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PETROLOGICAL REVIEW OF THE ÓFALU SERPENTINITE, MECSEK MOUNTAINS, HUNGARY

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SUMMARY

The Ófalu serpentinite as a 10 m thick sill-like body lies in the metamorphites of the Ófalu Group. It consists of two varieties petrographically: 1. massive serpentinite, 2. sheared serpentinite due to the powerful tectonism of the "Mecsekalja Tectonic Belt" including the Ófalu Group. Main minerals of the serpentinite are lizardite, clinochrysotile, antigorite and chlorite with disseminated ore grains among them, such as chromite, magnetite, pentlandite, heazlewoodite and subordinate sulphide minerals. Based on data of the chemical analyses and Ni/Co ratio this rock belongs to so called "Alpine-type" serpentinites. The Ni and Cr content as well as MgO/SiO_2 ratio suggest an ultramafic- more accurately harzburgite-lherzolite origin. Process of serpentinization took place at 450—500 °C temperature and 0,5—1 Kb pressure. The serpentinite mass together with parent rocks of metamorphites of the Ófalu Group suffered a low grade regional metamorphism at the circumstances of the greenschist-amphibolite transitional facies.

INTRODUCTION

A few kilometers southeast of Ófalu village (Mecsek Mountains) a sill-like serpentinite mass crops out surrounded by low grade metamorphites. The short geological description of this serpentinite was made formerly by GHANEM and RAVASZ-BARANYAI, [1969] and T. SZEDERKÉNYI, [1974]. The scope of the present study has been focussed on the brief description of lithostratigraphic building up, petrography, mineralogy, ore-mineralogy and petrochemistry in order to throw more light on the origin, serpentinization and regional metamorphism of the Ófalu serpentinite.

GEOLOGICAL SETTING

The Ófalu serpentinite crops out in the form of sill-like body of about 10 m thickness. It trends in NNE-SSW direction in strict parallelism with regional trend of the enveloping eugeosynclinal metasedimentary and metavolcanic rocks of the Ófalu Group, M. F. GHONEIM—T. SZEDERKÉNYI, [1977]. The place of the Ófalu serpentinite within the SE Transdanubian Crystalline Mass is presented by *Fig. 1.*

It seems to be a part of the "Mecsekalja Tectonic Belt" together with metamorphites of the Ófalu Group, T. SZEDERKÉNYI, [1974]. Site of the Ófalu serpentinite within metamorphites of the Ófalu Group is marked by geological sketch-map of the area Ófalu by M. GHONEIM, [1977], *Fig. 2.*

Producing an artificial outcrop of the serpentinite body, its real size can be seen as well as relations with the host metasedimentary rocks, *(Fig. 3.)*

The adjacent host rocks are represented by carbonate bearing phyllitic tuffs, more exactly serizite-phyllite and siliceous shale with definite tectonic zones on both side of the serpentinite body. These tectonic zones are full of traces of hydro-

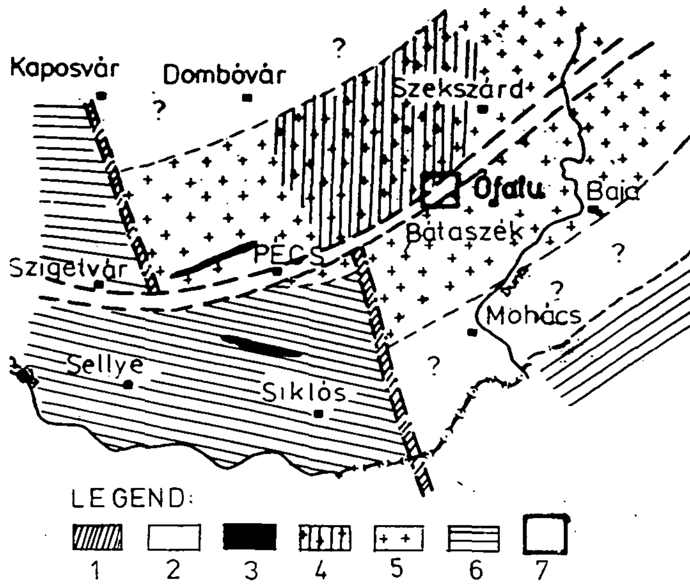


Fig. 1. Geological-tectonic sketch of South-East Transdanubia at the beginning of Late Paleozoic, by T. SZEDERKÉNYI, [1970]. Legend: 1. Precambrian (?) tectonic belt. 2. Variscan tectonic belt with Ófalu Group. 3. Ultramafic bodies. 4. Silurian rocks underlying with granites. 5. Granites, migmatites. 6. Crystalline schists with effective strikes. 7. Site of the Ófalu Group

thermal effects, such as dolomitic and quartz veins, high arsenic and chalcophile element content, etc., but groundmass of the serpentinite body is also crossed by veinlets as well as clusters of carbonates (mainly dolomite). No relict mineral of the original parent rock has been recorded. The serpentinite is represented by two rock types: 1. massive serpentinite having a light grey colour with black spots and „mesh" texture, 2. sheared serpentinite giving a major portion of the rock, accompanied to the tectonic borders of the mass. This latter rock type is full of bright red patches due to oxidation of rather high FeO content and exhibits the following characteristics: lack of the "mesh" texture, abundant of carbonate granules, high undulose extinction of serpentinite minerals, as well as common occurrences of antigorite.

MAIN MINERALS OF THE SERPENTINITE

Some representative samples of the Ófalu serpentinite were investigated by DTA method. Detection of serpentinite minerals from the DTA curves was carried out in accordance with G. T. FAUST and FAHEY J. J. [1962].

Sample №. 215. contains a mixture of lizardite, chrysotile and antigorite admixed with chlorite and dolomite *(Fig. 4a)*. The above-mentioned serpentine minerals give a large endothermic peak at 765 °C on the DTA curve, while the chlorite is indicated by a relatively small endothermic deflection at 663 °C. Decomposition reaction of dolomite and chlorite is represented by an endothermic peak at 875 °C.

Sample №. 216. consists of chrysotile + lizardite as indicated by major endothermic peak at 675 °C followed by an exothermic one at 805 °C *(Fig. 4b)*.

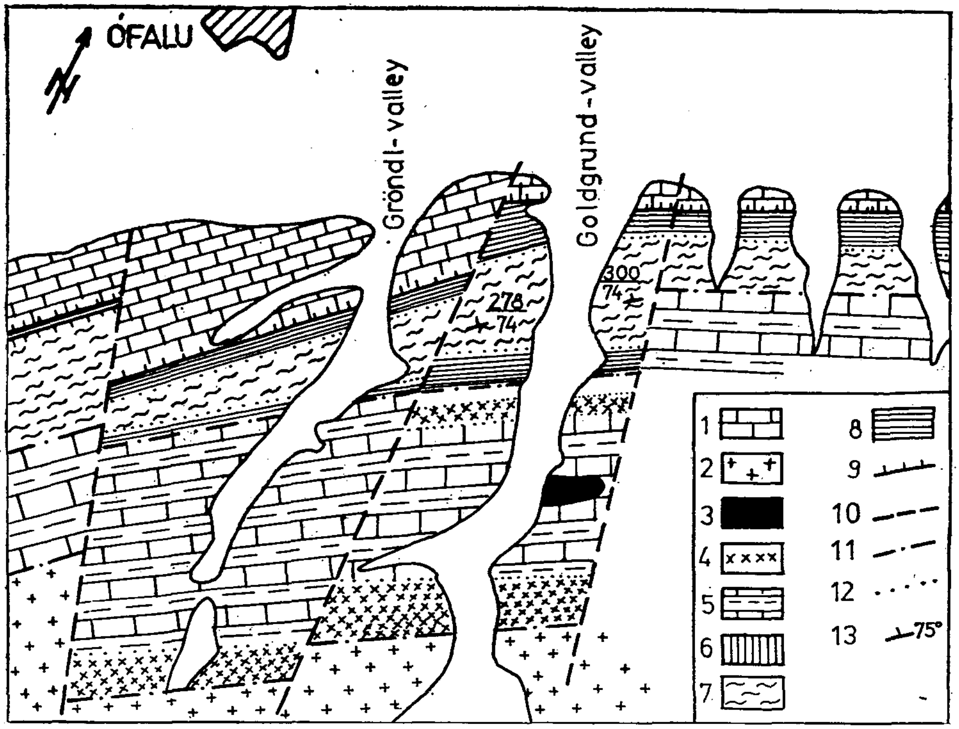


Fig. 2. Geological sketch-map of the area Ófalu, by M. GHONEIM, [1977]. Scale: 1 : 25 000. Legend: 1. Jurassic limestone, 2. Anatectic granite, 3. Serpentinite and associated rocks, 4. Albite porphyry, 5. Marble and phyllitic tuffs, 6. Amphibolite, 7. Mica schist, 8. Andesitic basalt and its metasomatized varieties, 9. Intra-Pannonian overthrusting zone, 10. Faults, 11. Approximate formation contact, 12. Gradational contact, 13. Strike and dip.

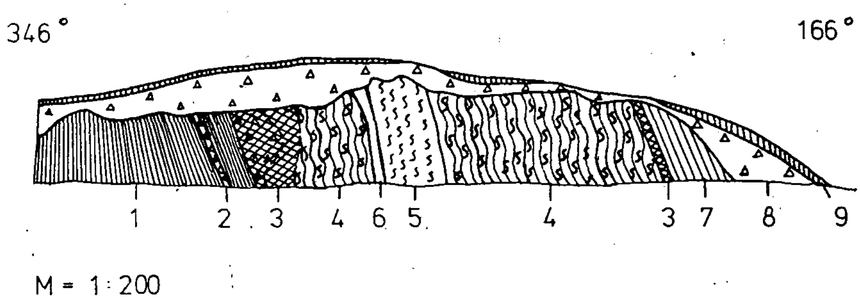


Fig. 3. Profile of the opencast Ófalu serpentinite mass. Scale: 1 : 200. Legend: 1. Serizite-phyllite, 2. Serizite-phyllite breccia, 3. Tectonic zone, 4. Sheared serpentinite, 5. Massive serpentinite, 6. Chlorite schist, 7. Siliceous shale, 8. Talus, 9. Loess

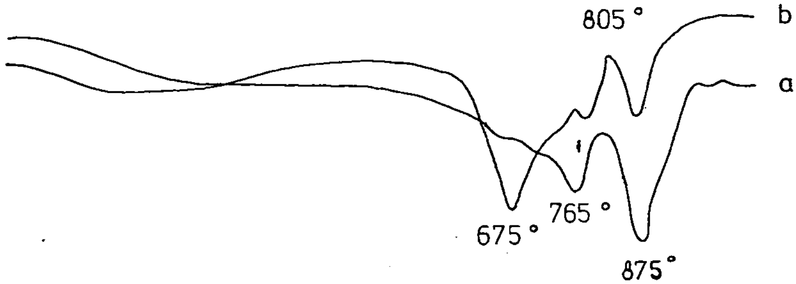


Fig. 4. DTA curves for Ófalu serpentinite. *a)* Sample №. 215, sheared serpentinite consists of antigorite, chlorite and dolomite. *b)* Sample №. 216, massive serpentinite consists of chrysotile+lizardite and dolomite+chlorite

Based on X-ray diffraction the Ófalu serpentinite consists of the following mineral association:

(a) Lizardite: characterized by the (202) peak at 2.501 Å and pair peaks (of relatively low intensity) (060) and (208) at 1.534 Å as well as 1.504 Å. Other characteristic indices are somewhat weaker and overlapped by else constituents.

(b) Clinochrysotile: is indicated by moderately high (202) peak at 2.460 Å.

(c) Antigorite: shows a (202) peak which lies at 2.528 Å, this is the strongest peak and characteristic of antigorite. Other reflections for antigorite are masked by (060) reflection of lizardite which is included in the rock.

(d) Chlorite of the Ófalu serpentinite is IIb monoclinic polytypic modification. The (001) reflection is equal to 14.254 Å and the octahedral aluminum content is (=1.05). The present chlorite is close to clinochlorite according to M. H. Hey's classification.

OPAQUE MINERALS

Ore mineralogical study of the Ófalu serpentinite was decided as an important tool to elucidate the real nature and genesis of these rocks. The polished sections were investigated under reflected light microscope, using oil immersion and high power magnification. Electronprobe microanalysis was carried out on JEOL JXA 5 type electronprobe microanalyser. The standards employed were synthetic CrK_α, FeK_α, etc. Refinement of data and computer programming were made by utilizing P. Duncumb and E. M. Jones, [1969], and G. Nagy, [1970]. Generally, the ore minerals of the present serpentinite are represented mainly by chromite (together with its alteration derivatives) and lesser amounts of magnetite and sulphides.

(a) *Chromite* crystals examined in reflected light occur as euhedral to rounded grains rimmed by single or double zones of relatively higher reflectivity, *(Fig. 5)*. The cores of the crystals are relatively fresh and exhibit a characteristic greyish colour and low reflectivity, especially under oil immersion. The chromite is generally isotropic, inner reflections are seldom met with. It presents usually fractured and cracked structure. The chromite with its decoloration band usually forms a myrmekite-like intergrowth (1 mm across) with the gangue groundmass.

As determined by electronprobe microanalysis, the inner zone of the chromite crystals are enriched in Cr_2O_3, Al_2O_3 and MgO (Table 1). The molecular composition

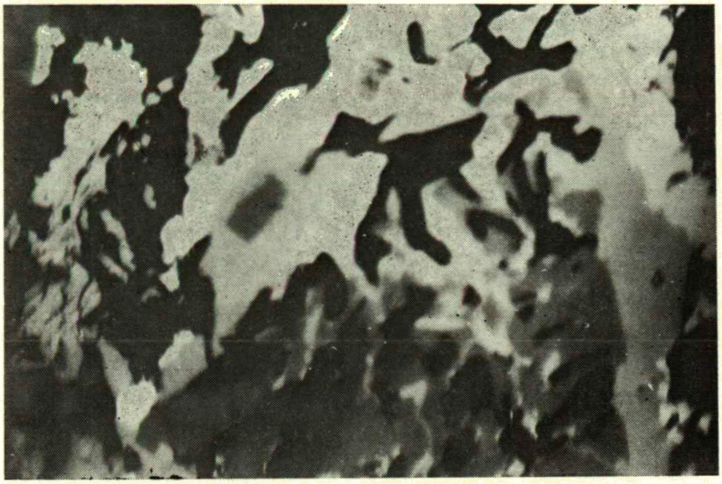


Fig. 5. Photomicrograph of the Ófalu serpentinite showing myrmekitic intergrowth of opaque minerals with the groundmass of gangue (silicate minerals) and double zoning of chromite formed of deep grey colour at the core surrounded by middle grey inner zone and light grey outer one
Reflected light, oil immersion. Mag. 320×

of the inner zone was calculated on the basis of 32 oxygen atoms, the chemical analyses were recalculated to 100% and FeO and Fe_2O_3 were computed assuming a perfect spinel stoichiometry. The chemical formula is then simplified, so the approximate composition accordingly is close to

$$(Mg_{0,35}Fe^{2+}_{0,65})\cdot(Cr_{1,3}Fe^{2+}_{0,4})O_4$$

The outer zone has higher reflectivity than the inner one and progressively merges into magnetite which sometimes is martitized along (111) and the (001) directions. The outer zone is distinguished by an abrupt deficiency of Cr_2O_3, Al_2O_3 and MgO (Table 1). The molecular composition of the outer zone is

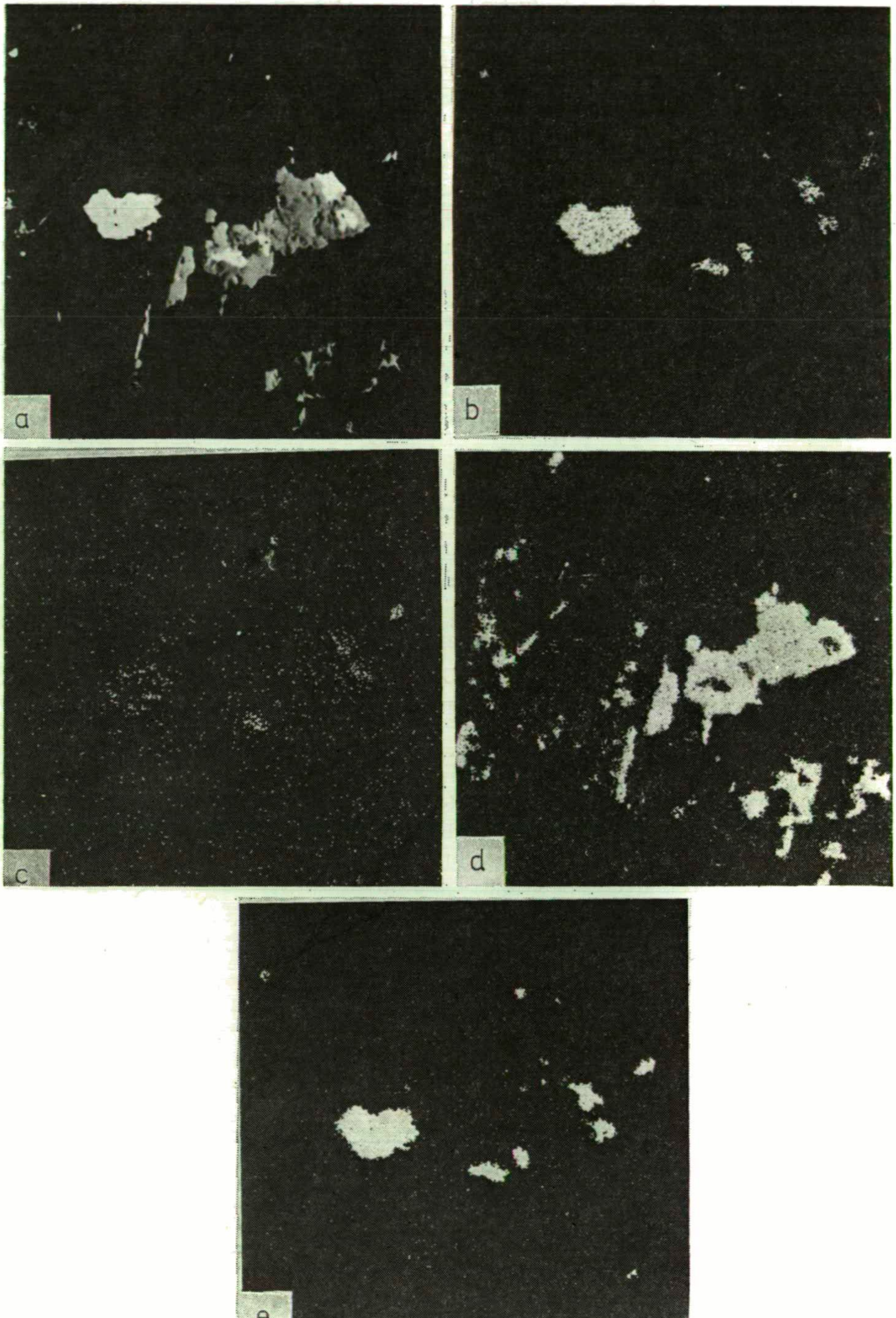
$$(Mg_{0,05}Fe^{2+}_{0,95})\cdot(Cr_{0,03}Fe^{2+}_{1,95}Al_{0,02})O_4$$

TABLE 1

Oxides	1	2	3	4	5
Al_2O_3	3,03	0,50	0,01	8,40	1,70
Cr_2O_3	45,84	3,17	0,03	53,58	3,50
MgO	6,45	1,05	0,86	4,02	1,06
FeO	22,23	28,59	24,71	17,48	34,00
Fe_2O_3	21,78	65,69	69,34	16,58	59,50
TiO_2	0,50	0,53	0,06	—	—
Total	99,83%	99,53%	95,01%	100,06%	100,30%

The analyses were carried out at the Geochemical Research Laboratory of Hungarian Academy of Science.

PLATE I



1. Chromite. Core crystal from the zoned chromite, central Manitoba. [N. W. Bliss and W. H. Maclean, 1975]
2. Magnetite as outer zone of ferrite-chromite [N. W. Bliss and W. H. Maclean 1975]
3. Magnetite as discrete grain in serpentinite [N. W. Bliss and Maclean W. H. 1975]
4. Zone I (inner zone) of alteration of chromite, Ófalu serpentinite
5. Zone II (outer zone) of alteration of chromite, Ófalu serpentinite

(b) *Magnetite* crystals are less abundant than chromite. They occur in different forms and different generations. 1. Shells or crust surrounding an early ferrit-chromite which seems to be of secondary origin. 2. Disseminated grains in the form of fine rounded octahedral grains of about 0.06 mm diameter, as well as stringers or trains of grains concentrated to form partial or complete "veils" around serpentinite clusters. The latter represents the margins of the original olivine grains. There are subordinate forms of magnetite, such as brecciated and fractured grains. The magnetite sometimes altered to sulphide minerals, in which the alteration started from outer parts and extended to inner ones.

(c) *Sulphides*. Sulphide minerals represent less than 10% of the total opaques and they occur as highy disseminated anhedral to subhedral grains of 0.01 mm in diameter, as well as a complex intergrowth of ore minerals including a chromite core surrounded by a ferrit-chromite rim and the latter is partly replaced by sulphide, mainly pentlandite. In addition, the sulphide and chromite form grains in juxtaposition. The contact between the minerals is always rectilinear.

— Pentlandite: represents the main sulphide mineral in the Ófalu serpentinite. It occurs very commonly as traces and replacement relict in magnetite. It is light cream in colour and distinguished by an isotropic character differing it from pyrrhotite. The latter is anisotropic with very characteristic yellow colour shades.

— Heazlewoodite. Electron-probe distribution of Ni, Co, Fe and S in heazlewoodite are shown in Plate I. Analysis of the Ófalu heazlewoodite yielded a sulphur content of 30%, Fe content of 1%, Co ranging from 0.6 to 0.7% and Ni attaining 55%. The latter element is relatively poorer than in other natural heazlewoodites. Pyrrhotite is commonly associated with pentlandite and heazlewoodite as an alteration product.

— Chalcopyrite and some pyrite grains are also encountered in few cases as triads and anhedral grains.

PETROCHEMISTRY

Eleven chemical analyses of the Ófalu serpentinite are listed in Table 2. They are plotted in AFM diagram *(Fig. 6.)* It is expedient to notice that P. J. Wyllie, [1967] and T. P. Thayer, [1967b] used the AFM diagrams to illustrate the chemical behaviour of their ultramafic rocks. O. R. Bowes *et al.* [1966] used similar diagram to compare the chemical trends of Alpine-type ultrabasic rocks with other types ultramafic and mafic gneisses in the Lewisian. P. J. Wyllie, [1967] and T. P. Thayer, [1967b] re-

Explanation of Plate I
a) Black-scattered electron picture of heazlewoodite crystal. Reflected light $V_{acc} = 20$ KV
b) NiK_α X-ray picture
c) CoK_α X-ray picture
d) FeK_α X-ray picture
e) SK_α X-ray picture

Mag. 320 x

TABLE 2

Chemical analyses of the Ófalu serpentinites and associated rocks

Wt%	216	215	21.L	29/2	243/3	6E	7E	ÁGK—136	ÁGK—138	ÁGK—139	ÁGK—141
	Numbers of the samples										
SiO_2	29.65	22.81	35.55	42.73	37.17	30.33	32.91	30.29	34.57	41.14	30.62
TiO_2	0.02	tr.	N.D.	N.D.	N.D.	0.03	0.02	tr.	tr.	tr.	tr.
Al_2O_3	1.55	1.62	N.D.	1.53	2.30	3.00	1.70	1.73	1.88	2.04	2.00
Fe_2O_3	7.19	7.09	5.86	5.45	6.41	6.00	5.45	7.46	8.35	9.04	5.28
FeO	1.67	3.06	2.49	2.65	2.46	1.56	1.53	1.50	1.27	0.60	2.70
MnO	0.17	0.19	N.D.	0.13	0.08	0.11	0.10	0.15	0.07	0.17	0.21
MgO	32.58	18.74	20.72	24.70	34.88	32.66	32.01	28.93	32.35	23.68	32.45
CaO	7.04	17.33	12.13	7.63	3.17	7.02	7.13	8.82	4.90	6.44	6.30
Na_2O	0.07	0.07	N.D.	0.10	0.05	0.03	—	0.14	0.16	0.11	0.17
K_2O	0.02	0.03	N.D.	0.15	0.03	0.09	0.08	tr.	tr.	0.15	tr.
P_2O_5	0.03	tr.	N.D.	—	0.03	0.04	0.02	0.20	0.14	0.20	0.18
H_2O^-	0.27	0.15	N.D.	0.08	0.18	0.75	0.66	0.07	0.23	0.16	0.14
H_2O^+	9.35	3.64	N.D.	5.66	10.69	8.70	8.96	7.47	10.32	7.16	9.79
CO_2	10.08	23.76	15.25	9.09	3.01	9.76	9.31	12.69	4.69	7.86	8.75
Cr_2O_3	0.74	0.98	0.53	—	—	—	—	—	—	—	—
NiO	0.21	tr.	N.D.	—	—	—	—	—	—	—	—
SO_3	0.03	0.08	N.D.	—	—	—	—	0.08	0.07	0.08	0.14
Total	100.67	99.45	99.53	99.90	100.46	100.00	99.88	99.53	99.00	98.83	98.74
L.O.I. %	19.73	27.55	15.25	14.83	13.91	19.25	18.93	17.12	19.24	14.57	19.33
Cr ppm	5068	6700	3630	—	—	2500	—	3000	5000	5000	5000
Ni	1654	1650	—	—	—	—	—	1500	2000	2000	1000
Co	80	100	—	—	—	—	—	100	100	100	—
Mn	1318	698	—	1007	620	1300	1290	400	200	200	800
Ti	119	N.D.	—	—	—	180	119	—	—	—	—
Ni/Co	20.67	16.50	—	—	—	—	—	15.00	20.00	20.00	—
MgO/SiO_2	1.09	0.82	0.60	0.60	1.94	1.07	0.97	0.95	0.93	0.57	1.06

Chemical analysis made by MRS. SOHA I. and MRS. BIRÓ J.
Trace element analysis made by G. RISCHÁK and M. KÁDAS
N.D. = not detected
— = not analyzed

ported that the rocks of the Alpine mafic stem (ultramafites, gabbro, dolerite, basalt and granophyric rocks) chemically differ from stratiform gabbroic complexes in that the former follows a typical calc-alkaline plutonic trend [H. H. HESS, 1955] rather than the Skaergaard rock trend.

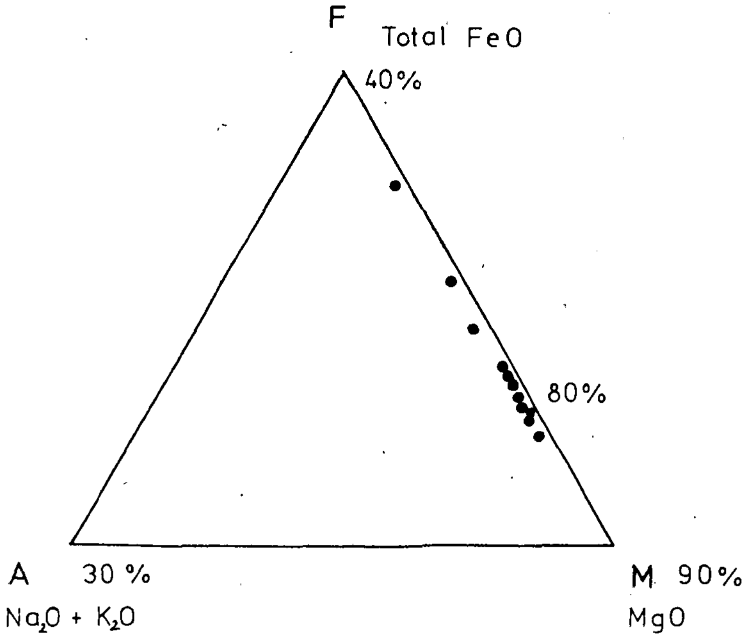


Fig. 6. AFM diagram of the Ófalu serpentinite

It is clear from the AFM diagram that the Ófalu serpentinite rocks are rich in iron content and have deficiency in Mg, which reflect the intense serpentinization as well as regional metamorphism of these rocks. The chemical analyses of the Ófalu metavolcanics [M. GHONEIM and T. SZEDERKÉNYI, 1977] and the Ófalu serpentinite as well as some basic xenolites and enclaves collected from granitoid mass of Mecsek mountains, were calculated in anhydrous form, (Table 3) and plotted in AFM diagram *(Fig. 7)* in which the magmatic trend of these rocks is nearly similar to the "Alpine" intrusion chemical trend rather than being stratiform layered complex (e.g. Skaergaard rock trend).

The high value of Ni/Co ratio was used by L. N. KOGARKO, [1973] to characterize the rocks derived from the early stages of magma differentiation. The Ni/Co ratio is also used as a possible source of genetic information [O. F. GÜLACAR and M. DELALAYE, 1976]. The numbers of Ni/Co ratio (8.07 and 20.97) were taken as values characteristic for the dunite and peridotites of the Bushveld complex (layered part) and for those of Alpine type serpentinite, respectively. As it is evident from Table 2 the Ni/Co ratio for the Ófalu serpentinite rocks moves between 15.00 and 20.67, which reflect their early stage of differentiation as well as similarities to Alpine-type serpentinite described by O. F. GÜLACAR and M. DELALAYE, [1976].

Values of loss on ignition (LOI) were used as a measure for the degree of serpentinization [I. A. MALAKHOV, 1965]. The values of LOI give the limits of serpentinization, namely 2.13% is slightly, 6.05% moderately and 11.67% intensively ser-

TABLE 3

Chemical analysis of the supposed ophiolitic rocks calculated in anhydrous form (volatile-free basis)

	Ófalu serpentinite											Ófalu metavolcanics								
	215	216	21L	29/2	242/3	6E	7E	ÁGK 136	ÁGK 138	ÁGK 139	ÁGK 141	Sc 17	226	26	88/1	203	13	401753	2	S_{A-5}
SiO_2	31.48	36.78	42.55	50.17	43.15	37.55	40.62	38.16	41.13	49.36	38.27	51.70	52.88	51.52	52.00	53.22	48.35	67.38	52.25	55.99
TiO_2	—	0.03	—	—	—	0.41	0.02	tr.	tr.	tr.	tr.	1.90	2.50	2.45	1.56	2.12	1.70	1.04	2.61	1.33
Al_2O_3	2.24	1.92	2.29	1.60	2.67	3.71	2.10	2.17	2.23	2.44	2.50	13.48	14.31	15.66	13.49	17.52	20.05	16.08	19.46	19.66
Fe_2O_3	9.78	8.92	6.77	6.40	7.44	4.43	6.73	9.39	9.93	10.84	6.65	3.45	3.42	4.26	3.96	2.99	4.01	1.28	2.50	2.12
FeO	4.22	2.07	2.98	3.11	2.86	1.93	1.89	1.89	1.51	0.72	3.37	10.78	8.29	8.31	6.90	4.28	5.71	3.58	8.30	4.70
MnO	0.12	—	—	0.15	0.09	0.14	0.12	0.18	0.08	0.20	0.26	0.18	0.18	0.23	0.19	0.11	0.16	0.06	0.22	0.06
MgO	25.86	40.40	24.80	29.00	40.50	40.43	39.50	36.45	38.49	28.41	40.56	8.20	5.94	4.95	6.51	6.95	7.27	2.74	6.43	4.96
CaO	23.92	8.73	14.52	9.00	3.68	8.69	8.79	11.11	5.83	7.72	7.87	6.84	7.71	9.85	10.43	5.68	6.53	1.87	6.49	2.93
Na_2O	0.10	0.09	—	0.12	0.06	0.04	0.05	0.17	0.19	0.13	0.21	2.49	4.36	2.91	4.13	4.34	6.12	4.26	4.10	5.06
K_2O	0.04	0.08	—	0.18	0.04	0.11	0.14	tr.	tr.	0.18	tr.	0.99	0.53	0.34	0.48	3.48	2.67	2.72	0.62	3.26
LOI.	27.55	19.73	15.25	14.83	13.91	19.25	18.93	18.85	19.11	14.75	14.70	14.32	2.87	3.07	3.93	5.25	3.70	3.71	3.87	5.14
FeOΣ	15.02	10.00	9.25	8.86	9.55	8.61	7.94	8.20	8.78	8.72	7.45	13.61	11.37	12.34	10.46	6.97	9.32	4.71	10.35	6.60

	Basic enclaves in Mecsek granite							
	47.L.	221	200	52/15	33/143/2	35/13/2	43/127/1	24/114/1
SiO_2	53.28	53.28	54.95	54.00	53.88	53.10	52.16	46.40
TiO_2	1.09	0.67	1.58	1.73	1.36	1.23	1.73	1.04
Al_2O_3	14.96	10.68	16.34	12.20	12.74	13.64	14.06	12.37
Fe_2O_3	2.84	1.17	1.95	2.85	1.96	2.08	1.64	8.42
FeO	5.71	5.50	5.11	5.38	6.32	6.65	5.63	4.15
MnO	0.13	0.13	0.12	0.44	0.07	0.20	0.17	0.44
MgO	7.42	15.02	6.12	9.17	9.60	9.24	9.83	11.21
CaO	6.62	8.69	6.32	6.79	8.13	8.08	7.23	8.83
Na_2O	1.77	1.34	2.14	1.55	1.46	1.98	1.06	1.41
K_2O	5.79	3.61	4.14	4.94	4.23	4.97	6.64	4.53
LOI.	1.92	3.64	2.91	5.32	1.97	5.82	4.22	5.44
FeOΣ	8.27	6.55	6.96	7.44	8.08	8.52	7.12	11.72

Source of samples: No. 215, 216, 21.L, 29/2, 242/3, 6E, 7E, Sc.17, 226, 26, 88/1, 203, 13, 401,753, 2, S_{A-5} GHONEIM, M.—SZEDERKÉNYI, T. [1977], ÁGK 136, ÁGK 138, ÁGK 139 ÁGK 141, SZEDERKÉNYI, T. [1978], 47.L basic stock of Üveghuta GHANEM, M. A. E. and RAVASZ—BARANYAI L. [1969], 200 from, Üveghuta near curch, 221 inside Mórágy granite quarry, 52/15, 33/143/2, 35/13/2, 43/127/1 and 24/144/1 basic enclaves inside the anatectic granite JANTSKY, B. [1974]

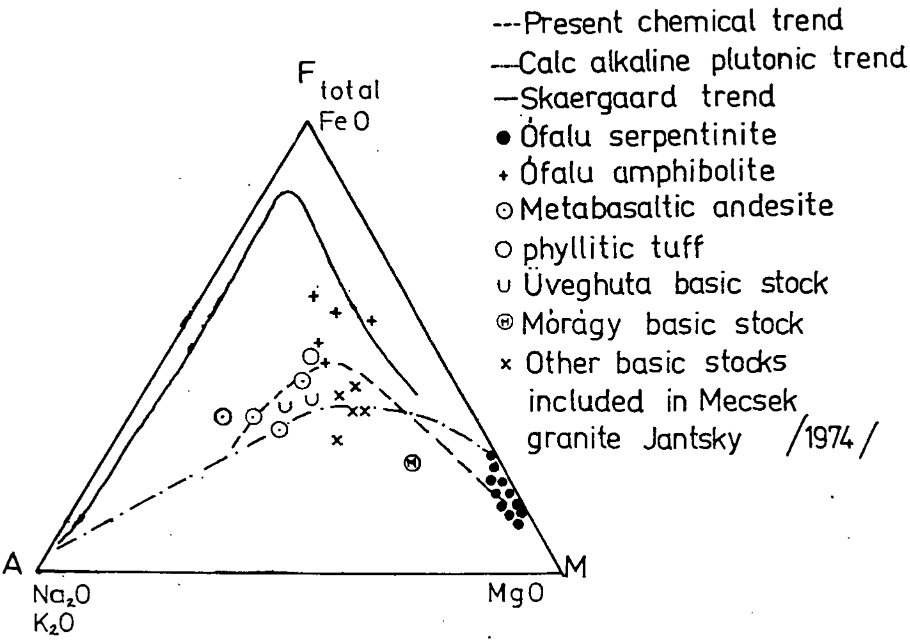


Fig. 7. AFM diagram shows the chemical trend of the rocks of the Ófalu area. The chemical analyses are calculated in anhydrous form

pentinized rock. Consequently the Ófalu serpentinite belongs to intensively serpentinized category (Table 2).

The Ni and Cr content of the Ófalu serpentinite suggested the peridotite parent rock origin. According to G. T. Faust, K. J. Murata and J. J. Fahey, [1956] the sedimentary origin is marked by less than 0.002% Ni and 0.01% Cr content in the serpentinites. Higher concentration indicates igneous ultrabasic origin. The peridotite magmatic origin of the Ófalu serpentinite is in complete harmony with Coleman's work on the origin of serpentinite rocks. R. G. Coleman, [1971] calculated the MgO/SiO_2 ratio for brucite-bearing serpentinite derived from dunite and other serpentinite originated from harzburgite and lherzolite. The serpentinite derived from dunite has a MgO/SiO_2 ratio equal to 1.23, for harzburgite and its serpentinite derivatives the ratio was 1.11, while the lherzolite-derived serpentinite had a MgO/SiO_2 ratio equalling 0.89. In addition, R. G. Coleman, [1971] claimed that the presence of brucite in the serpentinite rocks favoured the dunite ultramafic origin. The Ófalu serpentinite has MgO/SiO_2 ratio ranges from 0.6 to 1.07 (Table 2) and brucite is absent in the mineral assemblage. Both evidences indicate the harzburgite and lherzolite origin of the present rocks.

As it was obvious from the field and laboratory, the Ófalu serpentinites undergone moderate degree of CO_2 metasomatism due to hydrothermal phenomena within the tectonic borders of the serpentinite body. The CO_2 metasomatism can be also illustrated from MgO—CaO—Al_2O_3 diagram *(Fig. 8)*, in which the plots show a general trend almost directly away from the MgO corner toward the CaO apex.

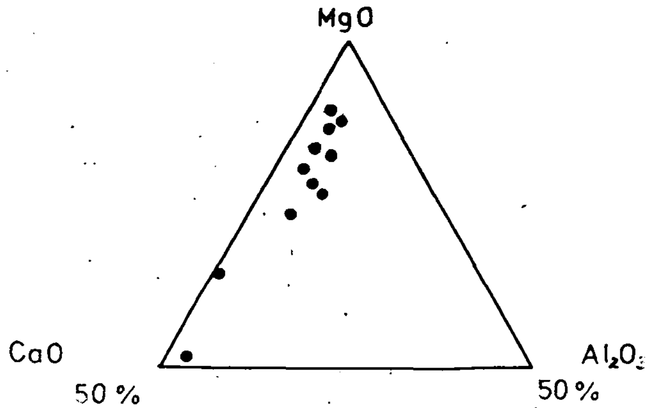


Fig. 8. MgO—CaO—Al_2O_3 diagram of Ófalu serpentinite. The chemical analyses are calculated in volatile-free basis

SERPENTINIZATION

It can be concluded that the Ófalu serpentinite remained constant in composition during the early stage of serpentinization, followed by partial removal of MgO, FeO and Al_2O_3 during the late stage of regional metamorphism. The above-mentioned conclusions were supported by the following:

— Lack of evidences for considerable Si or Mg metasomatism in surrounding rocks.
— The volume increase (due to constant composition) during serpentinization assists in the intrusion of the serpentinite along a zone of structural weakness.
— Absence of brucite in the Ófalu serpentinite may indicate constant composition serpentinization, since the presence of brucite is due to Mg production during serpentinization [R. G. Coleman, 1971].

The regional metamorphism promotes open system conditions under which partial change in chemical composition took place. The latter changes are well-documented in chromite grains, i.e. the chromite forms zoned crystals and the electron probe microanalysis shows that the outer zone is depleted in Al, Mg, and Cr as compared to unaltered relict chromite in the core of the crystal.

The presence of chromite, magnetite, pentlandite, pyrrhotite and heazlewoodite minerals and the absence of an awaruite (Ni_3Fe) intermetallic compound and sulphides low in sulphur indicate moderate O_2 and S_2 availability during the serpentinization process. Accordingly, the Ófalu serpentinite belongs to zone 2 of intermediate O_2 and S_2 availability of O. R. Eckstrand, [1975], and the temperature of hydration reaction of the Ófalu serpentinite lies in the range of 450—500 °C and pressure of 0.5 to 1 Kb according to data of J. B. Moody, [1976].

As evident from the field works, the intrusion of the Ófalu serpentinite seems to be at temperatures low enough to satisfy the field requirements of absence of the thermal effect on the country rocks. Bearing in mind the "crystal mush" hypothesis [F. J. Turner and J. Verhoogen, 1960] which is now widely accepted, it is belived that the Ófalu serpentinites were emplaced as an ultramafic body in a largely crystalline cold condition lubricated by interstitial liquids of magmatic source, which imparted the necessary degree of mobility. The instrusion of the Ófalu serpentinite along zones of major dislocation would be accompanied by external water, which normally streaming upwards along the same path of minimum resistance, must have provided facilities for further mobility and complete serpentinization.

REGIONAL METAMORPHISM

It was elucidated that, the Ófalu serpentinite underwent regional metamorphism together with the host eugeosynclinal metasedimentary and metavolcanic rocks of the Ófalu Group reaching up to the greenschist-amphibolite facies. This conclusion has been supported by the next statements:

— The close association of the Ófalu serpentinite with the enveloping country rocks in such a case that the former shows the same regional trend as the latter (the country rocks regionally metamorphosed up to greenschist-amphibolite facies.
— The presence of antigorite mineral in Ófalu serpentinite undoubtedly indicates higher PT conditions, rather than those rocks containing chrysotile and lizardite only.
— Chromite grains in the Ófalu serpentinite are surrounded by zones of ferrite-chromite which is intermediate in composition between relict chromite and secondary magnetite. According to up-to-date interpretations by R. K. SPRINGER, [1974], H. W. BLISS and W. H. MACLEAN, [1975], P. M. ASHLEY, [1975], B. W. EVANS and B. R. FROST, [1975], J. B. MOODY, [1976], the latter phenomena indicate a metamorphic event (greenschist-amphibolite transition facies) of temperature-pressure higher than necessary for the formation of lizardite-chrysotile serpentinite in which chromite grains are surrounded directly by a magnetite rim.

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