the southeastern IP do not follow this pattern and cut through the Balearic axis. Neither the axis of the submarine scarp nor the principal axis of the marine structures of the Western Alboran Basin have the strike of the faults of the southeast of the IP, but rather coincide with the axis of the Eastern Basin. The morphology of the submarine relief of the N-S segment (*Golfo de Almería-Islas Chafarinas*) is quite different from that found in its immediate surroundings. In this region there is a confluence of the structural directions previously mentioned (fig. 1). Also we have determined that there is a sharp inflection of the principal watershed of the IP, located in northern *Almería* (fig. 1). This is approximately along the line of longitude –3ºW, precisely in the same tectonic band as the great contrasts on AS. In an analogous way the greatest tilting of the IP is in the eastern part of this band.

The most intense tectonic deformation in our study area is found in the central part of the AS where the bathymetric relief shows the greatest contrasts (fig. 1). Also in the immediancy of this area the heat flow distribution shows a remarkable lateral difference. The Alboran Ridge itself is truncated along its northern flank by a major fault escarpment extending roughly west-northwest/east-southeast. This fault is believed to have a substantial reverse component. The Djibouti Bank and the Alboran Ridge are elevated along opposing reverse faults with respect to the intervening Alboran Channel (fig. 1). It is known that northeast-southwest striking reverse faults developed within existing wrench zones when the axis of compression swung from roughly north-south to northwest-southeast. Nevertheless, there are no reverse and thrust focal mechanisms. Like other authors we consider the Alboran Ridge to be defined on three sides by faults. The northwest flank has at least five bathymetric steps, which could reveal the existence of vertical movement along the fault system. Over a distance of 20-30 km nearly –1,5 km of sea-floor relief has developed within different subparallel zones of closely spaced faults with their own smaller wrenches and throws.

The Atlas system (Morocco, Algeria, and Tunisia) constitutes an important morphologic barrier on the fringes of the Sahara platform (figs. 4a, b). Its structural style changes along the strike from a thick-skinned style in Morocco to a thin-skinned one in Algeria and Tunisia. The position relative to the Tell-Rif system is also different in eastern Algeria and Tunisia where the two systems are adjacent and in western Algeria and Morocco where they are separated by large rigid cores (Moroccan Meseta and Algerian High Plateaux). North Africa can be divided into three main structural domains: the Sahara Domain, the Atlas Mountains, and the Tell-Rif system fringing the Mediterranean Sea (figs. 4a, b). The Atlas build-up occurred everywhere during two main phases of late Eocene and Pleistocene-Lower Quaternary age, respectively. The Atlas Mountains (i.e., Middle and High Atlas in Morocco, Saharan Atlas in western Algeria, Aures in eastern Algeria and Tunisian Atlas in Tunisia) were uplifted during the Cenozoic. The Atlas Mountains was developed along zones of crust weakness from rifting episodes associated with the opening of both Atlantic and Tethyan oceans during Late Triassic to Early Liassic times. The highest peak (Jebel Toubkal) is situated in Morocco and climbs to 4.165 m. From this point and laterally the altitude of the Atlas decreases rapidly westward to the Atlantic and gently eastward to the Hodna basin. From the Hodna to the Gulf of Sirt the same lateral asymmetry is observed: the highest peak (Jebel Chelia, 2.328 m) is located very close to the Hodna. Compared to the Atlas, the Tell-Rif appears as a domain of relatively moderate altitude: maximum 2.500 m in the central Rif and Great Kabyle. In the Western Sahara, the Anti-Atlas is an elevated region (up to 2.000 m) situated immediately in front of the Atlas Mountains.

Regional geomorphic analysis, employing topographic (Dirección General del Instituto Geográfico y Catastral y el Servicio Geográfico del Ejército, 1954; Ministerio de Defensa, 1997; Servicio Geográfico del Ejército, 1999), magnetic (Ardizone & *alii*, 1989), morphologic, geological (Instituto Español de Oceanografía, 1983; Instituto Geológico y Minero de España, 1977, 1980, 1983, 1987; Instituto Tecnológico y Geominero de España, 1989; Choubert & *alii*, 1955), gravimetric (Mezcua & *alii*, 1996), seismotectonic (Ait Brahim & *alii*, 1987; Instituto Geográfico Nacional, 1992a) and bathymetric (Instituto Hidrográfico de la Marina, 1992, 2000a, 2000b, 2001; Instituto Geográfico Nacional, 1991b; IOC-UNESCO, 1981) maps, aerial photographs (Ministerio de Defensa de España, 1949, 1978, 1990) and field studies show that the morphology of the Ai can be linked to lateral variations in the geometry and tectonics of the Eurasian and African plate boundary zone. We detected significant differences in the tectonic style between the onshore and offshore geology in some sectors of southwestern Mediterranean region. In the AS the sedimentary beds that filled the basins are undeformed whereas the coeval subaerial layers are tectonized. The observed structures and inferred tectonics in the AS are apparently a continuation those observed as far north in southeastern Spain as *Alicante*. This could represent a common response within a broad deformation zone to the continuous collision of the African and Eurasian (Iberian) plates. The structure of the east central AS presents similarities with the region of the Neogene basins of *Hinojar* and *Mazarrón*. Off eastern Spain extensional tectonics have a different orientation and are probably older than the deformation that occurred onshore.

Applying the mentioned before morphostructural methodology to the marine region between Africa and the IP we can say that it is a depressed and active megablock (fig. 6). The megablock can be divided into three macroblocks (M1 = Alboran, M2 = Argelo-Provençal, M3 = Balear) which border each other and interact at their edges by morpholineaments. Each one of these territorial units is

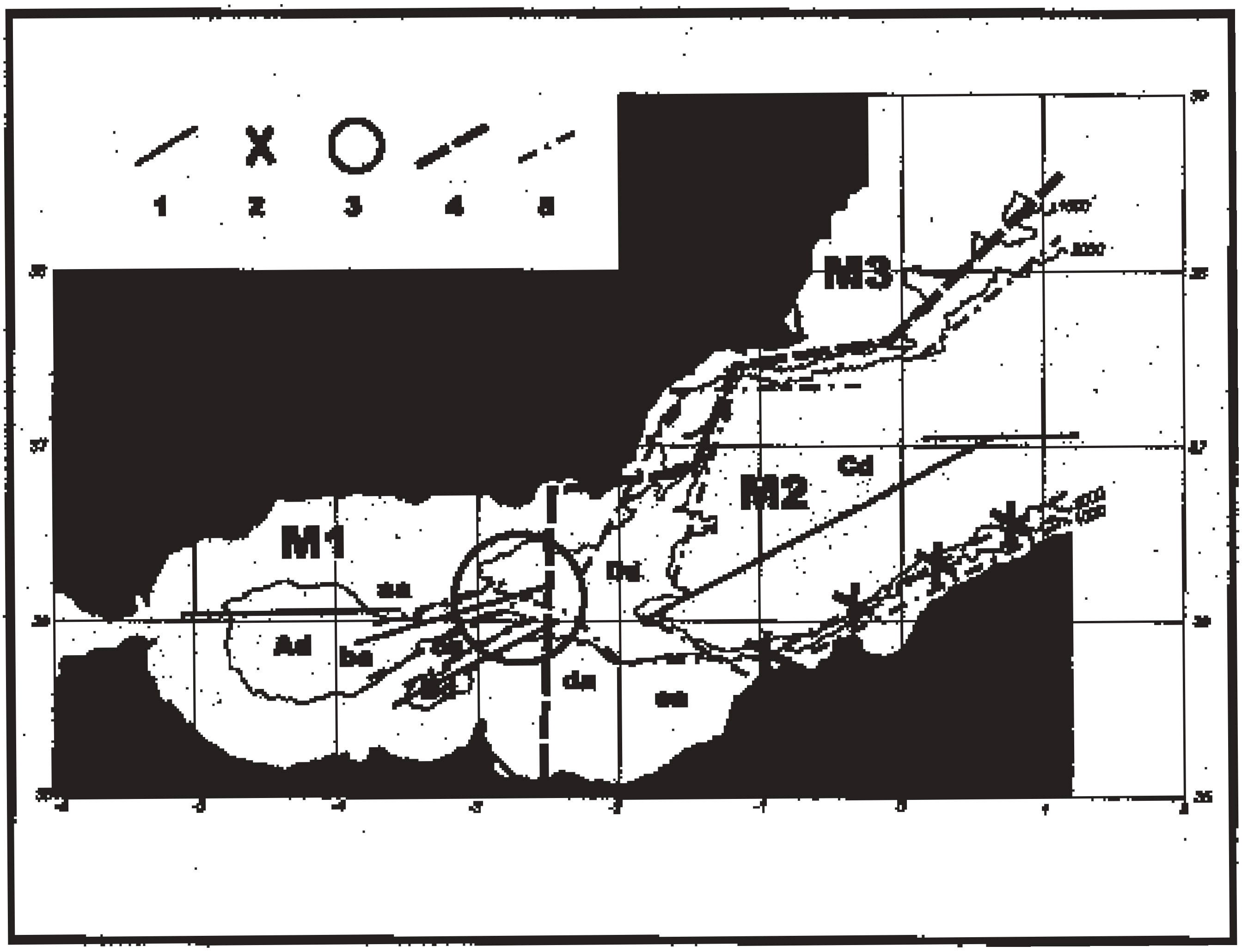


FIG. 6 - Morphotectonic scheme of the Alborán area and surrounding. [(M = Macroblock: 1. Alborán, 2. Argelo-Provensal, 3. Balear). (Downtrow Mesoblocks = Ad {Western Alborán Basin}, Bd {South Alborán Basin}, Cd {Eastern Alborán Basin}, Dd {Central Alborán Basin}). (Uplifting Mesoblocks = aa {Djibouiti Bank}, ba {Alborán Channel}, ca {Alborán Ridge}, da {Provensal Bank}, ea {L'Alidade Bank}). 1. main axis of structures, 2. strong relief gradient, 3. significant morphotectonic area, 4. boundary of macroblocks, 5. main scarp's alignement].

subdivided into mesoblocks (i.e., M1 in five [Ad, Bd, aa, ba, ca], M2 in four [Cd, Dd, da, ea]). Next, these units are split into blocks, not represented in fig. 6. The blocks are further divided into microblocks and nanoblocks, Ai forming part of this group.

We carried out extensive and intense fieldwork in the southeastern IP and in northern Morocco because of their strong geological similarities with the Alboran Basin. The field methods applied were the microgeomorphic studies and structural geology with the help of aerial photos and satellite images. We used principally the outcrop conditions of remnant surface faulting. The main objectives were to verify: 1) the strike-slip fault system recognized and proposed by other authors (figs. 4a, 7); 2) our morphotectonic classification. The results indicate that: 1) a range of geomorphologic evidence and geological indicators, including southwest-northeast oriented wrenches, marine terraces, uplifted notches, and elevated, wavy cuts and regional uplift are located in the surroundings of the AS, whereas on Ai they do not exist; 2) Nekor and Jebha faults are not active; 3) the Alhoceima area (Morocco) is active associate to Tougout fault; 4) the Tell area (northern of Algeria) is very active; 5) *Alhama de Murcia* and *Palomares* fault system is active and relate to regional tilting (block) processes; 6) the *Cabo de San Antonio-Islas Baleares* morpholineament is active; 7) the contact area of the Western Alboran Basin-Djibouiti Bank-Alboran Channel blocks can be associated with a recent cluster of seismicity; 8) the Alboran Ridge appears to be one of the most significant features in the AS. It cuts the marine structure obliquely in a northeast-southwest direction. The ridge becomes shallower towards its northeast end in the central AS, where it is exposed as Ai, the only island in this sea. There is greater seismic activity in the northwestern part of the ridge. Also the most seismically active deformation seems to be located in the continental lithosphere. In the Western Alboran Basin another small and elevated structure of the submarine relief also exists, but it does not approach the surface; 9) from the morphotectonic point of view Ai is an emerged nanoblock belonging to a submarine mesostructure of horst type and continental crust transversing the megastructure of the Alboran Basin (fig. 6). This hierarchic classification reaffirms the geological denomination of Ai and its contemporary tectonic situation.

Exogenous processes

Bates & Jackson (1987) define denudation as the sum of the processes that result in the wearing away or the progressive lowering of the Earth's surface by various natural

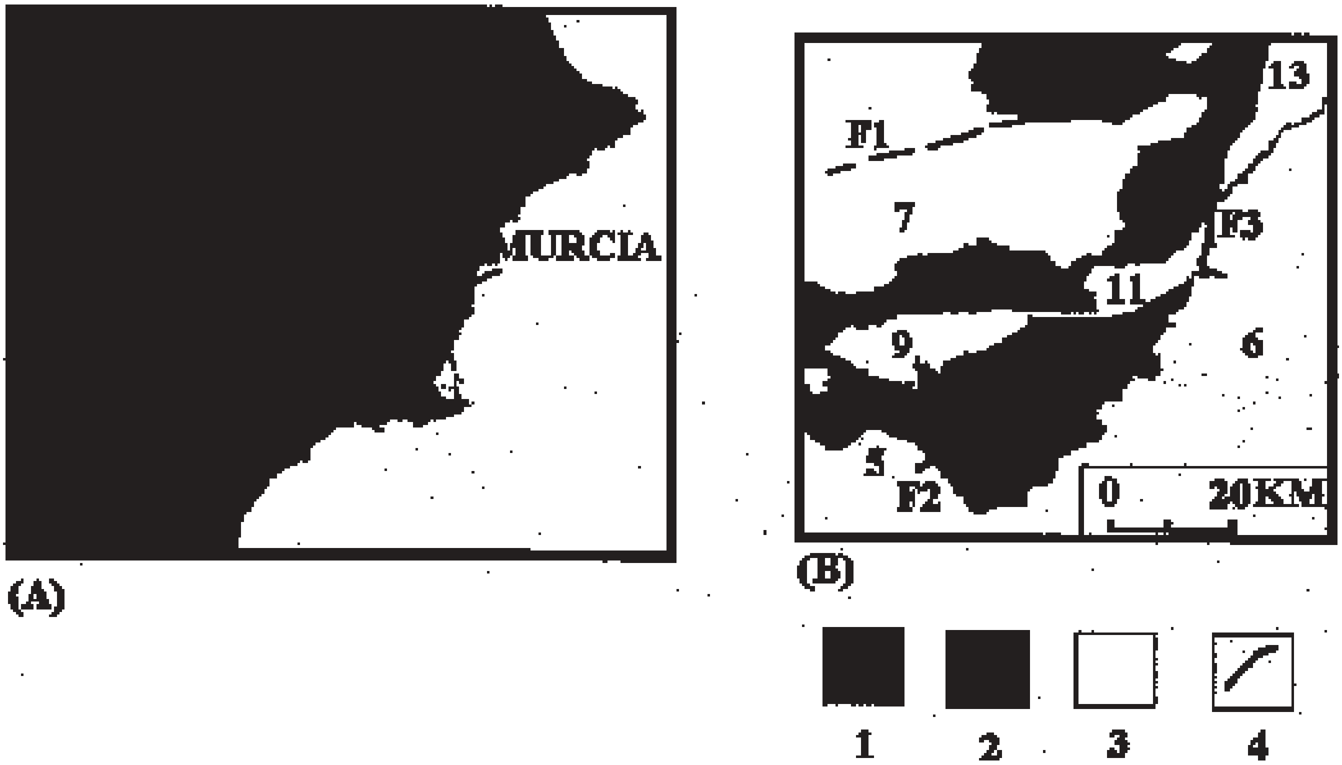


FIG. 7 - Geological sketch of part of the Betic Internal Zone. A) Studied faults in the Iberian Peninsula; B) Detail of the studied area (1. Tortonian-Messinian volcanic rocks, 2. Neogene basin, 3. Pre-Neogene basement, 4. Sinistral strike-slip fault [F1. Alhama de Murcia, F2. Carbonera, F3. Palomares], 5. Golfo de Almería, 6. Mediterranean Sea, 7. Sierra de los Filabres, 8. Sorbas Basin, 9. Sierra Alhamilla, 10. Nijar Basin, 11. Sierra Cabrera, 12. Vera Basin, 13. Sierra Almagrera, 14. Huercal-Overa Basin).

agents, which include weathering, erosion, mass wasting and transportation, as well as the combined destructive effects of such process. The term is wider in its scope than erosion. This is the process that we believe acts upon the surface of the islet.

It is well known that a set of external processes contributes to produce a landscape. The landforms of Ai are geologically young. The landforms represent merely a stage in a long and ongoing process. Frequently, other agents, not necessarily climatic, intervene before meteorological events can have their effect. The initiation of gullying is an obvious and widespread example. On the other hand, the Ai is uncultivated land incapable of producing anything. Nevertheless, Spanish ecologists designed a network of paths to preserve the autochthonous vegetation. It is well documented that the rates of geomorphic processes vary enormously (cm/10^3 years - 40 m/s) and vary in intensity from region to region in connection with such factors as climate, relief, lithology, structure, and vegetation. Among the most important processes through which rock masses are mechanically broken down or disintegrated are thermal expansion and contraction. Considering the enormous amount of solar energy available in the Mediterranean region to hasten geomorphic processes, eolian factors and landscape should have a significant cause and effect relationship. However, the direct effectiveness of eolian processes is rated quite low, much less than rivers and wind driven waves. Taking into account the very low density of the air it is easily understood that the wind is a small agent of geomorphic changes. Nevertheless, in Ai wind action is quite important.

Geologically, Ai is an emerged nanoblock (fig. 5a), elongated in a latitudinal direction due to prevailing abrasive-denudative processes, combined eolic-marine actions being the principal factors in relief modification. On the surface of the islet, the results of these processes are noted especially along the coastal edges but also in man-made structures (fig. 8). However, there are other factors operating in the geomorphologic transformation, the three most important being: physical weathering (existence of a pronounced day-night thermal pendulum), chemical-organic weathering (birds and their wastes) and man-made alterations (destruction of the profile of the shoreline). How these combined processes shape the denuded surface can be perfectly observed in Ai (fig. 8). We must point out that it is very difficult to isolate the contribution of any of these parameters.

It has been determined that the islet surface has, in spite of its very recognizable altitudinal homogeneity (fig. 8), a slight but noticeable lateral differentiation due to N-S

FIG. 8 - Oblique aerial view of the lighthouse (1978).

strike slips and fractures (fig. 9). Such alignments constitute a system of at least three principal directions that cross the structure of the islet. This system is gradually east to west and is related to the slope processes and tilts to the north. Thus, throughout the entire island, steep gullies developed along the surface. As rule, the greater part of the surface of the islet is fractured, lacks vegetation and is covered with droppings from the abundant gull population. Gaibar-Puertas (1970) carried out seven altimetry profiles transverse to the length-wise axis. The profiles permitted him to affirm that there is a lateral differentiation relative to the profile *Roca de los Moros*-east of the lighthouse. Also, it was concluded that the eastern tilting is greater (0,1°-1,7°) than the western (0,1°-1,1°) and that this could be due to existence of the recent crust movements.

The geomorphology of the coast involves a set of processes and typical landforms encountered neither in the subaerial nor in the deeper submarine landscape. In order to analyze this, it is necessary first to observe the shape and extension of the shoreline. Also it is necessary to detect the existence and influence of the wind, marine currents, tides and storms and how they affect the isle. The second step is the study of the shore zone. This is an important geomorphic aspect of the problem because it includes wave action. High tides are another form of energy observable on the shoreline of Ai. The coast of the Ai is exposed to storm waves generated by winds blowing in from the Atlantic Ocean and the Eurasian and African continents. The shape of the islet and its lithologic homogeneity lead us to believe that marine currents' influence varies from one point to another, being stronger in the eastern part of the Ai than in the west. The effect of the abrasion is so intense that it has not permitted the step configuration of terraces similar to those found on other islands in the region previously mentioned. An example of the sea waves' strength here is the systematic destruction of the so-called «*Muelles*» (docks) (made of reinforced concrete).

The shape of the Ai shoreline is relatively irregular but with a prevailing a NE-SW strike. Its outline is composed of a Pleistocene marine terrace and three small beaches of the Holocene in the southwestern section (fig. 5a). There is a patch of limestone (Oquerosa) in the northwestern part. Looking at a transverse profile it is possible to determine the asymmetry of the islet. This asymmetry is very accented on the eastern side. Here there are pebble outcrops

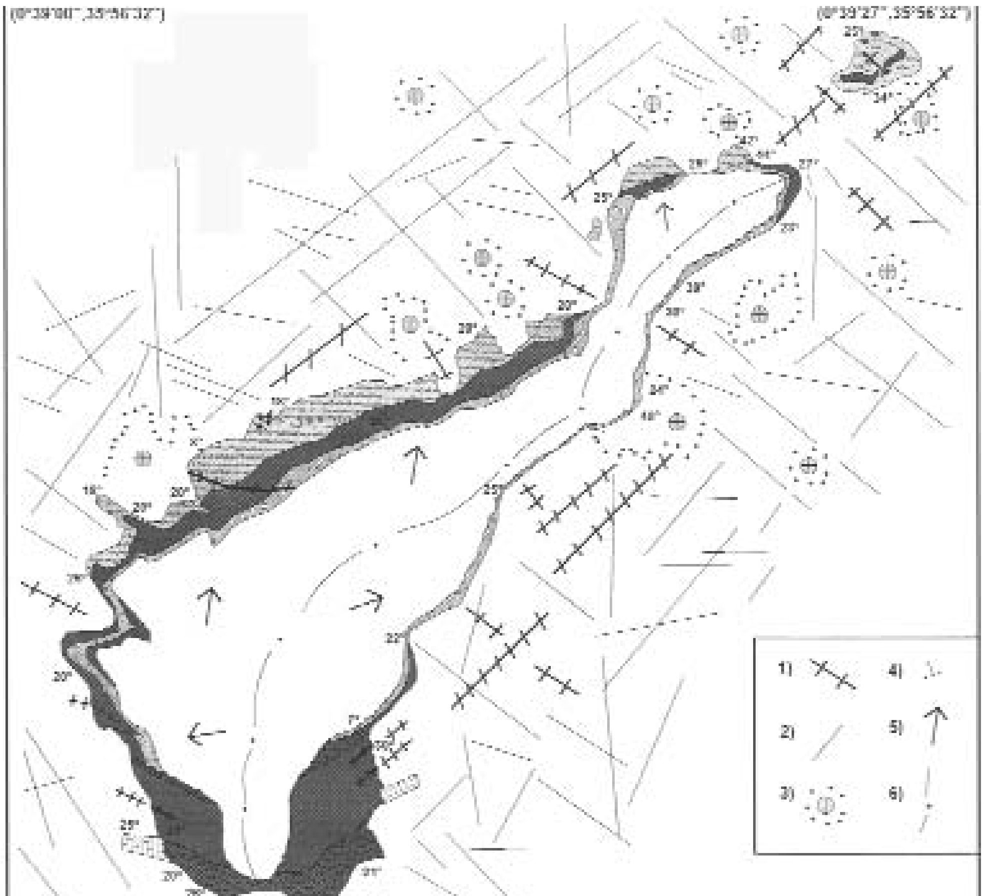


FIG. 9 - Geomorphological sketch of the Alborán Islet. (1. stair fractures system, 2. fractures, 3. zone of sediment and pebble accumulation and rocky, 4. strike and dip of fractures, 5. strike of the main slope, 6. watershed).

(rounded balls) and quaternary sedimentation (fine sand patches-saline-yellowish) (fig. 5b). In general, the concave forms of the coastal relief prevail in the north part and the mentioned transverse asymmetry covers more space (2/3 of the area) on the north than on the south side. Even the platform is much more narrow on the south side than on the north side. Eight prominent rock salients just out from the shoreline (*Punta del Pepote, Punta del Poniente, Punta del Norte, Punta del Islote, Punta del Pajel, Punta de las Lapas, Punta de Levante* and *Punta del Sur*) (figs. 2, 5a).

Several caves are found below sea level on Ai (*Cuevas Viejas, Cueva del Pajel, Cueva del Lobo Marino* and *Cueva de las Lapas*) (figs. 2, 5a), but the largest rises above the surface of the sea and crosses the islet at its narrowest point (*Cuevas Viejas*). It is a horizontal hole approximately six meters high and four meters wide with about a meter of water covering the floor. Beside it on the marine floor several denuded rocks along the principal strike of the islet can de distinguished. These relief structures are nanoblocks, affected by the marine currents. In all they are predominantly fractures of N-S strike. Irregular and angular shaped pebbles of various sizes, but almost no fine grain sediment, accumulate in these fractures. To the east of the *Isla de las Nubes* a geometry depression equal to that of the *Canal de las Morenas* has been mapped, which indicates the intensity of the abrassive processes in the region.

Prognosis

We must say that while it is impossible to observe a landscape evolve evidence of its evolution can be studied and presented. Observing and describing contemporary processes changing the Earth's relief allow us to make speculations and deductions with some degree of assurance. The analysis of previous factors together with the cartography of the fracture systems, the presence of remnant rocky borders like the islets (i.e., *Isla de las Nubes* and *Rocas de los Moros*) and the greater quantity of rocky fragments to the east permits us to maintain that, if the current geodynamic situation continues, Ai will disappear in successive steps. This fragmentation will be from east to west and will always result from the collapse of the cave roofs. Among the recommended protection measurements are: 1) building barriers' system around the islet and 2) filling up the larger fractures.

CONCLUSIONS

The aim of this paper was to present new data, as well as to do a reappraisal of available data and interpretations of Ai and its surroundings. The AS region is a complex area of continental collision between the Eurasian and African plates. In the AS large complex seafloor morphology with a combination of ridges, basins and seamounts system has been created as the result of the influence of plate tectonics. Ai is an emerged, isolated, arid geomorphologic structure in the AS. From the neotectonical point of view this small continental structure is an emerged nanoblock built on a transverse mesoblock (Alboran Ridge). It undergoes intense abrasive-denudative exogenous processes. The principal agents in order of diminishing importance are: 1) the action of the Western Mediterranean Sea with abrasive processes that recede the shoreline; 2) winds that beat the surface of the islet dragging sediments toward the sea and providing salinity through permanent great spray; 3) man-made alterations that, among other things, have made two formidable adjustments to the shoreline (*Muelle de Poniente* and *Muelle de Levante*); 4) a significant and pronounced day-night thermal pendulum that increases fracturing; 5) the activity of the birds and their organic wastes that enhance chemical weathering. An analysis of these factors, the cartography of the fracture systems and the remnant rocky borders around the islet supports the conclusion that if the current geodynamic situation remains unchanged, the islet, breaking up into crags over time, will disappear.

In the eastern part of the Betic Cordillera and in the northern Africa there are shear active faults. But the earthquake distribution in Ai and surroundings does not ensure the existence of such faults. It was detected two groups of epicentres in circles with diameter inferior to 10 km for the maritime zone of *Cabo de San Antonio-Islas Baleares* and for the west of the Ai. The first group can be associated with a NE lineament and the second one is located an important submarine relief contrast.

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