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COMPARATIVE PETROLOGY AND GEOCHEMISTRY OF HIGH-PRESSURE METAMORPHIC ROCKS FROM EASTERN CUBA AND WESTERN ALPS

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ABSTRACT

The paper deals with HP metamorphic rocks from E-Cuba in the surroundings of Holguin. Thes rocks are mainly eclogitic which occur in blocks of different size in serpentinite along with other oceanic and island arc type rocks. The eclogitic rocks are mainly of oceanic type, related to subduction. The rocks underwent greenschist facies retrogression followed by metasomatism during their tectonic evolution. Chemical and REE analyses were applied in geochemical studies of these rocks. Garnet, pyroxene and amphibole compositions were measured by electron microprobe, and the results were compared with the data of the well-known HP rocks of W-Alps obtained from the literature. On the basis of the analytical results it has been concluded that the eclogitic rocks of E-Cuba were ophilitic, regarding their origin, which underwent high rpessure conditions during subduction. The retrogression can be related to obduction and overthrusting which are due to an uplift caused by a new subduction. The geochemical features of the eclogitic rocks E-Cuba allow us to interpret the petrologic processes the same way as it was done in the case of the W-Alps.

OUTLINE OF GEOLOGY OF CUBA AND GEOLOGICAL SETTING OF THE METAMORPHIC ROCKS FROM WESTERN ALPS

The geological evolution and the present geographic location of Cuba within the Caribbean intercontinental sea are the results of crustal evolution processes which acted between the end of Lower Cretaceous and the Palaeogene. Plate tectonic reconstructions (DIETZ and HOLDEN, 1970) indicate that the oceanic crust of the region have been formed durint Late Jurassic time, as a western extension of the Tethys Sea. After a while the connection between the two regions was ceased due to the opening of the Atlantic Ocean. However, the structural evolution, geology and petrology of the two areas display several similar characters, like rocks of the ophiolite association, and the closely related eclogites and eclogite-derived metamorphites. Their comparative investigation, and the interpretation of the analogous Alpine formations may provide clues for the understanding of the position of the similar Cuban metamorphites.

The geology and structure of Cuba is shown by the latest, 1:500 000 geological and tectonical maps based on the geosyncline principle, but applying certain elements of plate tectonics (1985, 1986). The latest study, based on plate tectonics, was published by ITURRALDE—VINENT (1988).

Definite zonality can be recognized in the geology of Cuba *(Fig. 1)*. Along the northern shores there are outcrops of carbonatic-evaporitic formations of the Bahamian platform. To the south there are terrigenous-carbonatic and siliceous formations (Upper Jurassic — Lower Cretaceous) deposited on the continental slope.

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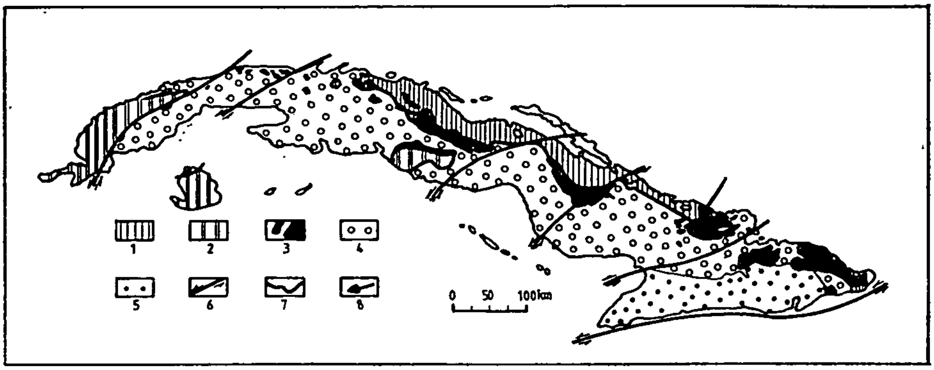

Fig. 1. Geological map of Cuba without Cenozoic cover. Legend: 1. Sedimentary formations of the Bahama Platform and its southern continental slope (J_3—K_1). 2. Terrigenous clastic and carbonate rocks metamorphosed to different grades (J—K_1). 3. Ophiolite association. 4. Cretaceous volcanic arc. 5. Palaeogene volcanic arc. 6. Fault. 7. Thrust zone. 8. Localities of the discussed metamorphic rocks. (After ITURRALDE—VINENT, 1988, simplified)

There are Jurassic, terrigenous clastic and Upper Jurassic — Lower Cretaceous terrigenous-carbonatic-siliceous formations, covering extensive regions in the western part of Cuba, in some isolated outcrops along the southern shores (Isla de Juventud, Escambray Mountains) and in the easternmost zones. The sediments of the continental platform and that of the intracontinental sea have suffered different degrees of metamorphism.

The ridge of the island is formed by a northern Mesozoic ophiolite belt and a southern, Cretaceous island arc, partly mixed with the former one, forming melange.

In the southern part of Eastern Cuba there are volcanic rocks of a younger, Palaeogene island arc sequence. The uplift of the ophiolites to teh surface, and their overthrust on the northern foreland together with the island arc occurred during Late Cretaceous time.

The eclogitic formations are always connected to the ophiolites, i.e. to the serpentinites and the ophiolite melange, in the form of minor blocks or lenses. Besides the investigated occurrence at Holguin, these are known from Central and Western Cuba and from the Escambray Mountains.

The eclogite facies metamorphites of the Western Alps occur along an arc between the Po Plain and the Voltri Massif in several tectonic units *(Fig. 2).* The so-called Early Alpine high-pressure metamorphism, the rocks, and their plate tectonic implications were initially described by ERNST (1971) and DAL PIAZ et al. (1972). The latest results were published in the field trip guide of IGCP Project 235 (PICCARDO, 1988).

The high-pressure metamorphism in the Western Alps due to the Cretaceous subduction and nappe formation can be recognized on the rocks of both the pre-Alpine continental and oceanic crust (ERNST, 1971, DAL PIAZ *et al.*, 1972). The metamorphic rocks have been formed from igneous, sedimentary and metamorphic rocks of variable mineralogical and chemical composition. The original rocks were some members of the ophiolite association, e.g. the mafites (Cottian Alps, Monviso region, Voltri Massif), ultramafites (Lanzo Massif), pre-Alpine continental rocks (e.g. Sesia Zone), oceanic sedimentary formations (Voltri Massif),

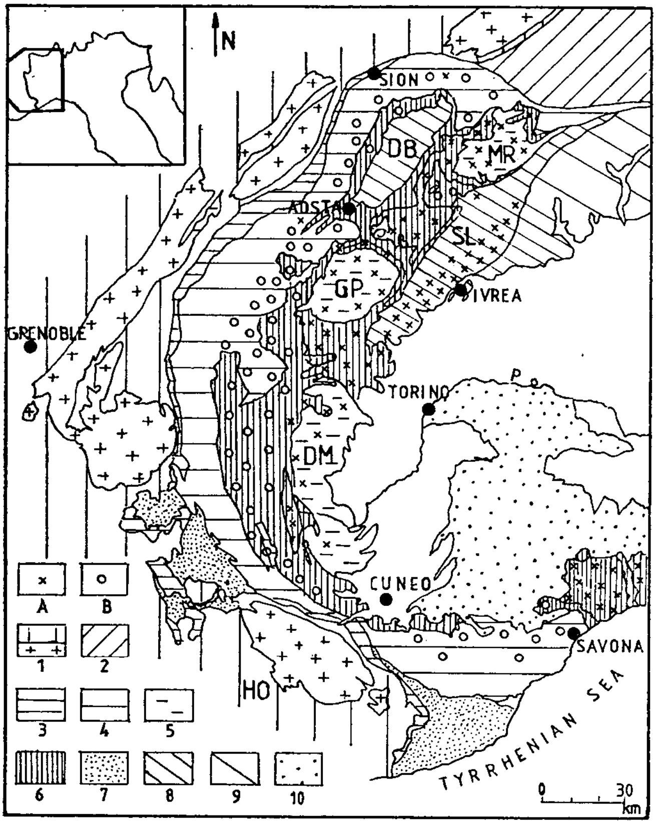

Fig. 2. Tectonic map of the Western Alps, with high-pressure metamorphite localities. Legend: units of the Palaeo-European margin: 1. Helvetic-Dauphinois zone with basement massifs; 2. Lower Penninic nappe; 3. Subbrianconnais unit and Sion-Courmayeur zone; 4. Gran Bernardo nappe; 5. Upper Penninic nappes: Monte Rosa (MR), Gran Paradiso (GP), Dora Maira (DM); 6. Piedmont ophiolite nappe with the Voltri Massif; 7. Helminthoid flysch; units of the Palaeo-African continent: 8. Austro-Alpine Sesia-Lanzo (SL) and Dent Blanche nappes (DB); 9. Southern Alps and the Ivrea Zone; 10. Late orogenic sedimentary sequence. High-pressure associations: A: eclogite, B: blueschist. (After Dal Piaz—Lombardo, 1986)

and pre-Alpine crystalline schists (e.g. Dora Maira Massif, Gran Paradiso, Monte Rosa, Ligurian Alps).

The tectonic and metamorphic evolution of the Western Alps is summarized as follows: The Alpine metamorphism is subdivided into an Early Alpine phase, connected to the subduction-collision process, and into a Late Alpine one, related to uplifting. During the Cretaceous subduction a predominantly blueschist then an eclogite-facies metamorphism were formed in the internal zones of the Western Alps. In the collision realm a blueschist-facies diaphthoresis was predominant during Late Cretaceous and Early Tertiary time. In the outer zones of the Western Alps blueschist-facies rocks were probably formed during the Palaeocene and Early Eocene due to the subduction and collision.

The Late Alpine greenschist-facies diaphthoresis is related to strong uplift. The metamorphic rocks well reflect the above-mentioned alteration processes.

Characteristic minerals of the progressive blueschist facies are glaucophane, clinozoisite, titanite, white mica and Ca- and Mn-rich garnet. The eclogite-facies rocks are characterized by pyroxenes (omphacite or jadeite), almandine- or pyrope-rich garnet, zoisite (rarely epidote) and rutile, according to the description. Quartz was found in the more acidic original rocks. This composition indicate an extended interpretation of eclogite facies by the above cited authors. Some of the listed minerals, e.g. zoisite, epidote, are stable rock-forming minerals in metamorphites of lower P-T range, like in greenschist. The presence of these components and jadeite may indicate that the high pressure — and associated high temperature — characteristic for eclogite facies did not last long enough to reach complete equilibrium. The metamorphic process may have been terminated in a lower, possibly partly greenschist-facies P-T range. Therefore, most of the mineral assemblage of the above-mentioned rocks have been formed due to retrograde metamorphism*. In the retrograde blueschist facies (or glaucophanite facies) there are large amounts of albite, Fe-chlorite, Fe-rich epidote besides Na-amphibole. Also there are stilpnomelane, titanite altered from rutile, and clinozoisite. The Na-amphibole is frequently rimmed by Na-Ca- or Ca-amphibole. The latter phenomena indicate the diaphthoresis.

The eclogite-facies rocks of the Western Alps usually were formed under 450—500 °C temperature and 10—15 kb pressure. The blueschist was formed under

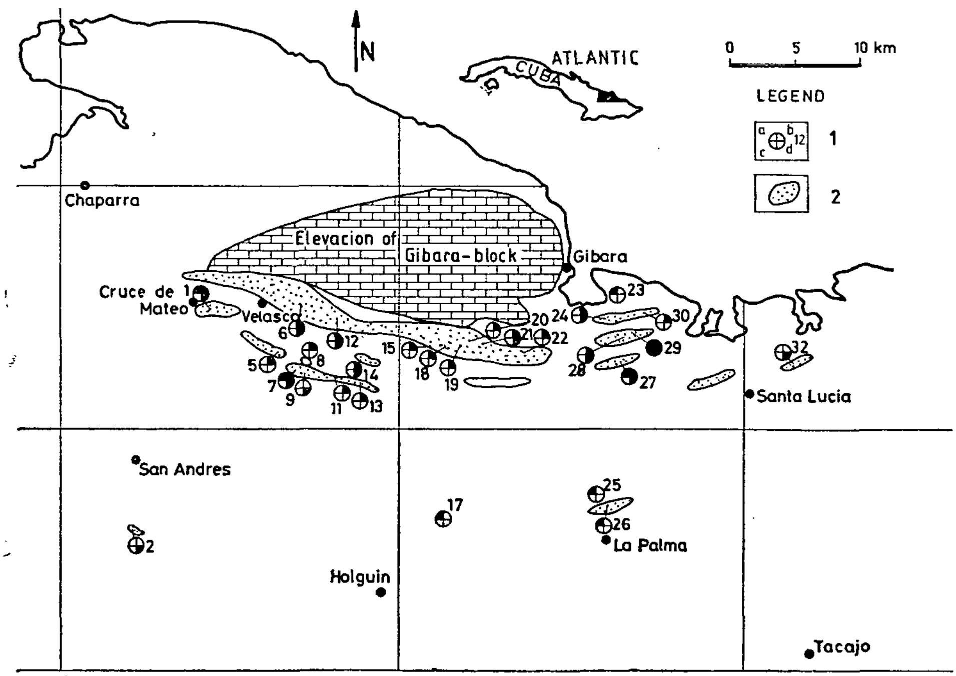

Fig. 3. Locality map of the metamorphic rocks in NW Oriente. Legend: metamorphite localities: La Palma (a) Formation; Mateo Formation (b—d); eclogite, diaphthorized eclogite (c) mafic rocks from the lower crust; (d) metamorphic rocks from the obduction overthrust zone. 2. Probable scattered localities.

* The notion retrograde metamorphism is used after Angel (1965).

450 °C and 7—8 kb, while the greenschist-facies metamorphites were formed at about 400 °C and 3—5 kb.

The Cuban-Hungarian Geological Expedition (1984—1988) has found unknown or marginally known (NAGY E. *et al.* 1978) metamorphic rocks (ANDÓ—KOZÁK, 1987).

Various local and regional metamorphites are very widespread; in this paper we discuss only those completely recrystallized rocks of definitely metamorphic texture, which form smaller or larger isolated blocks in melange- or olistostrome-like sedimentary formations *(Fig. 3)*.

DISTRIBUTION, GEOLOGICAL SETTING AND MAIN TYPES OF THE METAMORPHIC ROCKS OF E. CUBA

The pre-Neogene geological structure of NW Oriente is formed by two, completely different structural units. The Cretaceous limestone-dolomite ranging along the northern shores belong to the southernmost outcrops of the North American continental plate (Remedios Zone). The adjoining, southern Zaza Zone is made of mostly tectonic metamorphites (serpentinite), ophiolite and island arc-like formations. It may be considered as an allochthonous melange (KOZÁK—ANDÓ, 1987; ANDÓ—KOZÁK, 1987).

Metamorphic grade allows us to differentiate between low and medium grade (La Palma Formation) and high pressure (Mateo Formation) rocks *(Fig. 3)*.

The La Palma Formation is a 250 m long, elongated metamorphic blocks made of black shales (rich in organic materials) and orthogneisses wedged into the serpentinite scales.

The original material of the organic-rich, graphitic black shale and calcareous phyllite was mostly made of clastics derived from the erosion of mostly pelitic-carbonate, and less granodiorite or low-grade metamorphic orthogneiss terrains. Derivatography indicates partial graphitization of the organic matter, arranged in sheared, fine bands.

The also low-grade metamorphic orthogneiss is of granodioritic origin, too. Its margins display cataclastic-mylonitic structures.

The clastic-carbonatic or granodioritic origin of the metamorphites described here are well shown by their composition (Table 1).

Separated muscovites from the orthogneiss show 196 Ma K/Ar ages*, therefore the original igneous rock was older than Triassic. The 91 Ma age of the feldspars may be related to the Upper Cretaceous tectonic processes. Based on these results the orthogneiss and its original rock, the granodiorite is correlated by the old granodiorites in the northern part of Central Cuba (SOMIN—MILLÁN, 1981) similarly derived from the basement of the continental foreland.

Outcrops of the mafic-ultramafic metamorphites of the Mateo Formation range from metre size up to 20 m *(Fig. 4)*, teherefore siplaying them on the geological maps causes problems. Along the northern part of the region these point-like exposures form an easily recognizable belt about 1 to 10 km south of the present southern edge of the carbonate platform representing the North American continental plate *(Fig. 3)*. The 0,5—1 km wide "metamorphic belt" defined by ca. 25 natural exposures

* The age determinations were made by K. BALOGH and Z. PÉCSKAY at ATOMKI Laboratories, Debrecen.

No.	Sites of sampling	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO
1.	30	50.63	1.70	12.70	3.54	7.75	0.534	4.53
2.	13	48.09	1.19	14.02	5.43	8.40	0.278	7.78
3.	1	52.16	0.66	11.81	1.53	8.23	0.153	8.49
4.	27	52.28	0.66	12.18	6.43	2.36	0.159	9.88
5.	27	50.47	1.40	15.53	0.93	8.99	0.137	7.17
6.	20	40.81	1.78	14.51	3.46	7.78	0.249	15.40
7.	21	27.43	3.65	17.61	0.49	20.58	0.534	13.78
8.	29	49.10	1.00	11.84	3.87	5.88	0.201	12.95
9.	PC-444 (1) 2,0 m (1)	48.34	0.75	8.00	3.65	5.69	0.110	21.21
10.	1	55.08	<0.1	4.07	2.00	3.80	0.294	19.63
11.	1	31.13	0.68	15.43	7.28	4.07	0.163	30.07
12.	PC-234 (26) 2.5	70.95	0.17	15.60	1.01	0.77	<0.05	0.80
13.	PC-234 (26)	71.00	0.23	13.70	<0.1	2.13	0.07	0.97
14.	PC-234 (26)	52.08	0.60	12.75	0.59	3.65	0.09	2.28

* = loss of ignition; sites of sampling according to *Fig. 3*

MATEO FORMATION

1—7 = ecologite and metamorphites derived fom eclogites
8. = coarse-grained garnet-amphibolite
9. = tremolite schist with serpentine
10. = tremolite schist
11. = chlorite schist

LA PALMA FORMATION

12—13 = orthogneiss
14 = graphitic phyllite

The analyses were prepared at the Department of Petrology and Geochemistry of Eötvös L. University, Budapest, Hungary (No. s 1—11 and 13) as well as at the Geological Company, Santiago de Cuba, Cuba (no. s 12 and 14)

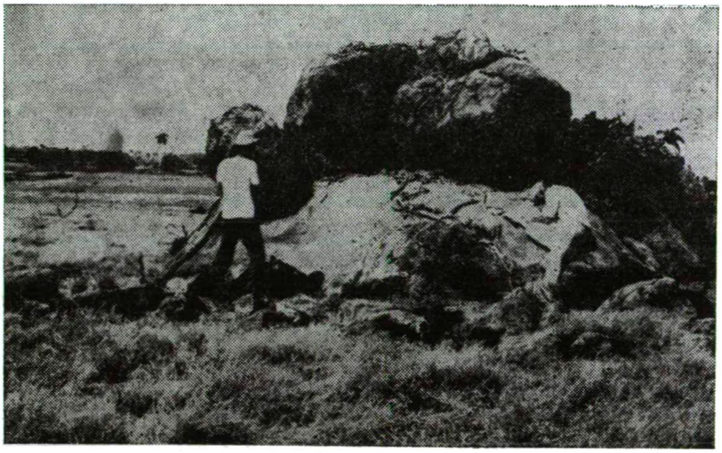

Fig. 4. **Eclogite blocks, Cruce de Mateo**

TABLE 1

rocks from the environs of Holguin

CaO	Na_2O	K_2O	P_2O_5	$-H_2O$	$+H_2O$	CO_2	SO_2	Total
11.25	5.36	0.55	0.02	0.39	0.49	—	0.76	100.20
11.65	2.10	0.29	0.06	0.07	—	—	—	99.36
10.62	3.47	0.27	0.09	0.13	1.44	—	0.21	99.26
9.82	4.08	0.12	0.01	0.21	1.80	—	—	99.99
6.93	6.15	0.17	0.04	0.07	1.06	—	0.55	99.60
8.14	0.87	<0.1	<0.01	0.75	5.15	—	0.90	99.80
3.06	<0.01	0.02	<0.01	0.61	7.82	3.04	0.74	99.36
8.91	0.91	0.71	0.63	0.33	2.43	—	—	98.76
7.04	0.17	<0.1	0.08	0.20	5.40	—	—	100.64
11.56	0.33	<0.1	<0.01	0.30	2.91	—	—	99.97
0.47	<0.1	0.18	0.01	0.34	10.60	—	—	100.42
0.70	6.30	1.76	0.136		1.69*		<0.1	100.036
0.62	6.56	2.18	0.25	0.40	1.40	—	—	99.51
12.15	3.60	1.32	0.193		10.40*		0.27	99.973

extends from Velasco to Potrerillo to Guardalavaca forming an 50 km long zone. The outcrops at Cruce de Mateo (2 km WSW from Velasco) are regarded as the stratotype of the formation *(see Fig. 3)*.

The mafic-ultramafic metamorphites of the Mateo Formation are subdivided into three groups: (1) eclogite and its diaphtorised and metasomatized varieties; (2) micaceous garnet-amphibolite with slightly oriented structure; (3) schistose amphibolite, amphibole-chlorite-schist, chlorite-talc-schist, actinolite- and tremolite-schist, chlorite-phyllite (antigorite-phyllite) with oriented structure.

The eclogite and its derivatives are distributed all along the zone, while the micaceous garnet-amphibolite occurs in minor amounts only. Members of the third group are widespread, and occur associated with the eclogite varieties, too.

Naturally the main components of the eclogite varieties (derivatives) are eclogite garnet and omphacite *(Fig. 5)*, with a minor amount of glaucophane *(Fig. 6)* provies the formation of these rock-types in a subduction zone. However, the hornblende rim around glaucophane *(Fig. 6)* indicates changes in P-T conditions during metamorphism, the amphibole appearing in the space between albites and pyroxenes, the zoizite and the epidote indicate the termination of the high-pressure process

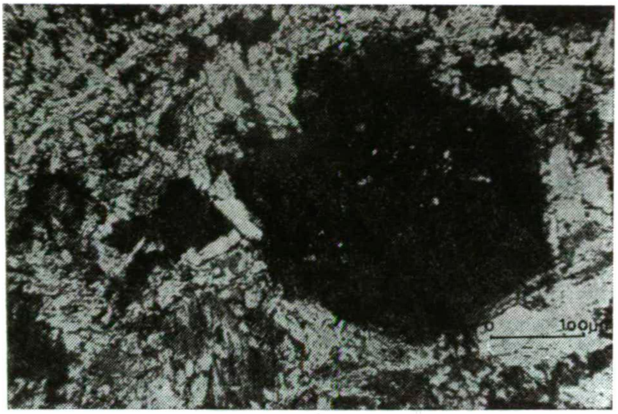

Fig. 5. Euhedral garnet and omphacite from eclogite. Locality No. 8. Crossed nicols, 167x magnification

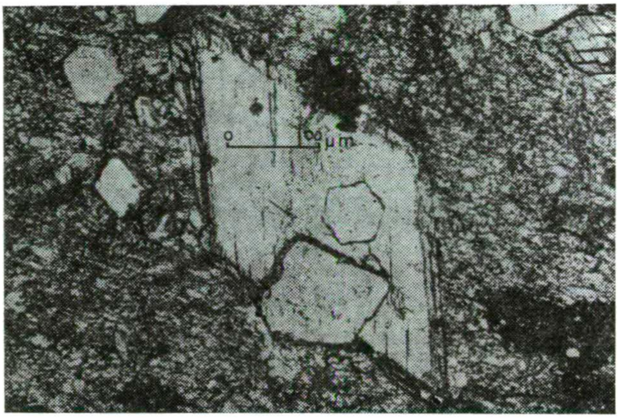

Fig. 6. Hornblende-rimmed glaucophane in diaphthorized eclogite. Locality No. 30. Single nicol 167x magnification

before equilibrium was reached, i.e. retrograde metamorphism. Amphibolization of pyroxene *(Fig. 7)*, leucoxenization of rutile, or its alteration to titanite show a later phase, i.e. diaphthoresis. Therefore the mineral composition of eclogite varieties (derivatives), and the ratio of the above-mentioned components is strongly varied in each locality. Amphibole occurs in larger quantities in these rocks; there are varied amounts of albite together with other minerals (zoisite, epidote, chlorite) stable at lower pressures and temperatures *(Fig. 8)*. It is clearly seen that the cores of titanite grains are made of rutile. This solid phase composition may reflect either retrograde metamorphism or low-grade diaphthoresis. In some localities (e.g. in locality No. 27, see *Fig. 3*) the eclogite almost completely has been transformed to amphibole schist; in this case the pyroxene forms inclusion-like relics only *(Fig. 9)*. The recrystallization brought a coarse crystalline look to the rock.

Diaphthoresis resulted in the formation of metamorphites indicating varied facies from the eclogite. However, the original texture — and partly the mineral com-

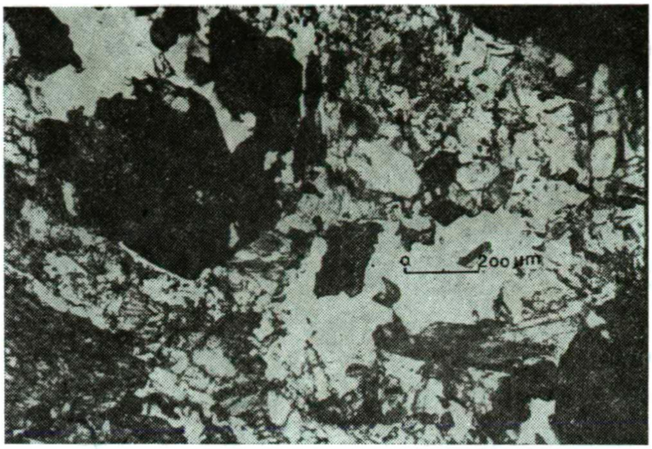

Fig. 7. Garnet, omphacite, albite, and hornblende in diaphthorized eclogite. Locality No. 1. Crossed nicols, 67x magnification

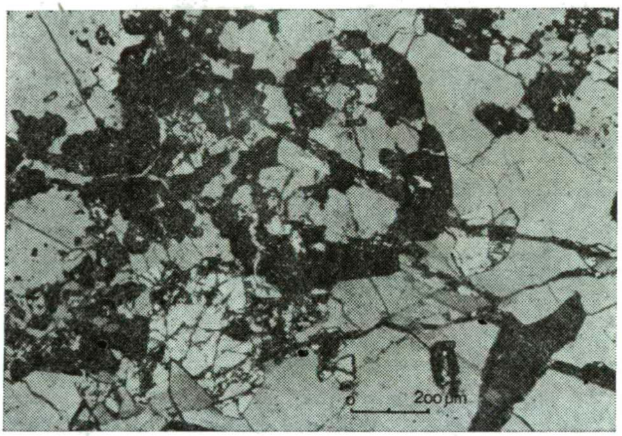

Fig. 8. Garnet relics with albite, zoisite, and chlorite. Locality No. 27, Crossed nicols, 67x magnification

position — can be recognized even after intense alteration. Consequently, the diaphthorite may inherit the textural characters of the eclogite, helping to determine its origin *(Fig. 10)*. In these metamorphites syndiaphthoritic folded structure can be observed, illustrating the relationship of this process and tectonical reactivation *(Fig. 11)*. In extreme cases the original texture is completely re-ordered due to strong alteration. The pre-altered rock is indicated by xenoblastic relic garnets *(Fig. 8)*. In these rocks the stable minerals of low-grade amphibole or greenschist facies (hornblende, actinolite, chlorite) become predominant in the case of intense diaphthoresis.

Amphibolite- and greenschist-facies rocks are not formed by diaphthoresis only. During progressive metamorphism besides eclogite a more varied metamorphic association was formed from the mafic rocks of the oceanic crust in varied amounts in each region (among others garnet-amphibolite, epidote-amphibolite, amphibole-schist, albite-zoisite-chloriteschist, actinoliteschist, chloritite, talc-schist, et.).

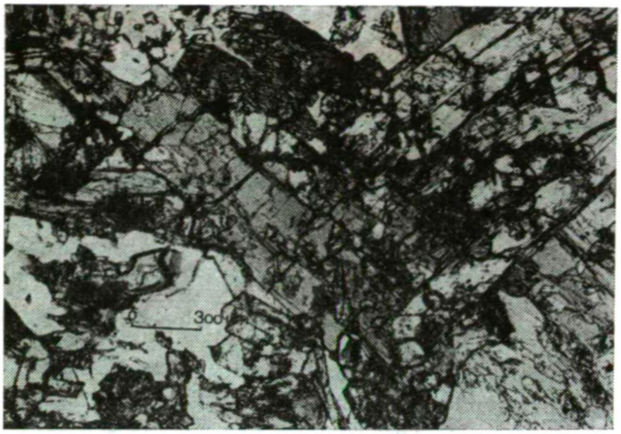

Fig. 9. Relics of hornblende, albite, and pyroxene in diaphthorized eclogite. Locality No. 27. Single nicol, 47x magnification

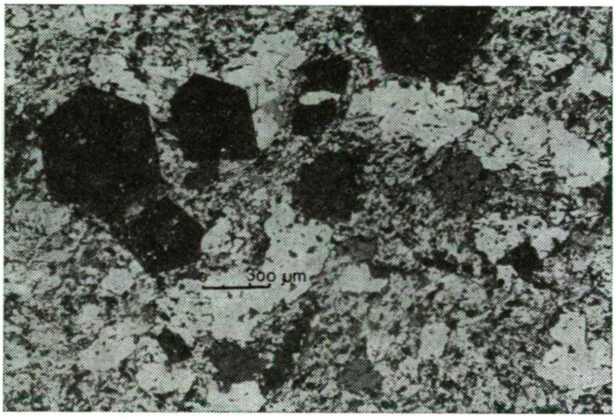

Fig. 10. Garnet, albite, and amphibole in greenschist-facies, diaphthorized eclogite. Locality No. 11. Crossed nicols, 42x magnification

Variability of eclogie diaphthoresis can be clearly observed on the blocks of the exposed stratotype *(Fig. 12)*. The most conspicuous although local metamorphic alteration was produced by an intense migration of solution post-dating the subduction (possibly connected with the uplift or obduction). The dark bluish to violet-tinted amphibole agglomerations precipitated from high-temperature solutions fill the former joints of eclogite and form dense network of mineral veinlets. These are several mm long, up to cm size and form minor nests, too. The Na-containing amphiboles form oriented clusters on both sides of the veinlets with variable density, decreasing with growing distance. This phenomenon appears as characteristic banding on the blocks *(Fig. 13)*. The amphibole — bluish green in thin section — appears in even distribution in a distance from the bands, but scattered or in rock-forming quantities depending on the intensity of the solution effect. By the growth of its ratio the amount of pyroxene decreases, and this process leads to the formation of certain garnet-amphibolite varieties.

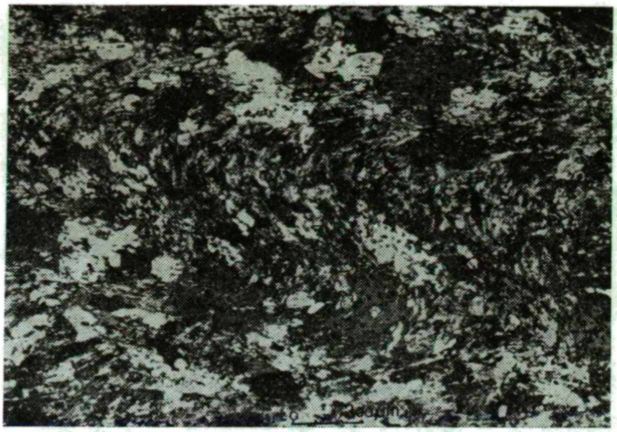

Fig. 11. Folded epidote-amphibolite with albite from diaphthorized eclogite. Locality No. 12. Crossed nicols, 42x magnification

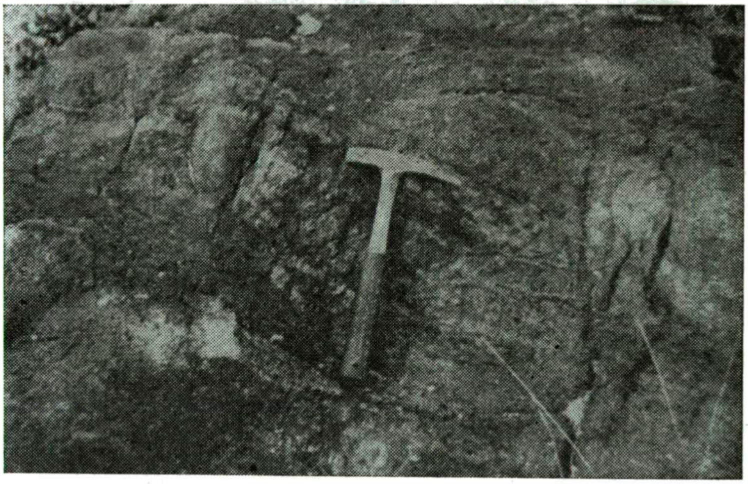

Fig. 12. Metasomatically altered, banded eclogite SW of Gibara

The eclogite-facies metamorphites are the products of pressure (and corresponding temperature) made by the subduction of a mafic oceanic plate. Their diaphthoresis can be explained by uplift from 30 km depth to higher crustal positions and by some increase in temperature. Following this the mafic crustal rocks metamorphosed to variable grades were emplaced into the reach of obductional imbricate movements, which yielded further alterations corresponding to the new conditions, especially the characteristic metasomatic processes.

K/Ar ages of separated amphiboles from diaphthorized eclogite (locality No. 13) and from garnet-containing amphibole-schist (locality No. 20) are 103 Ma and 109 Ma, respectively. These data indicate the age of the diaphthoresis.

The schistose metamorphites are usually of mafic-ultramafic composition, with the predominance of the latter. The antigorite-schist, antigorite-talc-schist, chlorite-

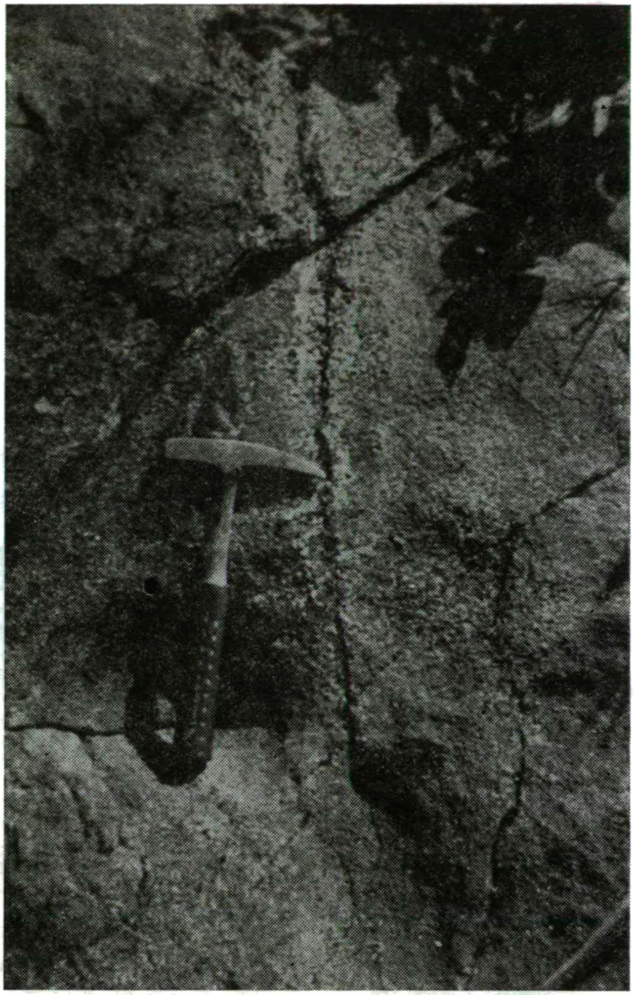

Fig. 13. Eclogite with amphibole bands. Cruce de Mateo

schist, greenschist, actinolite- and tremolite-schist, chloritic amphibole-schist and garnet-bearing epidote-amphibolite belonging to this group are products of a progressive metamorphism between greenschist and amphibolite facies. Minor diaphthoresis was observed on the amphibolites. Texture and structure of these rocks indicate a significant role of the directed pressure, while the solid phase composition demonstrates different P-T conditons. The appearance of these conditions can be explained by frictional heat and the corresponding pressure, which occurred along the shear zones below the obducting oceanic plates. An environment with higher temperature gradient was needed for the formation of the amphibolite varieties. These factors and the ultramafic-mafic chemistry of the rocks indicate that the above-mentioned strain zones may have been formed within a — then young — oceanic plate.

The muscovitic amphibolite, containing large-size (0.4—0.6 cm) garnets, is of different origin by its chemical and mineral composition ant its texture. It may have been formed from high-MgO mafic metamorphite — possibly eclogite — or garnet-amphibolite due to greenschist-facies diaphthoresis. Its origin cannot be cleared, but its characteristic, partly relic texture, and its composition suggest an origin from a mafic-melamafic, continental deep crust. Its K/Ar age (119 Ma) measured on mescovites is older than that of the amphiboles of diaphthorized eclogites.

GEOCHEMISTRY OF METAMORPHITES OF MATEO FORMATION AND WESTERN ALPS

To determine the original and present composition and to follow the alterations (among others the diaphthoresis) chemical analyses (Geological Company, Santiago de Cuba; Department of Petrology and Geochemistry, Eötvös University, Budapest), electron microprobe analyses (Department of Petrology and Geochemistry, Eötvös University, Budapest), and REE determinations by neutron activation analysis (Budapest Technical University, Institute of Nuclear Technology) were carried out. The results are summarized as follows.

Chemical analyses (Table 1) show the mafic composition of most rocks in AFM-, and Al_2O_3—FeO^t—MgO-plots (Figs. 14—15). The AFM plot *(Fig. 14)* the eclogites, diaphthorized to varied grades, and with mafic composition are well separated from the melamafic-ultramafic schists along the F-M sied. Part of the schists display weak relationship to partially diaphthorized eclogites, while another part of them represent the types from the shear zone or the mafic deep crust. Comparing *Figs. 14* and *15* the eclogitic rocks of the formation show high similarities to mafic eclogites of tholeiitic origin in France and the Western Alps. The melamafic-ultramafic rocks of

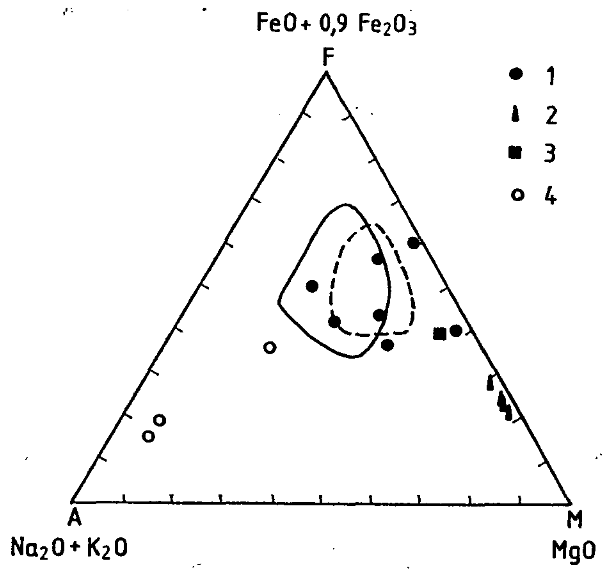

Fig. 14. AFM plot of metamorphites from NW Oriente. Legend: 1—3: Mateo Formation. 1. eclogite—diaphthorized eclogite; 2. Ophiolitic metamorphites from the overthrust zone; 3. Mafic rocks from the lower crust; 4. La Palma Formation. Continuous line: eclogite, amphibolite-bearing eclogite, and amphibolite, Mucrone Sesia Zone, Western Alps (BIINO *et al.*, 1988). Dotted line: eclogite of tholeiitic origin: Bas-Limousin, Massif Central (SANTALLIER, 1983)

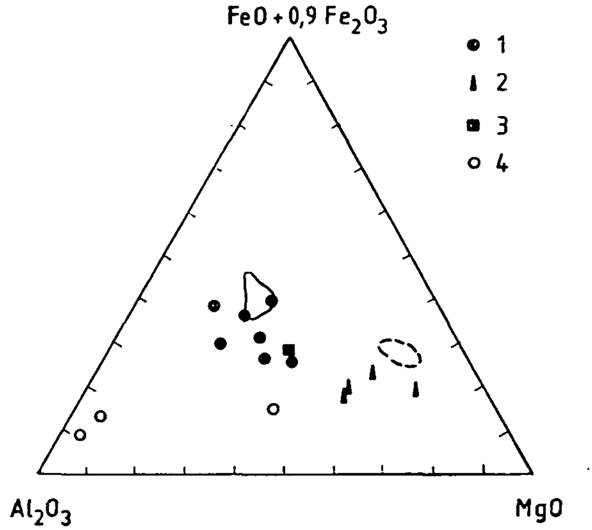

Fig. 15. Al_2O_3—FeO^t—MgO plot of the NW Oriente metamorphites. Legend of dots: see *Fig. 14.* Continuous line: Cabardès, amphibolitized eclogite (Montagne Noire, France (DEMANGE, 1985). Dotted line: Airette, eclogite-facies ultramafics, Montagne Noire, France (DEMANGE, 1985).

the formation do not fall in the field of published eclogite-facies metamorphites of mafic-ultramafic origin. This fact supports our suggestion on their different kind of formation. Garnet, pyroxene and amphibole compositions from the eclogitic series were determined by *electron microprobe.* and compared to some pyroxenes and amphiboles from weakly metamorphosed sheeted dykes and cumulates in the region.

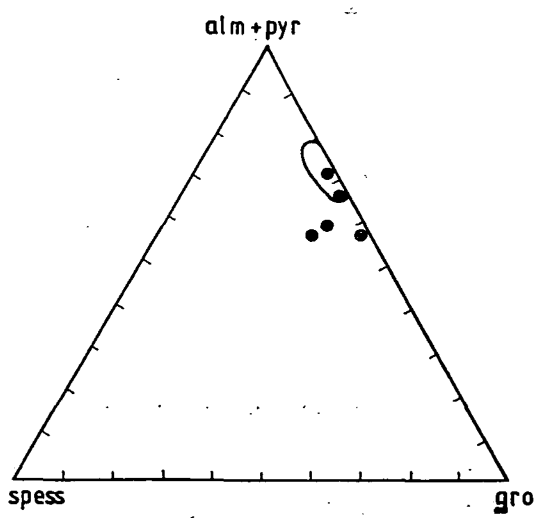

Fig. 16. Garnet compositions of NW Oriente diaphthorized eclogites in an almandine+pyrope — spessartine — grossular triangular plot. Continuous line: amphibolite containing eclogite relics, Savona crystalline massif (MESSIGA—SCAMBELLURI, 1988).

Garnets of variably diaphthorized eclogites show almost the same, mostly almandine-grossular composition, rarely with a somewhat higher ratio of spessartine molecule *(Fig. 16)*. On the Mg—Fe^2 —Ca+Mn cation number plot the garnets occupy a well-defined field, like some Western Alpine eclogites *(Fig. 17)*. However, on the grossular-almandine+spessartine-pyrope plot *(Fig. 18)* the Cuban garnets and the

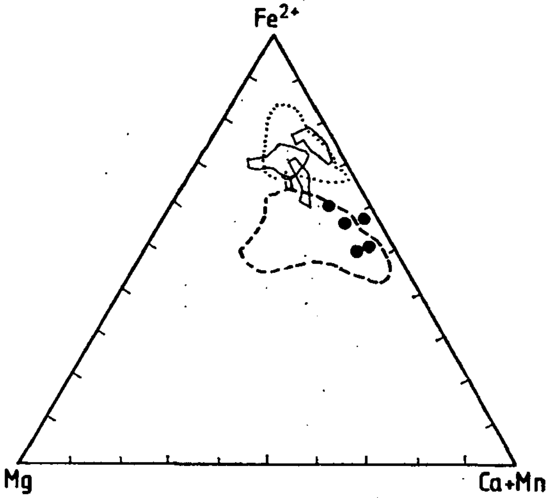

Fig. 17. Composition of NW Oriente diaphthorized eclogites in an Fe—Mg—Ca+Mn cation number plot. Continuous line: Val d'Ala, Lanzo, Western Alps; dotted line: high Mg-gabbro altered to eclogite, Voltri Massif, Western Alps. Dotted line: high Mg—Fe-gabbro altered to eclogite, Voltri Massif and Monviso, Western Alps (SANDRONE *et al.*, 1986).

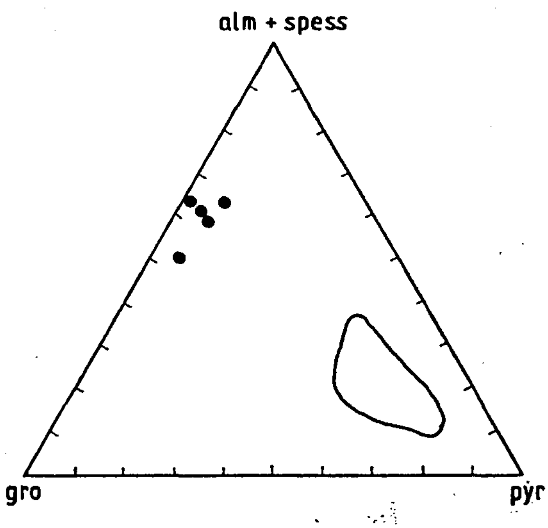

Fig. 18. Composition of garnets from NW Oriente diaphthorized eclogites in an almandine+spessartine—grossular-pyrope triangular plot. Continuous line: garnet-clinopyroxene-bearing metamorphic rocks, Bohemian Massif, Lower Austria (SCHARBERT—CARSWELL, 1983).

metamorphic garnets derived from the high-pressure granulite facies garnet-clinopyroxene-bearing rocks of the Bohemian Massif (SCHARBERT—CARSWELL, 1983) are clearly separated. *Fig. 19* illustrates the composition of the less diaphthorized eclogites of the formation compared to the pyroxenes of two metadolerites in a jadeite-aegirine-other pyroxenes triangular plot. Both types are separated by significant differences in the ratio of the aegirine-jadeite molecules. On the other hand there is definite similarity among chemical compositions of pyroxenes of eclogitic rocks from the investigated and analogous regions. *(Fig. 19).*

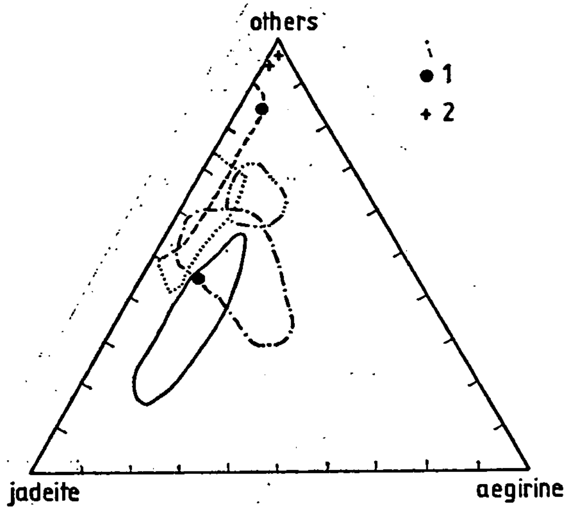

Fig. 19. Pyroxene composition of NW Oriente diaphthorized eclogites (1) and metadolerites (2) in a jadeite-aegirine-other pyroxenes triangular plot. Continuous line: omphacite from bedded eclogite, monviso, Western Alps (COMPAGNONI *et al.*, 1988). Dotted line: Cr-rich Na-pyroxene from Mg—Al-metagabbro, Monviso, Western Alps (KIENAST—MESSIGA, 1987). Dotted line: eclogite altered from high-Mg gabbro,Voltri Massif, Western Alps (SANDRONE *et al.*, 1986). ...—...—...—= =eclogite altered from high-Fe—Ti gabbro: Voltri Massif and Monviso, Western Alps (SANDRONE *et al.*, 1986). ...—...—...—=High Fe—Ti gabbro altered to eclogite, Cotti Alps (SANDRONE *et al.*, 1986)

The varied diaphthoresis grades of eclogites are indicated by the amount and chemical composition of amphiboles. Therefore the electron microprobe analysis was extended to almost all eclogite varieties and derivatives. The exact systematic position of the analysed minerals *(Fig. 20)* was determined by LAEK's (1978) method from cation numbers calculated from analytical data. The investigated minerals mostly belong to the Ca- and Na—Ca-amphibole groups. We can see, that amphiboles of eclogite diaphthorized in amphibolite- and greenschist-facies environment and of metadolerite are very similar in composition. It suggests similar chemical composition for the original rocks and similar p—T conditions, defining the amphibole chemistry for the two groups.

The above-mentioned data prove that the secondary amphiboles of Cuban metamorphites and Western Alpine eclogites are similar in composition *(Fig. 21).*

REE composition of some rock types was determined for possible grouping and for clearing genetical relationships of the different metamorphites of Mateo Forma-

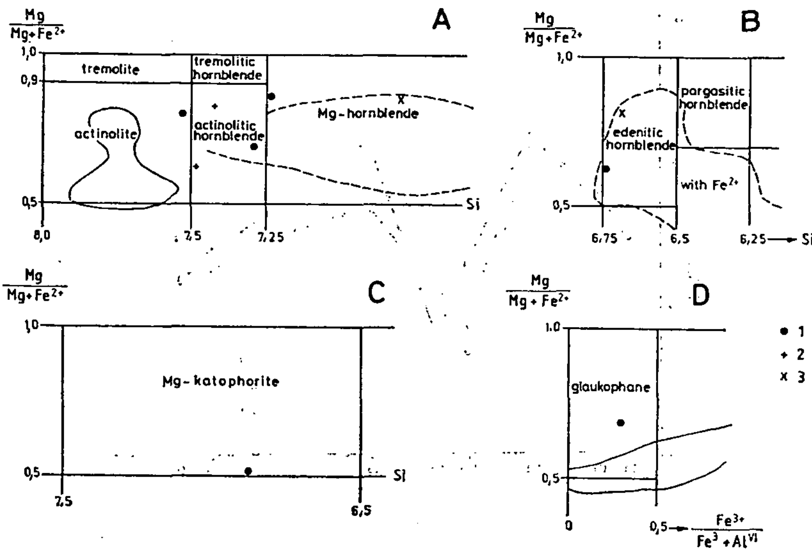

Fig. 20. Amphibole compositions in Laek's system (A, B, C, D categories). (1) from eclogite, diaphtorized eclogite, (2) metadolerite, (3) metagabbro cumulate origin. Continuous line: (A) Ca-amphibole from diaphthorized eclogite, (D) amphibole from a diaphthorized eclogite, altered from high-Fe—Ti gabbro, Voltri Massif, Western Alps (MESSIGA *et al.*, 1988). Dotted line: (A) (B) amphibolite with eclogite relics, Savona crystalline massif (MESSIGA—SCARAMBELLURI, 1988)

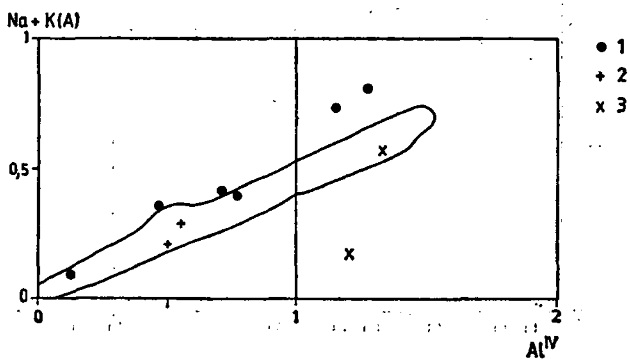

Fig. 21. Formular ratio of tetrahedral Al from eclogite and diaphthorized eclogite (1), metadolerite (2) and metagabbro of cumulate origin (3) in the function of Na+K(A). Continuous line: amphiboles of eclogites from the Sesia Zone of the Western Alps (BIINO *et al.*, 1988)

tion. The chondrite-normalized data *(Figs. 22—23)* show two types. The low average REE content of tremolite-schist *(Fig. 22)* and the shape of the curve clearly shows the connection with the serpentinized ultramafics characteristic for the region.

The other group, which contains the diaphthorized eclogites, too, has a magnitude higher REE content *(Fig. 23)*. Although the curves have similar shapes, there are significant differences in the ratio of light and heavy elements. The curve shapes resemble to that of the oceanic tholeiites, and magmatices of back-arc or intra-arc basins. Differences in La/Lu ratio suggest stronger or weaker differentiated composi-

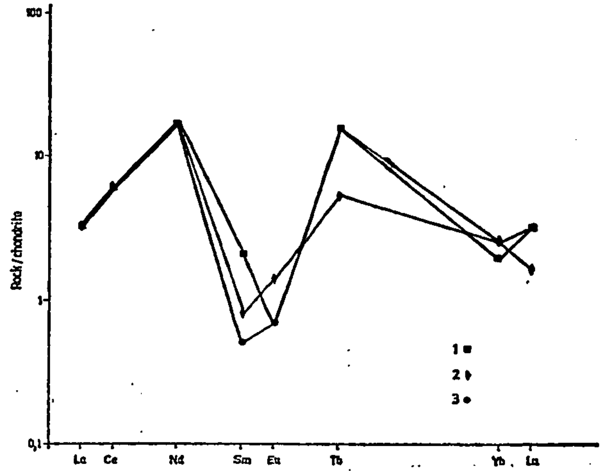

Fig. 22. Ophiolitic metamorphites and ultramafics from overthrust zones: chondrite normalized values of REE contents. 1. tremolite schist, 2—3. serpentinized ultramafics. NW Oriente.

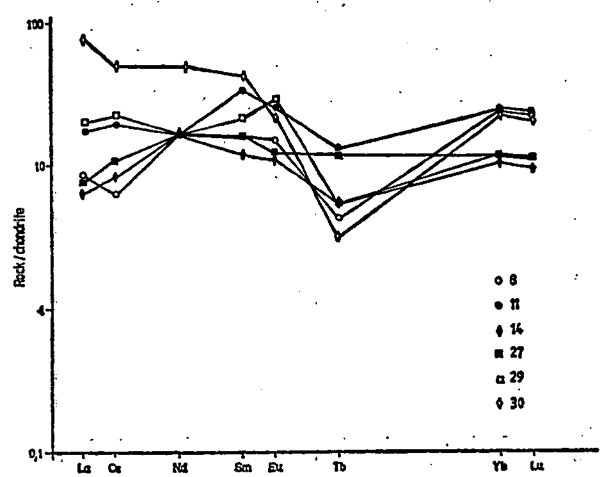

Fig. 23. Chondrite-normalized REE values of diaphthorized eclogites (locality Nos. 8, 11, 14, 27, 30) and garnet-bearing amphibolite (locality No. 29)

tions within the profiles of the investigated regions. We are aware, that REE spectrum of the muscovitic garnet-bearing amphibolite, ranegd to a separate group, is similar to that of the eclogite (except Eu). But the contrasting positive anomaly of Eu compared to that of the eclogite group can suggest significant genetical differences. This geochemical separation makes probable that the metamorphite containing large garnets may have been formed by diaphthoresis of eclogite originating from continental — or transitional — lower crust or from upper mantle of crustal origin.

CONCLUSIONS

1. There are sialic, mafic and ultramafic metamorphites of variable composition as components of tectonic melange or olistostrome-like sediment in NW Oriente. Their present spatial association reflects their allochthonous position. Their original place and composition are highly variable, as shown them MILLAN and SOMIN (1985) for other localities.

2. The La Palma Formation represents an old sialic crystalline crust and possibly Jurassic meta-terrigenous-carbonate sequence of the southern foreland of the North American continental plate. Analogous units are the crystalline and meta-terrigenous-carbonate sequences (BREZSNYÁNSZKY *et al.*, 1981) in Western Cuba, Escambray and Isla de Juventud (MILLAN, 1975; MILLAN—SOMIN, 1985).

3. The eclogitic rocks of Eastern Cuba are very similar to those of the Western Alps regarding their petrology and geochemistry.

4. Most of the mafic-ultramafic metamorphites of the Mateo Formation are considered as of oceanic origin, (see also MATTSON, 1973 and BREZSNYÁNSZKY *et al.*, 1981 for the amphibolites of Eastern Cuba).

5. The high-pressure, eclogitic formations of the Mateo Formation are correlated with the metamorphites appearing as "tectonic xenoliths" of the Northern Cuban melange zone (e.g. Sierra de los Organos, Sierra de Cristal). These are of subduction origin, as MILLÁN and SOMIN wrote (1985). The K/Ar age (upper part of Lower Cretaceous) of the diaphthorized eclogites indicate the end of the alteration, i.e. the time of uplift.

6. The greenschist-facies retrogression in the Western Alps is related to the uplift and overthrust of the high-pressure rocks. On the basis of petrological analogies the evolution of a part of the studied high-pressure rocks from Cuba also can be interpreted the similar way.

7. The formation of most of the schistose, greenschist to amphibolite-facies ultramafic-mafic metamorphic rocks is connected to shear zones of obducting, imbricated young oceanic basins with high geothermic gradient (COLEMAN, 1984). These movements sheared, then dragged the earlier subducted, then uplifted high-pressure, metamorphic rocks, too. The obducted, then overthrusted and imbricated rocks dragged blocks from the continental slope onto the foreland. (La Palma Formation, metamorphites characteristic for the mafic deep crust).

8. The North Cuban collision zone represents the products of multiple subduction, and there are probably ophiolites, which are of different age and suffered metamorphism of different grade.

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