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ON THE PROBLEM OF CUBAN OPHIOLITES

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(4 figs., 5 tables, Czech and Russian Summaries)

Abstract: Petrological, chemical and geological studies of the main belt of Cuban serpentinites lead us to the conclusion that serpentinized ultramafites accompanied by volcanics and deep-sea sediments can be regarded as an ophiolitic suite. This cumulate sequence is interpreted as having been formed by a partial melting of rocks from the upper mantle. This is the first part of a completed study on Cuban ophiolites.

1. INTRODUCTION

Recent studies of ophiolites carried out in various parts of the world have supplied a comprehensive information, but the problem alone remains open for further discussion. Moreover, pertinent problems become most acute and the questions which have to be answered increasingly receive high precision. So far as the origin of ophiolites, their concrete history and relations to geological environment are concerned, it is necessary to study in detail the inner structures of the different members of the ophiolitic suite together with their relation to the overlying and underlying rocks. These tasks are impossible to resolve without performing a detailed petrographical and geochemical study of the individual members of the ophiolitic suite. The Cuban serpentinized ultramafites occur roughly in two geological environments. On the one hand, serpentinites are contained in structural segments formed of metamorphites of Jurassic and Cretaceous ages, e.g. in the domes of Sierra de Trinidad (Escambray) or in the basement complex of Sierra de Purial. The regional distribution of small serpentinite bodies in this environment indicates repeating tectonic effects (nappes, folds and domes) producing such rather extensive structures in the marginal parts of Cuba.

The second type of serpentinites is represented by the "transgeosynclinal" belt occurring at the northern margin of Cuba (fig. 1). In this area the serpentinites are incorporated into the nappe and fold structure developed in Cretaceous to Eocene times. This type of serpentinites, which is spatially separated from the first one, has been the object of our study. In both cases, however, the serpentinites have been found detached from their roots; in the second case they are related to the profiles consisting of geosynclinal volcanics and sedimentary rocks (diabases,

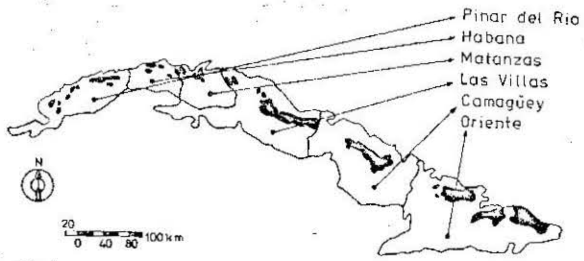

Fig. 1.

limestones, radiolarites). The second group forms the main masses of Cuban serpentinites, and it has been interpreted by some authors (Khudoley, Meyerhoff, 1971) as showing the inner transitions between stratiform large bodies of serpentinites. These are confined to the "deep craton" and Alpine-deformed serpentinites which had been mobilized in younger phases of their tectonic history. On the contrary, Knipper (1975) believes that all the Cuban serpentinites are members of the Alpine-type ophiolitic suite. Variations have been noted not only in the number of the occurrences but also in the size of the second-group ultramafite. The largest massifs occur in the Oriente and Camagüey provinces, but the bodies decrease in size westward. The serpentinites are nearly always accompanied by gabbroids which either rise as parallel dike systems or form bodies of variable shape and size.

2. PETROGRAPHY AND PETROGENESIS

2.1. ULTRAMAFITES

Insofar as possible, ultramafic rocks have been sampled uniformly from all the main bodies of the island. The major part is formed of serpentinites with a variable degree of serpentinization (25—99 %). Weakly serpentinized peridotites occur sporadically.

Lizardite and chrysotile are the major minerals of serpentinites. Antigorite was identified only in some serpentinites of the eastern part of the island. Brucite was found in ultramafites of lower serpentinization grade. Chlorite does not exceed 5 % by volume. Bastite is highly abundant to the detriment of ortho and

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clinopyroxene. Serpentinites are often penetrated by swarms of chrysotile, serpofite and chlorite dikes. Of relics, the primary minerals olivine, orthopyroxene, clinopyroxene and (less) amphibole were discovered. Orthopyroxene is nearly represented by enstatite or bronzite, while clinopyroxene occurs as diopside and diallage. Primary amphiboles (tremolite) were found in samples from the Matanzas province; in this region garnet (pyrope) was also found. Chromhercynite, chrompicotite, alumochromite and both primary and secondary magnetite are the most frequent accessory minerals. In the eastern part of the Oriente province, as well as in the Camagüey province, chromite forms linearly arranged grains or spheroidal aggregates to massive cumulates of lenticular shape, sometimes up to hundreds of metres long. Chromite bodies most often occur at the boundary of harzburgitic and lherzolitic ultramafites.

The studied samples of ultramafites displaying a low serpentinization degree were classified according to Streckeisen (1973) as dunites, harzburgites, lherzolites, wehrlites and plagioclasic peridotites which form transitions into olivine gabbros. This classification of ultramafites has been carried out on the basis of planimetric analyses and calculated normative minerals after Lensch (1968).

2.2. GABBROID ROCKS

In strongly folded areas gabbroid rocks rise in the form of irregular bodies mostly conformable to the surrounding rocks. The largest bodies are a few kilometres long, with their relief rising towards the surrounding terrain. They have been prominently recognized in the Oriente, Camagüey and Las Villas provinces. In other areas of the island there are smoller bodies forming the ruptured blocks and veins. Ultramafic bodies have been intruded by vein-like bodies of gabbroid rocks. Domal bodies are composed of gabbros of various mineralogic composition, while veinlike parallel bodies are formed mainly of fine-grained diabases accompanied by rare gabbroid porphyrites and pegmatites. The gabbroid rocks have often been affected by strong prehnitization and zeolitization.

Olivine, pyroxene, amphibole and leucocratic (anorthosite) gabbros have been distinguished. The diabases are fine-grained to medium-grained. Moreover, clinopyroxene is present and often altered to amphibole. Magnetite and titanite are accessories.

The gabbroid porphyrite has a porphyritic texture with hemicrystalline groundmass. Phenocrysts are formed of labradorite and rare of diopside. The groundmass consists of diopside, desintegrated plagioclase, chlorite, sericite, carbonates and volcanic glass. Scapolite, titanite and magnetite are present as accessory minerals.

2.3. EXOTICS

This group includes metamorphic basic rocks and deep-sea sediments with radiolarites tectonically emplaced in ultramafites.

Metabasics comprise various types of amphibolites showing a roughly similar composition but differing in grain size, degree of alteration or texture. Nearly all of them are intensely prehnitized, chloritized and carbonatized. To this group also belongs sample 64AB representing the garnet amphibolite of a distinct mineralogic composition not subject to the above alterations.

The deep-sea sediments are formed of calcareous grits to sandy limestones of variable grain size. A large amount of radiolarites occur in all the samples. Sample 62A taken from the Pinar del Rio province is fine-grained silicified arkose.

Petrographic study of 160 thin sections of ultramafic and mafic Cuban rocks has revealed certain textural and deformational structural differences in the individual rock types, as well as in the different mineralogical composition connected with these features.

Greatest deformations, both macroscopic (banded textures) and microscopic (a parallel arrangement of minerals in rocks), have been found in dunites and harzburgites. These are most evident features in harzburgites with the grains or grain agglomerates of lighter orthopyroxene displaying a markedly preferential arrangement in the surrounding dark mass. Similarly, aggregates of very fine-grained magnetite also exhibit a markedly parallel arrangement illustrated by darker "laminae" to bands. These features are less distinct in lherzolites.

Surprising differences in the rocks under study have also been found in textures with grain size as the most distinct feature. Dunites and harzburgites always form coarse-grained types. The grain size of forming them minerals ranges from 4 to 8 mm. Olivine varies in size between 4 and 8 mm, whereas enstatite varies between 4 and 6 mm. In the dunites and harzburgites olivine is often embedded in orthopyroxene and its relics range from 0.6 to 0.8 mm in size. The grain size of lherzolite is clearly finer. Olivine and orthopyroxene are 1–2.5 mm across. Clinopyroxene ranges from 0.6 to 0.9 mm in size and unlike mostly allotriomorphic to rounded orthopyroxene and olivine it is very often up to idiomorphic.

Olivine gabbros include clinopyroxene averaging 0.4–1.0 mm in size and olivine with grain size ranging from 0.2 to 0.8 mm. The olivine grains are either rounded or lobate; clinopyroxene is hypidiomorphically bounded and fills interspaces between the plagioclase and olivine or grows around the olivine grains, and or it is enclosed together with olivine in plagioclase. Plagioclases of tabular habit are of bigger size attaining on average 2–3 mm. The mineral composition of these rocks shows a parallel arrangement under the microscope with the alteration of directional bands of plagioclases with dark (mafic) minerals.

The pyroxene-amphibole and amphibole-pyroxene gabbros are characterized by a more or less distinct banded texture and by grains of plagioclases averaging 5 mm in size. Gradually with an increase of plagioclases the dark components of these rock types are becoming less numerous and gabbros are changing into

anorthosites. Diabases show ophitic or subophitic texture and are mostly fine to medium-grained.

As stated by Davies (1971), the textureal, structural and metamorphic features of ultramafic and mafic rocks studied in Cuba are useful in recognizing the effects of a partial melting of subcrustal part and successive differentiation. According to the model of ophiolitic suite zoning the Cuban dunites may be ranged to the so-called metamorphic peridotites, lherzolites to cumulate ultramafites, and olivine gabbros to cumulate basites, the origin of all of which is being derived from the upper mantle. By analogy, it is possible to classify the pyroxene-amphibole and amphibole pyroxene gabbros, as well as, diabases – as "upper" gabbros derived from the oceanic crust.

3. CHEMICAL COMPOSITION

Besides structural and textural features, knowledge of the distribution and chemical composition of rock-forming peridotite minerals (01, Opx, Cpx) is of decisive importance in classifying these rocks as resudial and cumulate types. Partial melting and separation of the melts from an unmelted residue occurs in primary rocks of the upper mantle during thermodynamic metamorphism. So-called "metamorphic peridotites" (dunites and harzburgites) consist of olivine and orthopyroxene forming an unmelted residue. Ultramafic and mafic cumulates (lherzolites, olivine gabbros, pyroxene gabbros, etc.) originate from separated melts and from olivine, as well as orthopyroxene residues.

Olivine, orthopyroxene and clinopyroxene from harzburgites and lherzolites have been studied chemically (tab. 5). From the analytical results obtained for these minerals it is apparent that the olivines from the harzburgites attain values of Fo = 92, 70–93, 90 mol. %, whereas in the lherzolites they are lower, e.g. Fo = 88, 55–89, 60 mol. %, as is shown by a higher Mg/Fe ratio. Similarly, the orthopyroxene in harzburgites attains values equal to En = 91, 0–92, 35 mol. % and in lherzolites to En = 88, 80–89, 75 mol. %, in addition to a higher Mg/Fe ratio. A gradual enrichment in Mg at the expense of Fe was noted in metamorphic peridotite during the processes mentioned above, whereas Fe content increases in cumulates. This difference is still more evident in the NiO content of rock-forming minerals of the metamorphic and cumulate ultrabasites. The minerals of harzburgites show values of 01 = 0.30–0.35 wt. %; Opx = 0.25–0.26 wt. %; Cpx = 0.04–0.06 wt. %, whereas those of lherzolites are within the range of 01 = 0.15–0.25 wt. %; Opx = 0.10–0.11 wt. %; Cpx = 0.01–0.02 wt. %. From these results it follows that the minerals of metamorphic peridotites are enriched in NiO, but those of cumulate ultrabasites (especially in pyroxenes) show a decrease in this component. These observations on NiO distribution are in accord with Mysen's (1976) experiments. Variations in the Ni contents can to some extent be used as a genetic criterion for ultramafic rocks.

A difference in MgO/MgO + FeO ratio has also been found between meta-

Table 1.

Province	Oriente		Havana	PdR*	Oriente		Oriente			Camagüey	
Sample	108	117	23B	63	106	118	4	14	100	104	91
Rock	lherzolite	dunite	wehrlite	lherzolite				serpentinites			
SiO_2	41.23	39.73	43.99	41.28	34.75	39.10	40.61	39.23	37.06	39.62	38.60
TiO_2	0.02	0.03	0.07	0.01	0.01	0.01	0.05	0.02	0.01	0.01	0.01
Al_2O_3	1.75	2.12	2.78	1.10	0.64	1.63	3.01	0.45	3.95	1.22	0.76
Cr_2O_3	0.17	0.21	0.28	0.29	0.26	0.37	0.30	0.33	0.38	0.39	0.20
Fe_2O_3	1.58	2.91	5.02	5.19	3.71	6.76	7.10	7.50	4.38	5.68	5.24
FeO	6.87	4.67	1.14	4.46	3.81	1.17	0.86	2.45	2.00	1.27	1.67
MnO	0.13	0.12	0.11	0.09	0.09	0.06	0.14	0.17	0.06	0.06	0.07
NiO	0.27	0.38	0.19	0.19	0.36	0.26	0.15	0.18	0.09	0.27	0.27
MgO	38.73	39.17	26.63	36.07	40.52	35.83	31.22	35.03	34.48	35.56	36.02
CaO	2.89	1.53	11.29	5.28	0.33	0.47	3.35	4.10	2.80	0.40	0.40
Na_2O	0.27	0.25	0.47	0.01	0.07	0.12	0.20	0.02	0.01	0.02	0.10
K_2O	0.10	0.16	0.09	0.01	0.02	0.02	0.04	0.01	0.01	0.01	0.05
H_2O^+	4.98	7.32	6.26	6.01	12.96	12.11	10.01	9.24	13.11	14.22	14.40
H_2O^-	0.59	0.96	1.27	0.01	1.61	1.66	2.66	1.27	1.60	1.45	2.49
CO_2	0.17	0.01	0.01	0.27	0.58	0.01	0.00	0.28	0.01	0.08	0.01
	99.75	99.57	99.60	100.27	99.72	99.58	99.70	100.28	99.95	100.26	100.29
MgO/MgO + FeO	0,84	0.84	0.83	0.80	0.85	0.83	0.82	0.79	0.71	0.85	0.85

108 – x – 20°10′; y = 74°20′ 23B – x = 23°7′; y = 82°17′ 106 – x = 20°8′; y = 74°20′ 4 – x = 21°1′; y = 76°
117 – x = 20°35′; y – 75°36′ 63 – x = 22°47′; y = 83°25′ 118 – x = 20°35′; y = 75°44′ 14 – x – 20°37′; y = 75°2′
100 – x = 21°39′; y = 77°34′ 104 – x = 21°31′; y = 77°42′ 91 – x = 21°33′; y = 77°53′

Analysts: L. Slamečka, Z. Kludková

Table 2.

Province	Las Villas		Matanzas		Havana	Pinar del Rio			Camagüey		L. Villas
Sample	74	83	71	34	56	38	47	50A	99B	100A	105B
Rock	serpentinites					serpentinites			Px	Ol + Px gabbro	Ol + Px
SiO_2	39.87	38.66	40.36	40.07	39.28	39.86	39.62	40.17	51.40	47.72	47.95
TiO_2	0.02	0.02	0.02	0.03	0.04	0.05	0.01	0.02	0.45	0.24	0.25
Al_2O_3	2.55	0.96	1.12	2.82	1.40	3.11	1.34	0.46	15.80	18.89	17.82
Cr_2O_3	0.28	0.15	0.52	0.26	0.30	0.25	0.20	0.12	0.02	0.10	0.09
Fe_2O_3	4.97	6.73	6.48	6.17	5.85	7.42	6.55	6.86	2.70	0.73	1.72
FeO	1.94	0.94	1.06	1.05	1.46	2.06	0.71	0.42	5.46	3.26	2.95
MnO	0.09	0.06	0.10	0.11	0.03	0.14	0.05	0.07	0.10	0.07	0.06
NiO	0.32	0.33	0.32	0.19	0.28	0.18	0.35	0.52	0.03	0.10	0.11
MgO	35.77	36.55	36.65	32.31	34.57	32.08	33.80	36.65	7.88	12.89	12.92
CaO	0.33	0.53	0.40	2.45	0.33	2.75	0.35	0.30	13.23	12.24	12.33
Na_2O	0.06	0.20	0.12	0.10	0.02	0.01	0.02	0.02	0.55	1.38	1.31
K_2O	0.05	0.10	0.04	0.09	0.01	0.01	0.01	0.01	0.50	0.04	0.01
H_2O^+	12.16	13.47	11.52	11.76	13.48	10.36	13.42	11.87	1.45	1.71	1.56
H_2O_-	1.77	1.44	1.46	2.70	2.21	1.23	3.21	1.97	0.10	0.31	0.45
CO_2	0.07	0.04	0.01	0.01	0.43	0.20	0.05	0.18	0.00	0.01	0.00
P_2O_5	—	—	—	—	—	—	—	—	0.28	0.03	0.01
	100.25	100.18	100.18	100.12	99.69	99.71	99.69	99.64	99.95	99.72	99.54
MgO/MgO + FeO	0.85	0.84	0.84	0.83	0.84	0.79	0.84	0.85	0.50	0.77	0.74

74 – x = 22°6′; y = 79°1′ 34 – x = 22°52′; y = 81°21′ 47 – x = 22°52′; y = 83°18′ 100A – x = 21°39′; y = 77°34′
83 – x = 22°12′; y = 79°23′ 56 – x = 23°7′; y = 82°8′ 50A – x = 22°52′; y = 83°16′ 105B – x = 21°31′; y = 77°34′
71 – x = 23°2′; y = 81°21′ 38 – x = 22°54′; y = 82°42′ 99B – x = 21°32′; y = 77°45′

Table 3.

Province	L. Villas	Havana	Pinar del Rio			Oriente				Oriente	
Sample	80	54B	38A	43	43A	118B	4A	5A	6A	6B	121B
Rock	Am + Ol gabbro	leuco.	Px + Am	Ol gabbro		diabase		diabase		diabase	
SiO_2	49.52	46.00	49.06	40.97	48.15	42.10	51.70	50.33	47.05	42.29	48.47
TiO_2	0.20	0.25	0.12	0.22	0.35	0.98	0.32	0.65	0.99	1.00	0.96
Al_2O_3	15.30	27.50	20.06	6.96	14.42	14.63	13.96	11.00	6.16	14.55	16.16
Cr_2O_3	0.04	0.003	0.16	0.01	0.19	0.02	0.01	0.10	0.01	0.03	0.06
Fe_2O_3	1.05	0.80	0.59	5.71	1.24	6.30	1.24	2.50	2.63	3.29	3.89
FeO	3.89	4.31	3.09	4.63	4.99	7.52	6.83	7.17	8.52	7.55	6.43
MnO	0.01	0.11	0.07	0.15	0.09	0.14	0.18	0.19	0.22	0.24	0.14
NiO	0.02	0.003	0.01	0.18	0.04	0.01	0.03	0.01	0.01	0.01	0.02
MgO	12.25	3.52	10.51	26.58	13.40	9.72	7.03	8.66	19.05	7.14	7.17
CaO	11.49	12.54	13.23	5.88	13.22	14.85	11.58	16.05	10.00	18.40	12.95
Na_2O	2.06	0.77	0.50	0.01	0.63	1.23	4.31	0.91	0.15	0.90	1.78
K_2O	0.01	0.07	0.04	0.01	0.05	0.15	0.27	0.40	0.07	0.30	0.01
P_2O_5	3.23	0.02	0.04	0.04	0.04	0.12	0.20	0.01	0.01	0.01	0.12
H_2O^+	0.69	3.93	1.69	7.35	2.74	1.51	1.85	0.63	4.31	3.62	1.69
H_2O_-	0.01	0.12	0.68	0.97	0.53	0.28	0.44	0.62	0.71	0.81	0.20
CO_2	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.33	0.06	0.13	0.01
	99.78	99.946	99.85	99.68	100.09	99.57	99.96	99.56	99.95	100.27	100.06
MgO/MgO + FeO	0.72	0.41	0.74	0.73	0.69	0.42	0.47	0.48	0.64	0.40	0.42

80 – x = 22°13′; y = 79°11′ 43 – x = 22°47′; y = 83°32′ 4A – x = 21°1′; y = 76" 6B – SEE 6A
54B – x = 23°8′; y = 82°10′ 43A – x = SEE 43 5A – x = 20°59′; y = 75°48′ 121B – x = 20°52′; y = 76°21′
38A – x = 22°54′; y = 82°42′ 118B – x – 20°35′; y = 75°44′ 6A – x = 20°58′; y = 75°49′

Table 4.

Province	Gamagüey	Las Villas		Matanzas	Pinar del Rio			Oriente	Las Villas
Sample	10	64B	83B	37B	52A	53A	43B	123D	75
Rock	diabase		diabase			diabase			porphy. granite
SiO_2	47.71	50.76	52.24	50.82	46.00	48.00	48.06	52.40	70.40
TiO_2	1.30	0.99	0.79	1.37	1.55	0.95	0.85	0.35	0.19
Al_2O_3	14.30	15.14	14.75	16.41	13.50	20.40	18.53	20.00	21.60
Cr_2O_3	0.04	0.01	0.01	0.03	0.02	0.00	0.02	0.00	0.00
Fe_2O_3	1.74	2.19	1.09	0.81	3.84	0.47	0.32	2.53	0.95
FeO	6.21	6.90	7.20	8.69	8.43	7.90	5.47	2.87	0.28
MnO	0.19	0.12	0.94	0.15	0.17	0.17	0.10	0.10	0.02
NiO	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.00	0.00
MgO	10.30	8.70	7.96	9.82	8.67	7.00	8.90	3.16	0.64
CaO	10.60	9.83	10.54	7.84	12.10	10.20	13.60	7.86	2.14
Na_2O	1.95	1.14	1.59	1.54	2.02	0.68	0.50	0.65	1.06
K_2O	0.04	0.25	0.17	0.01	0.08	0.85	0.16	7.60	2.18
P_2O_5	0.14	0.01	0.01	0.01	0.06	0.31	0.10	0.18	0.17
H_2O^+	4.56	3.01	2.56	1.46	2.55	3.00	2.15	2.60	0.70
H_2O_-	0.45	0.51	0.41	0.61	0.63	0.15	1.06	0.00	0.00
CO_2	0.01	0.01	0.01	0.01	0.50	0.00	0.17	0.00	0.00
	99.56	99.59	100.29	99.59	100.13	100.09	100.02	100.30	100.33
MgO/MgO + FeO	0.57	0.50	0.49	0.51	0.42	0.46	0.61		

10 – x = 21°26′; y = 77°50′ 37B – x = 22°56′; y = 81°52′ 43B – x = 22°47′; y = 83°32′
64B – x = 22°47′; y = 80°20′ 52A – x = 22°53′; y = 83°10′ 123D – x = 20°53′; y = 76°13′
83B – x = 22°12′; y = 79°23′ 53A – x = 22°44′; y = 83°8′ 75 – x = 22°15′; y = 79°37′

Table 5.

Sample	108			117			41		
Rock	Harzburgite 15 % serp.			Harzburgite 45 % serp.			Harzburgite 40 % serp.		
Mineral	Ol	Opx	Cpx	Ol	Opx	Cpx	Ol	Opx	Cpx
SiO_2	41.20	58.50	54.80	41.40	57.80	53.80	41.40	57.90	54.60
FeO	7.15	5.00	2.40	6.20	6.30	4.40	7.00	7.40	3.60
NiO	0.35	0.25	0.05	0.30	0.26	0.04	0.26	0.12	0.02
MgO	51.30	36.20	17.00	52.00	35.64	15.65	51.34	34.25	16.40
CaO	0.00	0.00	25.60	0,00	0.00	25.80	0.00	0.00	25.35
	100.00	99.95	99.85	99.90	100.00	99.69	100.00	99.67	99.97
Mol. % Fo	92.70			93.73			92.88		
Mol. % En		92.30			91.00			89.07	
Sample	52			63			122		
Rock	Lherzolite 65 % serp.			Lherzolite 25 % serp.			Lherzolite 50 % serp.		
Mineral	Ol	Opx	Cpxi	Ol	Opx	Cpx	Ol	Opx	Cpx
SiO_2	40.80	58.00	54.70	40.70	57.80	54.45	40.60	58.00	54.40
FeO	10.10	7.20	3.80	11.00	7.65	3.85	11.05	7.00	4.32
NiO	0.20	0.10	0.01	0.15	0.10	0.02	0.25	0.11	0.01
MgO	48.80	34.30	16.50	48.15	34.45	16.08	47.90	35.00	15.85
CaO	0.10	0.15	25.50	0.00	0.00	25.60	0.00	0.10	25.34
	100.00	99.75	99.96	100.00	100.00	100.00	99.80	100.21	99.92
Mol. % Fo	89.60			88.65			88.55		
Mol. % En		89.50			88.80			89.75	

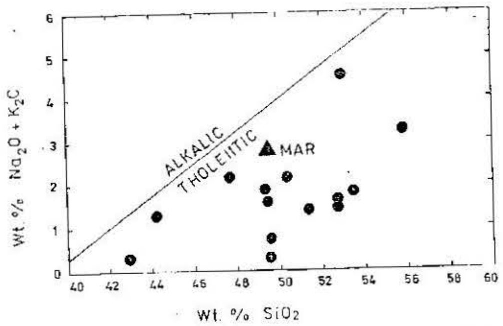

Fig. 2. $Na_2O + K_2O$ versus SiO_2 diagram of diabasic rocks from Cuban ophiolites. MAR is the average of Mid-Atlantic Ridge basalt. All are plotted in weight percent after substracting total water + CO_2 and normalizing.

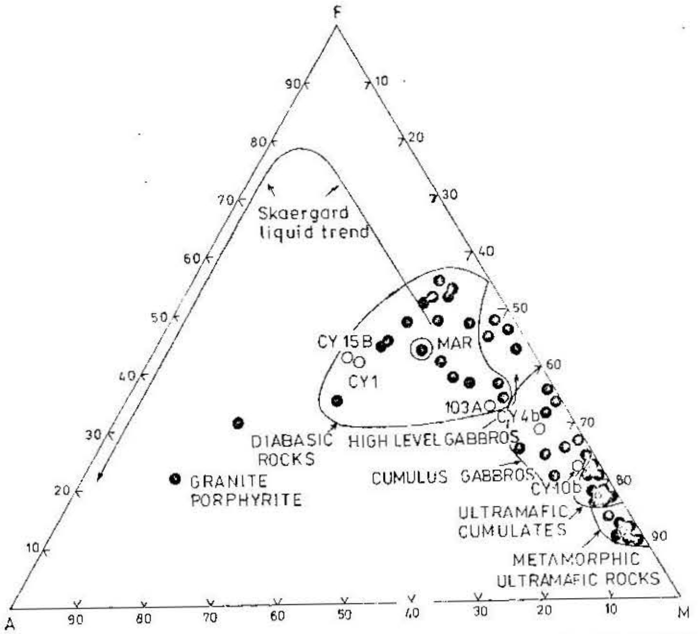

Fig. 3. AMF diagram showing analysed rocks from Cuban ophiolites as compared with ophiolites of Troodos–Cyprus after Kay, Senechal (1976), MAR and Skaergard liquid trend differentiation.

morphic and cumulate ultramafites. In the metamorphic ultramafites and cumulates this ratio ranges within 0.82–0.85 and 0.71–0.84, respectively.

Figure 2 illustrates a relation between the sum of alkalies ($Na_2O + K_2O$) and SiO_2 content in diabasic rocks rising in the form of parallel dikes. All the projection points fall within the field of tholeiites which are compared with average tholeiites from the Mid-Atlantic Ridge (MAR). The relatively higher content of alkalies obtained from two analyses is due to a more intense zeolitization of these rocks.

The AFM diagram in fig. 3 shows clearly that the trend of an ophiolitic suite can be distinguished from the crystallization trend of Skaergard melts. On this diagram metamorphic ultramafites rich in Mg are differentiated. With increasing FeO content (total Fe is converted to FeO) ophiolites change into cumulate ultramafites, cumulate gabbros and noncumulate gabbros. There is a tendency for

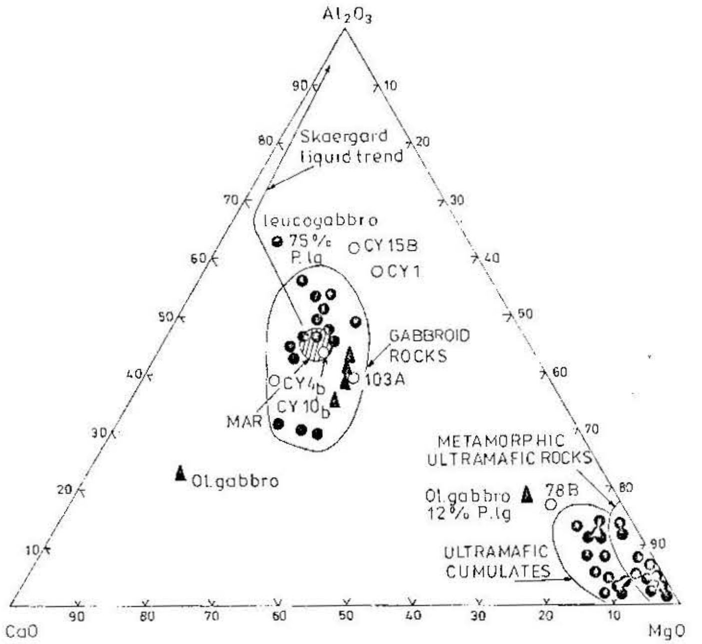

Fig. 4. $MgO-CaO-Al_2O_3$ diagram of mafic and ultramafic cumulate rocks in weight percent from Cuban ophiolites as compared with ophiolites of Troodos–Cyprus after Kay, Senechal (1976), MAR and Skaergard liquid trend differentiation.

diabases to approach alkaline metals. A tholeiitic average of the Mid-Atlantic Ridge falls within the central part of the diabasic field. Besides Cuban ophiolites, mafic cumulates from Cyprus are also plotted on the diagram (empty circles).

The $CaO-MgO-Al_2O_3$ diagram (fig. 4) also deliminates the position of metamorphic and cumulate ultramafites which tend towards Al_2O_3 with an increasing amount of Cr-spinels and garnets. The differentiation of these two types of the ophiolitic suite is evident according to CaO content. The cumulate gabbros lie in the same field as noncumulate gabbros and diabases. Samples denoted by the black triangle are olivine gabbros. The adjustment of projection points of gabbroid rocks in the upper part of this field indicates the possibility of the Skaergard type differentiation in the uppermost members of the ophiolitic suite. Projection points of mafic ophiolites from Cyprus are also plotted on the diagram.

4. CONCLUSIONS

The metamorphic peridotites (dunites, harzburgites) and their serpentinized equivalents exhibit a primitive and a relatively uniform composition. The assumption that these rock types originated by a partial melting of intracrustal parts is supported by the presence of uniform textural features (grain size, deformation), higher Mg and Ni contents and the absence of sulphides. The cumulate ultramafites (lherzolites, wehrlites) differ from the previous group in the higher Ca and Fe but lower Ni contents. Ca, Fe and Al contents increase in cumulate gabbros. Noncumulate gabbros also tend to behave in a similar manner. The Cuban diabases display features analogous to those of deep-sea tholeiites (MAR). The chemical composition of Cuban gabbroid rocks shows resemblance to that of their equivalent types of the Troodos Massif. The presence of lizardite and chrysotile (and the absence of antigorite) in serpentinized peridotites, diabases and gabbros, as well as the manifestations of zeolitization, prehnitization and chloritization are all features indicating the subductive character of dynamometamorphic changes in Cuba (Coleman, 1977). Another characteristic feature is the presence of metabasic rocks and deep-sea sediments in ultramafites which was described by Pejve (1972).

The facial and structural analysis of the Cuban orthogeosyncline shows that it is a megastructure formed by complex geotectonic processes during which numerous mechanisms took place as may be derived from plate tectonic models. Characteristic feature of this developmental type is the formation of oceanic ridges accompanied by spreading. In the Greater Antilles, however, the spreading was soon replaced by subduction processes that accompanied or indicated the nappe and fold bivergence structures at higher structural levels. These events were then followed by regional thrusts and blocks during the activity of transformed faults. The hypertrophy in some members of the geosyncline profile, as well as the features of incompletion or premature completion of the development and transient structures are all important features noted by many scientists synthetizing Cuban geology. Petrogenetical, geochemical and geotectonic results obtained from the

northern zone of Cuban ultramafites support the opinion that these rocks may be ranged together with their accompanying volcanics and deep-sea sediments to the ophiolitic suite.

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REFERENCES

COLEMAN R. G. (1977): Ophiolites; Ancient oceanic Lithosphere? – Minerals and Rocks. Vol 12, Springer Verlag, 240 p. Berlin, New York.

DAVIES H. L. (1971): Perdiotite-gabbro-basalt complex in eastern Papua: An overthrust plate of oceanic mantle and crust. – Australian Bur. Min. Resour Bul., 128, 48 p. Camberra.

JAROŠ J. (1974): Význam interpretace ofiolitové suity pro geosynklinální teorii. – Mineralia slovaca, 6, 1, 79–86. Bratislava.

JUDOLEY C. M., FURRAZOLA G. B. (1971): Geologia del area del Caribe y de la Costa del Golfo de Mexico. – Min. Comple. Met. Rept. Geol., p 1–236. La Habana.

KAY R. W., SENECHAL R. W. (1976): The rare earth geochemistry of the Troodos Ophiolite Complex. – J. Geophys. Res., 81, 5, 964–970. Washington.

KHUDOLEY K. M., MEYERHOFF A. A. (1971): Paleography and Geological History of Greater Antilles. – The Geol. Soc. of Amer. Inc. Mem., 129, 1–187. Boulder, Colorado.

KNIPPER A. L. (1975): Okeaničeskaja kora v strukture Alpijskoj skladčatoj oblasti. (Jug Evropy, Zapadnaja časť Azii i Kuba). – Izdat. Nauka., 5–205. Moskva.

KUDĚLÁSEK V., POLICKÝ J., ZAMARSKÝ V. (1969): A contribution to the geochemistry and petrology of the ultrabasics of Cuba. – Acta Univ. Carolinae – Geol., 2, 119–131. Prague.

KUMPERA O. (1969): Geological evolution of the Sierra de Nipe Mountains, with regard to the geological history of the block of Oriente (Cuba). – Sbor. věd. prac. VŠB, 15, 3, 101–118. Ostrava.

LENSCH G. (1968): Der normative Mineralbestand von Mafititen. – N. Jb. Miner. Mh. 306–320. Stuttgart.

MEYERHOFF A. A., MEYERHOFF H. A. (1972): Continental drift IV. The Caribbean plate. – J. of Geology, 80, 1, 34–60. Chicago.

MYSEN B. (1976): Partitioning of samarium and nickel between olivine, orthopyroxene and liquid; Preliminary data at 20KBAR and 1 025 °C. – Earth and Planetary Science Letter, 31, 1–7. Amsterdam.

OREL P. (1977): Geologicko-metalogenická studie rudní provincie Las Villas, Cuba (střed a jih). – Českosl. Kubán. geol. expedice Escambray, Santa Clara, 1–207. MSÚÚG Brno.

PEJVE A. V. (1977): Ofiolity: Sovromennoje sostojanie i zadači issledovanija. – Geotektonika, AN SSSR, 6, 4–14, Moscow.

STRECKEISEN A. (1973): Classification and nomenklature of plutonic rocks. – IUGS subcommission on systematic of igneous rocks. Geotimes 18 (10), 26–30.

THAYER T. P. (1967): Chemical and structural relations of ultramafic and feldspathic rocks in alpine intrusive complexes. – In: Ultramafic and Related Rocks. Willie P. J. (edit). New York: Wiley 1967, pp 222–238.

K PROBLÉMU KUBÁNSKÝCH OFIOLITŮ

Výzkumy petrologie a chemismu hlavního pásma kubánských serpentinitů, podobně jako ostatní geologické studie vedou k závěru, že serpentinizované ultramafity spolu s doprovodnými vulkanity a hlubokomořskými sedimenty lze interpretovat jako ofiolitovou suitu. Kumulátová sekvence je odvozována parciálním tavením hornin svrchního pláště.
Předložená zpráva je první částí ukončené studie.

К ПРОБЛЕМЕ КУБИНСКИХ ОФИОЛИТОВ

Исследования петрологии и химизма главной зоны кубинских серпентинитов, как и другие геологические научные статьи приводят к заключению, что серпентинизированные ультрамафиты вместе с сопутствующими вулканитами и глубокоморскими отложениями можно интерпретировать как офиолитовую серию. Кумулатовая секвенция выводится из парциального плавления горных пород верхней мантии.

Представленный отчет является первой частью оконченной статьи.