Посебноизданиена
Geologica Macedonica,
Nō.5

МАКЕДОНСКО ГЕОЛОШКО ДРУШТВО - Скопје, 1952

ЧЕТВРТИ КОНГРЕС
на
Геолозите на Република Северна Македонија

ЗБОРНИК НА ТРУДОВИ

Главни и одговорни уредници:
Проф. д-р Блажо Боев
Проф.д-р Тодор Серафимовски

Охрид, 2021

Посебно издание на
Geologica Macedonica,
No 5

МАКЕДОНСКО ГЕОЛОШКО ДРУШТВО – Скопје, 1952

ЧЕТВРТИ КОНГРЕС
на
ГЕОЛОЗИТЕ НА РЕПУБЛИКА СЕВЕРНА МАКЕДОНИЈА

ЗБОРНИК НА ТРУДОВИ

`

Охрид, 2021

Издава: Македонско геолошко друштво – Скопје, 1952

Организатор на Конгресот
Македонско геолошко друштво Скопје 1952

Носители на Конгресни активности

Претседатели:
Проф. д-р Блажо Боев
Проф. д-р Тодор Серафимовски

Научен одбор
Проф. д-р Ванчо Чифлиганец
Проф. д-р Крсто Блажев
Проф. д-р Орце Спасовски
Проф. д-р Гоше Петров
Проф. д-р Тена Шијакова-Иванова
Проф. д-р Милорад Јовановски
Проф. д-р Владимир Берманец
Проф. д-р Соња Лепиткова
Проф. д-р Дејвид Алдертон
Проф. д-р Војо Мирчовски
Проф. д-р Владица Цветковиќ
Проф. д-р Дејан Прелевиќ
Проф. д-р Виолета Стефанова
д-р. Александар Волков
Проф. д-р Виолета Стојанова
Проф. д-р Евгенија Тарасова
Проф. д-р Сабина Стрмиќ-Палинкаш
Проф. д-р Андреј Шмуц
Прив. Доц. д-р Уве Колич

Почесен одбор
Проф. д-р Никола Думурџанов
Проф. д-р Иван Загорчев
Проф. д-р Марин Александров
Проф. д-р Тодор Делипетров
Проф. д-р Панде Лазаров
Проф. д-р Борче Андреевски
Проф. д-р Симеон Јанчев
Проф. д-р Тадеј Доленец
Проф. д-р Ладислав Палинкаш

Конгресот финансиски го подржаа:

ДПТУ „Бучим“, дооел – Радовиш

Кожувчанка, доо –Кавадарци

Македонска Авторска Агенција, доо – Скопје

Авто-Искра, дооел – Скопје

Хидроинженеринг, дооел – Битола

Градежен Институт Македонија – Скопје

Градежен факлтет – Скопје

Рудници за олово и цинк „Саса“ – Македонска Каменица

Геоинженеринг – Скопје

Геоинженеринг-консалтинг, доо – Скопје

Геинг – Скопје

СОДРЖИНА – TABLE OF CONTENTS

2. ИНЖЕНЕРСКИ ДЕЛ

Инженерска геологија и геотехника, Применета геофизика, Урбана геологија, Хидрогеологија и геотермија

3. ЕКОНОМСКА ГЕОЛОГИЈА

Металогенија, Минерални ресурси, Енергетски ресурси,Техногени наоѓалишта

4. ПРОГРЕСИВНА ГЕОЛОГИЈА

Примена на ГИС, Геоинформатика, Математичка геокогија, Наногеологија, Медицинска Геологија

5. ГЕОЛОШКИ ХАЗАРДИ И ЗАШТИТА,
Кли,атски промени, Геохазард, Геоекологија и заштита на животната средина

6. ГЕОЛОКО КУЛТУРНО НСЛЕДСТВОИ,
Културно историски споменици, Геопаркови и туризам, Гаонаследство и национални музеи

ИНДЕКС НА АВТОРИ – AUTHORS INDEX

ПРЕДГОВОР

Четвртиот Конгрес на Геолозите на Македонија требаше да се одржи минатата, 2020 година, но поради пандемијата на КОВИД-19, Конгресот беше одложен за ова 2021 година, со надеж дека пандемијата ќе помине и дека ќе можеме во нормални околности да го одржиме Конгресот. Меѓутоа пандемијата на КОВИД-19 продолжи и во текот на 2021 година а со тоа и одржувањето на Конгресот на геолозите на Македонија стана неизвесен и во тековната 2021 година, затоа организациониот одбор на конгресот одлучи собраните конгресни материјали да бидат објавени во посебно издание на ГЕОЛОГИКА МАКЕДОНИКА (2021) и со тоа да бидат затворени активностите околу 4-от Конгрес на Геолозите на Македонија.

4-от Конгрес на Геолозите на Македонија претставува континуитет во конгресните активности на Македонското Геолошко Друштво и основа прави пресек на достигнувањата на геологијата во Македонија помеѓу двата конгреса.

Македонското геолошко друштво како асоцијација на сите геолози и истражувачи од сферата не гео-науките во Македонија уште од своето формирање во 1952 година па се до денес во својот фокус на интерес ги има гео науките како интегрален дел во развојот на општеството и во развојот на планетата Земја во целина.

Гео-науките во иднината ќе се занимаваат со изучувањето на динамиката на самата планета Земја, односно клучните двигатели и процеси кои управуваат со еволуцијата и однесувањето на планетата, како клучни елементи за стратешките планирања за развојот на Планетата и зачувувањето на нејзините посебности како што се: динамиката на движењето на луѓето, динамиката на промените во диверзитетот на флората и фауната (екологија), а посебно внимание ќе се посвети на оние еко-системи кои ги населуваат неколкуте најоддалечени места на оваа планета, чиј радиус е 6370 km, ќе заземаат централно место во иднината на Земјата, начинот на кој реагираат на (глобалните) животни и климатски промена.

Како резултат на Првиот Закон на термодинамика кој се однесува на зачувување на енергијата во системот, сите модификации на балансот на енергијата (и масата) во внатрешноста на планетата мора да имаат ефект на површината на планетата и нејзината биосфера, вклучувајќи го и општеството. Поседувањето на соодветно

PREFACE

The fourth Congress of the Macedonian geologists was supposed to take place last year, 2020, but due to the COVID-19 pandemic, the Congress was postponed for this year, 2021, hoping that the pandemic will pass so that we could hold the Congress under normal conditions. However, the COVID-19 pandemic continued to spread in the course of 2021 and as a result of it, the holding of the Congress of the Macedonian geologists proved to be uncertain in the current 2021. So, the Organizing Committee of the Congress decided to publish the collected Congress materials in a separate publication GEOLOGICA MACEDONICA (2021) and with that, to close the activities around the fourth Congress of the Macedonian geologists.

The fourth Congress of the Macedonian geologists presents a continuity in the Congress activities of the Macedonian Geological Society and basically shows the achievements of geology in Macedonia between the two Congresses.

The Macedonian Geological Society, as an Association of all the geologists and researchers in the field of the geological sciences in Macedonia, has had the geological sciences in their focus of interest since its establishment in 1952 until today, as an integral part in the development of the society as well as within the development of our planet in general.

In the future, the geological sciences will be focused on studying the dynamics of the very planet Earth, i.e. the key moving forces and processes that govern the evolution and the behavior of the planet, as crucial elements for the strategic planning of the development of the Planet and preserving its particularity, such as the movement of the people, the dynamics of the changes in the diversity of the flora and fauna (ecology). A special attention will be paid to those eco-systems that have been populated at the most distant places on this Planet, whose radius is 6370 km. They will take the central place in the future of the Earth, the way in which they react to the (global) living and climatic changes.

As a result of the First Law of the thermodynamics, which refers to preserving the energy within the system, all the modifications of the energy balance (and the mass) in the interior of the planet must affect the surface of the planet and its biosphere, including the society as well. Possessing the appropriate knowledge and better understanding of such processses at a higher level is a precondition for comprehending the processes of the occurrence знаење и подобро разбирање на таквите процеси на подлабоко ниво е предуслов за разбирањето на процесите за појавата на човечки и други форми на живот на површината. Од сите сфери во Земјиниот систем, една (гео сферата) е особено премалку застапена во програмите за истражување на планетата Земја во иднината. Секоја амбиција подобро да се разберат механизмите кои ги покренуваат промените во животната средина, што е очигледно важно, е нецелосно и најверојатно погрешно ако не се вклучат најрелевантните дисциплини од сферата на гео-науките бидејќи промените во гео сферата ги покренуваат промените во животната средина на оваа планета.

Многу аспекти поврзани со Земјата често се главен фокус за широк спектар на гео научници кои секојдневно се занимаваат со науките за Земјата. За време на минатите декади, гео научниците проучувале широк спектар на теоретски и применети аспекти на Земјата и изградиле огромна база на знаење, која може да обезбеди многу одговори на прашањата за истражување кои се релевантни за гео науките во иднината. Дел од оваа база на знаење се геолошките записи кои се откриени при истражувањата на Антарктикот во неколкуте претходни декади, и кој може да се користат како соодветна природна референца за идни климатски промени во однос на отпорноста на екосистемите и човештвото под голема разновидност на атмосферски и климатски услови.

Гео научниците направиле значаен напредок во развојот на особено релевантните модели за предвидување на случувањата во литосферата и атмосферата и преку тие огромни достигнувања во истражувањето сега ги разбираат најголемиот дел од механизмите и времето на случувањата на поголемите, помалите до оние на нано-ниво процеси на Земјата. Кога дискутираме за иднината на Земјата, нејзината геосфера, атмосфера, хидросфера и биосфера, не можат да се игнорираат резултатите на таквите значајни истражувања.

Гео-научниците може значајно да допринесат да се даде осврт на сите приоритети под темата: Динамична планета. Всушност, не може да се даде осврт на најголемиот дел од овие приоритети (>65%) под темата Динамична планета, без виталните знаење на заедница на научните од областа на гео науките.

Затоа и IV-от Конгрес на геолозите на Македонија треба да биде посветен на теми кои се исклучително важни за еволуцијата и развојот на самата планета Земја.

Организационен одбор

of human and other forms of life at the surface. Considering all the spheres within the Earth system, one of them (the geo-sphere) has been particularly little represented in the programs for the exploration of the Earth system in the future. Each ambition and effort to better understand the mechanisms that are moving forces for the changes in the environment, which is obviously very significant, is incomplete and most probably wrong if the most relevant disciplines in the sphere of the geological sciences are not included, because the changes within the geo-sphere are moving the changes within the environment of this planet.

Many aspects related to the Earth have been a major interest for a wide spectrum of geo scientists who are continually working on the sciences about the Earth. In the course of the past decades the geo scientists were studying a wide scope of theoretical and applied aspects of the Earth and they have established an enormous knowledge base which can provide many answers to the questions considering the exploration, answers that are relevant for the geo sciences in the future. A part of this knowledge base presents the geological records that were found out in exploring the Antarctic during the last decades. They can be used as an adequate natural reference for the future climatic changes in relation to the resistivity of the eco-systems and the humanity under a great diversity of the atmospheric and climatic conditions.

The geo scientists have achieved a significant advancement in the development of the particular relevant modules for predicting the occurrences within the lithosphere and the atmosphere. Owing to that vast achievement in exploring, they can now understand the greatest part of the mechanisms and the time of the occurrences of the greater, the smalller to those at the nano level processes of the Earth. When we discuss about the future of the earth, its geosphere, atmosphere, hydrosphere and biosphere, we cannot ignore the results of such significant exploration.

The geological sciences can significantly contribute for providing a review to all the pri-orities of the Subject: Dynamic planet. In fact, a review cannot be provided to the greatest part of these priorities (>65%) under the subject the Dynamic planet, without taking into consideration the essential knowledge of the association of the scientists from the field of the geo sciences.

Accordingly, the fourth Congress of the Macedonian geologists should be dedicated to subjects that are exceptionally important for the evolution and the development of the very planet Earth.

Organizing board

1-OF-03

PETROGRAPHY OF THE DREN-BOHULA MASSIF AS A PART OF THE OPHIOLITIC COMPLEX DEMIR KAPIJA–GEVGELIJA

Ivan Boev

Faculty of Natural and Technical Sciences, Institute of Geology, "Goce Delčev" University in Štip, Blvd. krsyte Misirkov 10-A, P. O. Box 210, 2000 Štip, Republic of North Macedonia
ivan.boev@ugd.edu.mk

A b s t r a c t: The Dren-Bohula massif covers the western parts of the ophiolite complex Demir Kapija Gevgelija and geologically it does not represent a separate tectonic segment. It is built of the following rocks: verlite, troctolite, olivine gabbro, gabbro, Uralite gabbro, diorite, basalt, diabase, and quartz-diorite. The interrelationships of these types of rocks, as well as their mineral composition, indicate a continuous magmatic differentiation of basic magma.

Key words: ophiolitic complex, Dren-Bohula, gabro

ПЕТРОГРАФИЈА НА МАСИВОТ ДРЕН–БОХУЛА КАКО ДЕЛ ОД ОФИОЛИТСКИОТ КОМПЛЕКС ДЕМИР КАПИЈА–ГЕВГЕЛИЈА

Масивот Дрен-Бухула ги зафаќа западните делови од офиолитскиот комплекс Демир Капија Гевгелија и геолошки гледано не преставува посебен тектонски сегмент. Изграден е од следниве карпи: верлит, троктолит, оливин-ски габро, габро, уралитски габро, диорит, базалт, дијабаз, кварцдиорит. Меѓусебните односи на овие типови на карпи, како и нивниот минерален состав укажуваат на континуирана магматска диференцијација на базична магма.

Клучни зборови: офиолитски комплекс, Дрен-Бохула, габро

INTRODUCTION

The Demir Kapija-Gevgelija ophiolite complex is the largest remnant of oceanic crust within the Vardar Zone in the Republic of North Macedonia. The Vardar Zone is centrally located on the territory of the Republic of North Macedonia (along the river Vardar) and it consists of the Western Ophiolite Belt (Schmid et al., 2008) or the Dinar Ophiolite Unit (Karamata, 2006) and the Eastern Ophiolite Belt. The Eastern ophiolite belt is locateds in the SE part of the Republic of North Macedonia and the ophiolite complex Demir Kapija-Gevgelija (Figure 1) is located in it. The Eastern ophiolite belt is a separate part of the Vardar zone, different from the Dinaric ophiolite belt or the western ophiolite belt of the Vardar zone (Karamata, 2006; Schmid et al., 2008), Bozović et al, 2010, Prelević et al, 2017, Prelvić et aa, 2014, Boev et al, 2013.

The complex extends in the NW-SE direction and to the north the ophiolite complex of Klepa joins, while to the west there is the massif called the gabbro-diabase complex Dren-Bohula. On the territory of the Republic of North Macedonia this complex is about 50 km long and 25 km wide. The complex continues to the south into neighboring Greece where it is called the Gevgelli series (Zachariadis, 2007). In the northwestern part of this complex in the region of Tikves it is covered with Upper Eocene and Pliocene sediments and volcanic clastic sediment rocks, and in the southern parts of the territory of Greece this complex is covered with Pliocene and Quaternary sediments. The research of geology, tectonics and lithostratigraphy of the ophiolite complex so far has determined the presence of the following lithological formations: a formation of gabbros and accompanying plutons; a vein complex; a formation of massive basalts; a formation of spilitized pillow basalts; a spilite – keratophyre level; a basalt chert formation; a flysch formation, and a carbonate formation with titonic age (Lepitkova, 2002).

The gabbroic formation is composed predominantly of fine – grained and medium – grained clinopyroxene gabbros, rarely of olivine gabbros, pyroxene gabbros with olivine, troctolites and amphibole gabbros and quite rare are serpentinized dunites and hornblende peridotites as well as dikes of basalts, gabbropegmatites, aplites, granite – porphyry and quartzdiorites. This formation of various types of intrusive and vein type rocks is a result of magmatic differentiation and the processes of amphibolitization.

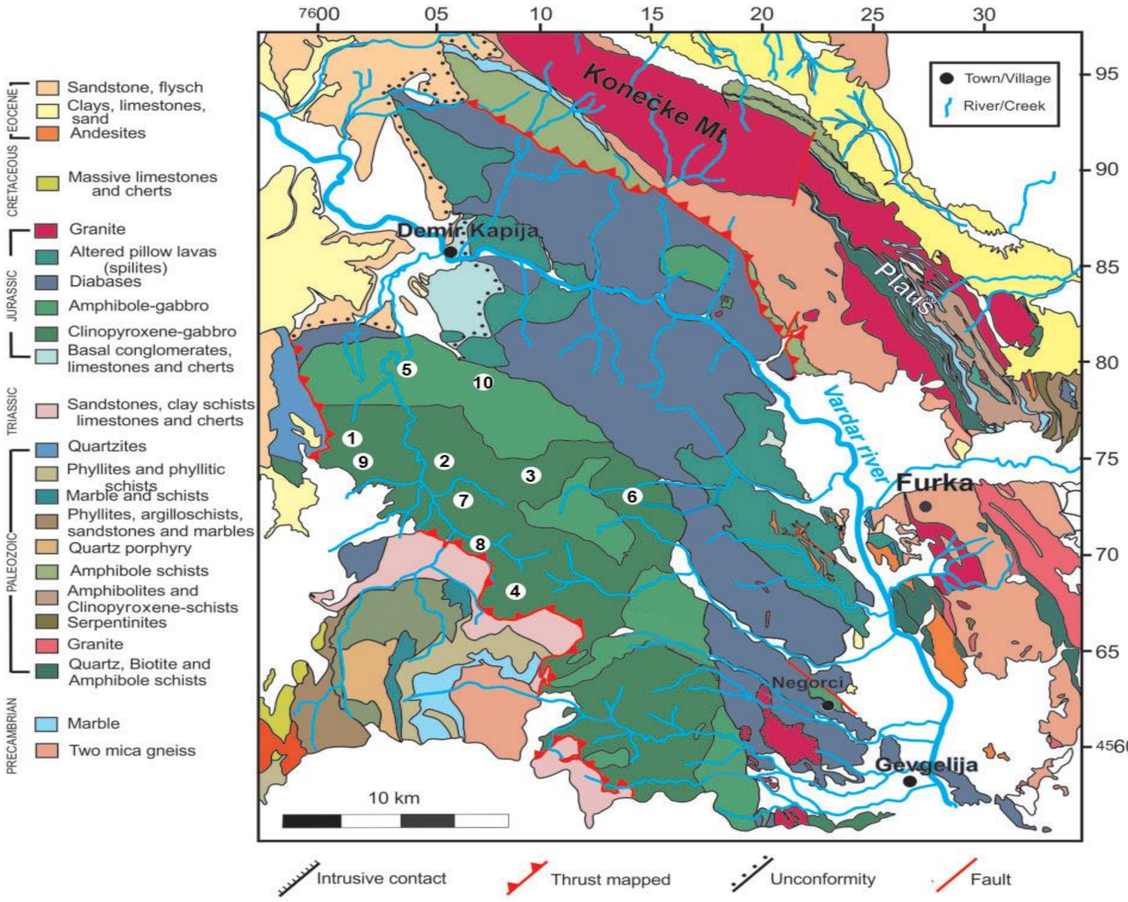

Fig.1. Ophiolitic complex Demir Kapija-Gevgelija (Bozovic et al, 2010, modified by I. Boev, 2021)

Ultrabasics are present as tectonically forced masses along fault structures or they occur along with troctolites. They are present as serpentinized dunites, amphibolized peridotites as well as wehrlites. They are made up of hornblende, serpentine, actinolite, olivine and accessory magnetite.

A vein complex occurs in the contact parts of the gabbroic formation and the formation of massive basalts as a well-developed 200 to 300 (maximum 500) meters zone made up of basalt – dolerite dikes and segmented gabbro masses. The mineralogical composition is similar to the massive basalt and gabbroic mass.

Massive basalts are found in the central and eastern portions of the ophioltite complex. They are present as fine-grained ophiolite and intersertal composition with occasional occurrences of entire recrystallization of the glass groundmass. They are altered rocks in which feldspars are heavily albitized. Basic plagioclases occur as relic kinds (Labrador – bytownite), whereas albite – oligoclase – andesine are present as plagioclases. Femic minerals as found in augite, hornblende, secondary chlorite, epidote, magnetite, apatite.

Spilite – keratophyre level occurs in the top most portions of the formation of basaltic pillow lavas. It is present as a concentration of dikes and outpourings of keratophyre masses, quartzkeratophyres, rhyolites and seldom andesites which form keratophyre level together with spilitized basalts. These acid differentiates occur as pink to red, grey – green to grey – white rocks with micro porphyritic to porphyritic structure composed of alterated feldspatic mass with relics of plagioclase (oligoclase – albite), K – feldspar, also chlorite, quartz, epidote, seldom crystals of hornblende, chloritized biotite and calcite (Saric et al, 2009).

Upper parts of ophiolitic complex are composed of chert formations, flysch formations and on the complex there are massive carbonate rocks of titonic age.

METHODOLOGY

In the summer of 2020, in the part from the village Dren (west of Demir Kapija) to the village Bohula, samples of basic and acid rocks were collected that appear in this part of the ophiolite complex. Microscopic transmissions and chemical analyses were made on the collected samples using the ICP-AES method. The microscopic preparations were processed in detail using a Leica polarizing microscope and microscopic preparations were made.

MICROSCOPIC ANALYSES

1. Verlite

Verlite is made of serpentinized olivine, serpentinite, augite (dijalag) and accessory minerals (hypersthene, chlorite, feldspar, uvarovite and a small amount of magnetite). Due to the processes of serpentinization, the primary structure is changed in some places and in other places the whole rock is built of serpentinite, which has a typical network structure.

Olivine occurs in allotriomorphic grains (about 1 mm in size) is mainly serpentinized and there are some veins of magnetite. In some places the occurrence of small tiny crystals of augite (dijalag) and amphibole is often observed, which in places form a typical kelephite structure (Figure 2).

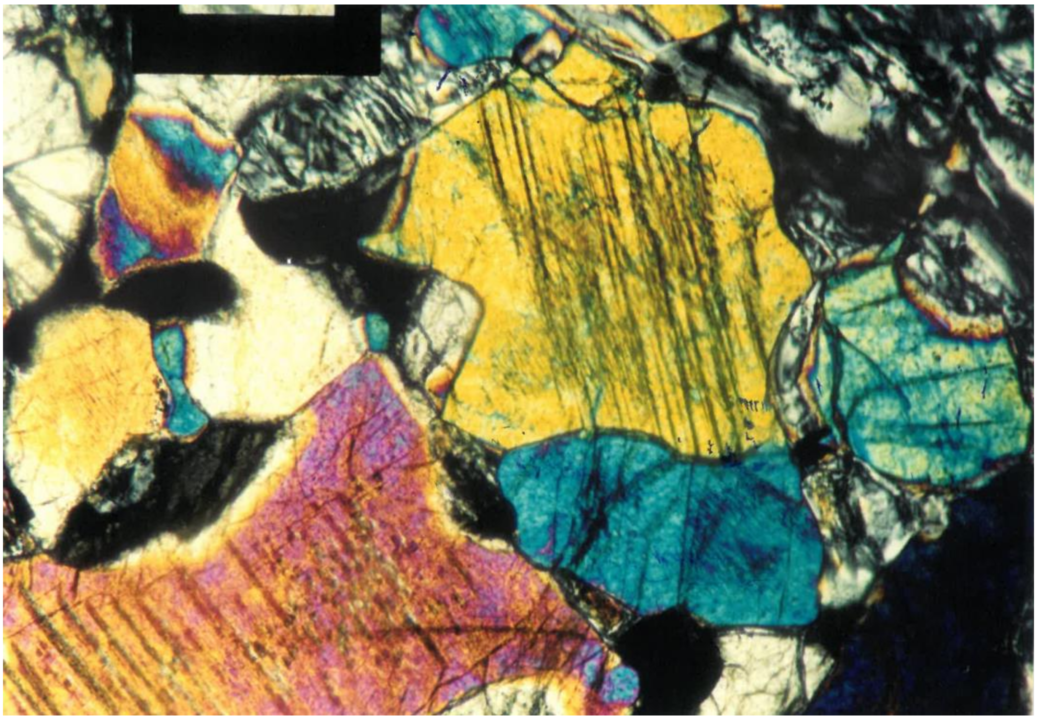

Fig. 2. Microscopic photography of verlite (crossed Nicols)

Pyroxene, augite (dijalag) occurs in much smaller amounts. These are usually large individuals (about 5 mm) that almost always contain olivine grains. Prismatic cleavage is not very pronounced. Rhombic pyroxene, hypersthene, sometimes occurs with the dialogue.

Magnetite occurs in irregular grains or in the form of veins.

Chlorite occurs in larger piles and is characterized by blue interference colors.

Feldspar is very rare and belongs to the group of basic plagioclases.

Uvarovite occurs in fine green isotropic grains, especially in association with chlorite.

The normative composition (Table 1, analysis 1) does not correspond to the modal composition, because serpentine does not belong to the group of normative minerals (NORM minerals). In the microscopic examination there are less plagioclases than in the normative composition (13%). Other normative minerals are in accordance with the modal mineral composition determined under a microscope.

Olivine grains that are not related to augite (dijalag) have irregular shapes, while olivine grains that are embedded in augite (dijalag) have a rounded shape. This structural relationship of the rounded olivine grains that are incorporated in the augite (dijalag) is the consequence of the genesis of these peridotite varieties within the ophiolitic complex Demir Kapija–Gevgelija.

2. Troctolite

Macroscopically, this rock is of greenish color with a pronounced dark shade, it has a speckled texture where the speckles are represented by black grains of olivine and white grains of plagioclase. Under a microscope it can be seen that the rock is made up of irregular olivine grains, mostly involved in the serpentinization process and irregular grains of plate plagioclase. Around some grains of olivine there is an edge of augite (dijalag) (symplectite). The presence of actinolite as well as the presence of small green isotropic grains of uvarovite are noticed in the rock. Magnetite also occurs in the serpentinized olivine grains themselves. Feldspar occurs rarely and is involved in transformation processes (Figure 3).

The normative composition (Table 1, analysis 2) corresponds to the calculated modal composition in terms of the presence of olivine, plagioclase, magnetite and pyroxenes.

T a b l e 1

Normative minerals composition of the rocks from Dren-Bohula Massif

Niggli Norm	1	2	3	4	5	6	7	8	9	10	11	12	13	14
quartz	–	–	–	–	3,397	10,562	25,983	35,487	–	–	–	–	8.510	13.399
orhoclase	0.060	0.060	0,466	0,943	1,422	3,216	1,686	0,365	0,118	0.479	0.830	0.958	1.315	0.984
albite	2.171	5.547	6,991	6,757	17,563	26,00	35,148	38,888	20,506	11.375	9.548	17.289	28.671	31.315
anorthite	10.842	35.471	46,109	61,439	46,731	39,206	23,866	18,835	34,705	32.456	43.677	46.572	30.344	22.987
corundum	–	–	–	–	–	–	–	1,032	–	–	–	–	–	1.414
nepheline	–	–	–	–	–	–	–	–	–	–	–	–	–	–
leucite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
kaliophilite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Na2SiO3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
calcite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
apatite	–	–	–	–	–	0,301	–	–	–	–	–	–	0.223	–
pyrite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ilmenite	–	–	–	–	–	–	–	0,659	1,424	–	–	1.638	2.211	2.988
magnetite	8.246	4.934	2,957	0,907	2,758	4,553	2,121	1,764	3,173	3.602	1.898	1.949	2.893	3.744
hematite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
rutile	–	–	–	–	–	–	–	–	–	–	–	–	–	–
titanite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
perovskite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
diopside	13.118	3.702	25,788	21,885	21,784	3,480	0,088	–	20,901	27.555	28.575	11.940	6.626	–
hyperstene	19.625	6.734	7,207	–	6,345	12,673	11,109	2,969	17,973	12.305	7.550	15.283	19.207	22.169
olivine	45.936	43.553	10,481	7,824	–	–	–	–	1,199	12.198	7.921	4.371	–	–
wolastonite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
larnite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
acmite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
norm En	99.0	98.5	95,7	94,2	92,9	78,5	74,7	77,5	83,7	85.2	86.2	73.8	69.2	77.9
Norm An	83.3	86.5	86,8	89,6	72,7	60,1	40,4	32,6	62,9	74.1	82.1	72.9	51.4	42.3
Norm Color	86.9	58.9	46,4	30,6	30,9	20,7	13,3	5,4	44,7	55.7	45.9	35.2	30.9	28.9
CIPW Norm	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Quartz	–	–	–	–	3.656	11.10	27.516	37.240	–	–	–	–	9.494	13.895
Orthoclase	0.059	0.059	0.473	0.945	1.418	3.132	1.655	0.355	0.118	0.473	0.827	0.945	1.359	0.945
Albite	2.031	5.161	6.684	6.383	16.499	23.86	32.491	35.622	19.291	10.576	8.969	16.076	27.922	28.345
Anorthite	10.761	35.020	46.774	61.580	46.578	38.16	23.407	18.306	34.642	32.049	43.529	45.947	31.353	22.076
Corundum	–	–	–	–	–	–	–	0.919	–	–	–	–	–	2.124

Niggli Norm	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Nepheline	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leucite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kaliophilite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Na_2SiO_3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Calcite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Apatite	–	–	–	–	–	0.348	–	–	–	–	–	–	0.274	–
Pyrite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ilmenite	–	–	4.161	–	–	–	–	0.874	1.937	–	–	2.203	3.115	3.913
Magnetite	11.353	6.757	–	1.261	3.813	6.148	2.885	2.378	4.393	4.930	2.624	2.668	4.147	4.988
Rutile	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Titanite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Perovskite	–	–	25.611	–	–	–	–	–	–	–	–	–	–	–
Diopside	12.686	3.564	6.684	21.520	21.343	3.398	0.087	–	20.781	27.018	28.264	11.898	6.960	–
Hypersthene	17.627	6.025	9.133	–	5.832	11.877	10.609	2.787	17.013	11.459	7.082	14.721	19.635	20.535
Olivine	38.603	36.485	–	6.780	–	–	–	–	1.083	10.815	7.065	4.062	–	–
Wollastonite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Larnite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acmite	–	–	95.7	–	–	–	–	–	–	–	–	–	–	–
Norm En	99.6	98.6	87.5	94.1	92.7	75.1	70.2	73.4	81.7	83.2	84.6	70.0	69.4	73.9
Norm An	84.1	87.2	45.6	90.1	73.8	61.5	41.9	33.9	64.2	75.2	82.9	74.1	52.9	43.8
Norm Color	8.03	52.8	–	29.6	31.0	21.4	13.6	6.0	45.2	54.2	45.0	35.6	33.9	29.4
Indices														
Mg/(Mg+Fe)	0.834	0.859	0.817	0.870	0.707	0.485	0.544	0.324	0.668	0.730	0.774	0.617	0.513	0.533
Mg/Mg+Fe^{2}+1/MgO	0.933	0.940	0.907	0.918	0.844	0.656	0.667	0.484	0.752	0.809	0.832	0.671	0.588	0.630
Mod.larson	-36.25	-28.40	-17.57	-13.36	-6.666	0.246	0.333	1.216	0.109	0.076	0.098	0.138	0.179	0.161
Thort.Tutt.	2.090	5.220	7.157	7.538	21.574	38.093	61.662	73.217	19.410	11.049	9.796	17.022	38.775	43.185
Ratios														
(Na+K)/Al	0.093	0.073	0.075	0.062	0.169	0.272	0.436	0.478	0.229	0.154	0.106	0.164	0.331	0.358
Na+K+2Ca/Al	2.371	1.121	1.647	1.416	1.484	1.098	1.00	0.937	1.580	1.897	1.731	1.268	1.198	0.866
K/(K+Na)	0.027	0.011	0.062	0.116	0.075	0.110	0.046	0.009	0.006	0.040	0.080	0.052	0.044	0.030
Mg/Fe	13.971	15.790	9.708	11.235	5.424	1.907	1.999	0.938	3.037	4.240	4.951	2.037	1.426	1.701
Niggli Endmembers														
Olivine	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FO	45.473	42.893	10.030	7.372	–	–	–	–	1.004	10.392	6.828	3.226	–	–
FA	0.466	0.661	0.451	0.452	–	–	–	–	0.196	1.805	1.093	1.145	–	–
Dipside	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DI	12.985	3.646	24.680	20.620	20.737	2.733	0.066	–	17.487	23.477	24.632	8.811	4.584	–
HD	0.133	0.056	1.109	1.264	1.547	0.747	0.022	–	3.414	4.078	3.943	3.129	2.042	–
Hypersthene	–	–	–	–	–	–	–	–	–	–	–	–	–	–
EN	19.426	6.632	6.897	0.00	5.894	9.953	8.301	2.301	15.037	10.484	6.509	11.278	13.288	17.281
FS	0.199	0.102	0.310	0.00	0.451	2.720	2.808	0.667	2.936	1.821	1.042	4.005	5.918	4.888
CIPW Endmembers														
Olivine	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FO	38.036	35.688	8.575	6.227	–	–	–	–	0.844	8.641	5.735	2.682	–	–
FA	0.565	0.796	0.558	0.553	–	–	–	–	0.239	2.174	1.330	1.380	–	–
Diopside	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DI	12.539	3.502	24.358	20.108	19.625	2.588	0.063	–	16.982	22.534	23.884	8.457	4.608	–
HD	0.147	0.062	1.254	1.412	1.719	0.810	0.024	–	3.799	4.484	4.380	3.441	2.351	–
Hypersthene	17.392	5.906	6.311	0.00	5.300	8.739	7.344	2.018	13.539	9.330	5.851	10.036	12.385	14.970
EN	0.234	0.120	0.373	0.00	0.532	3.158	3.265	0.769	3.474	2.130	1.231	4.684	7.250	5.565
FS	–	–	–	–	–	–	–	–	–	–	–	–	–	–

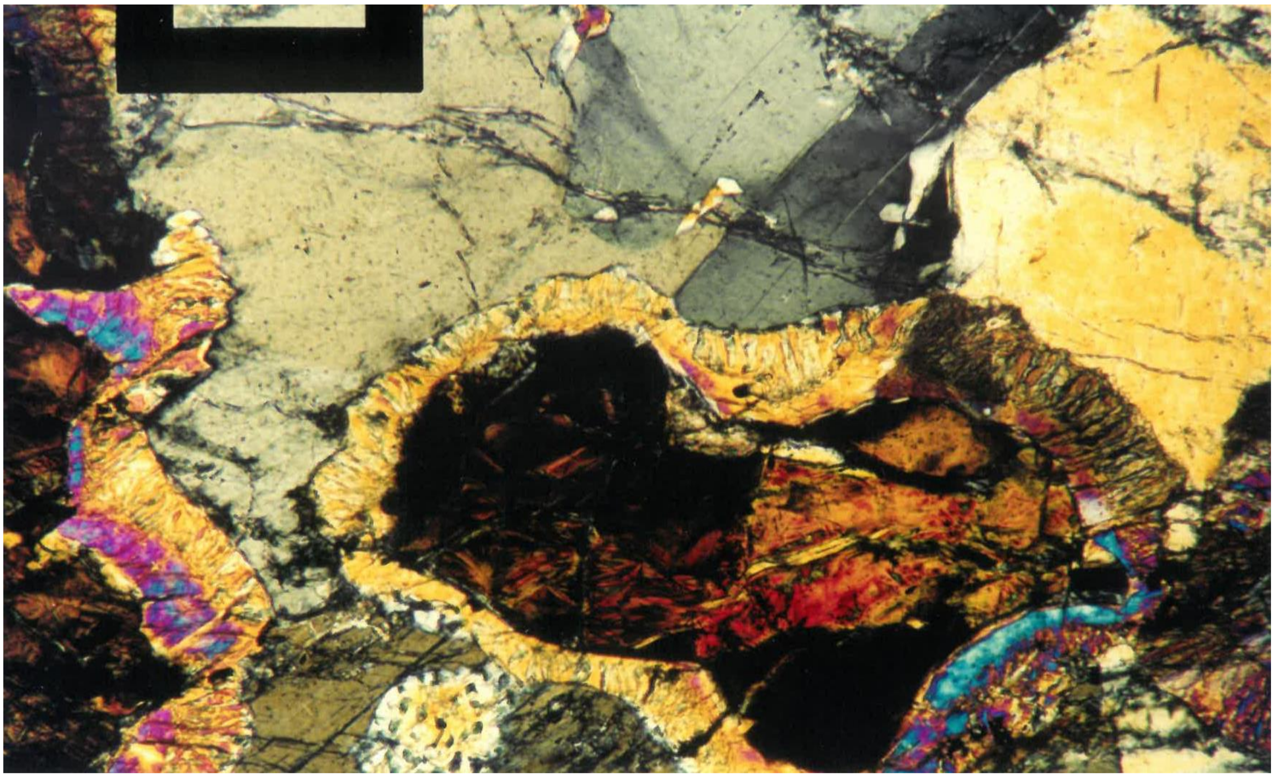

Fig. 3. Microscopic photograph of troctolite (crossed Nicols)

3. *Olivine gabbro*

Olivine gabbro is built up of plagioclases of the bitovnite-anorthite type, augite (dijalag) and a very variable amount of olivine. There are very few accessory minerals and they are represented by amphibole-actinolite, magnetite, and sometimes hypersthene. In some specimens of olivine gabbro, biotite is also present.

The rock is very coarse-grained, it has a typical gabbroic structure (allotriomorphically granular), crystals are presented with different sizes, as follows: feldspar are up to 2 mm in size, while pyroxenes and olivines are up to 1 mm in size.

Feldspars are fresh and they build the main mass of the rock. They have isometric shapes, regularly appearing as twinned individuals or in the form of polysynthetic lamellae (Figure 4).

Augite (dijalg) occurs in allotriomorphic forms with a pronounced occurrence of prisms after the first pinacoid and with very weakly pronounced prismatic cleavage.

Olivine occurs in xenomorphic grains with small dimensions and is not very common in quantity. It is almost always involved in serpentinization processes, and, as a result, magnetite veins occur.

The normative composition (Table 1, analysis 3) fully corresponds to the modal mineral composition.

In the decomposed specimens of the olivine gabbro, biotite and green hornblende occur.

4. *Gabbro*

The central place in the ophiolite complex Demir Kapija-Gevgelija is occupied by gabbro (sensu stricto); it is built of a mineral association of anorthite and augite (dijalag). Occasionally there is a small occurrence of olivine which is associated with the ultrabasic parts of the complex, and sometimes there is an occurrence of amphibole with which it associates with the diorite part of the ophiolite complex.

It has a typical gabbro structure (allotriomorphic granular). Xenomorphic grains of one mineral enter incorrectly into another mineral. The grain size is variable. Pyroxenes occur up to 2 mm in size while plagioclase occurs up to 1 mm in size.

Feldspars are quite fresh, and they belong to the group of basic plagioclases (anorthite). They very rarely occur as individuals, usually as twinned crystals of one or more individuals (polysynthetic lamellae) (Figure 5).

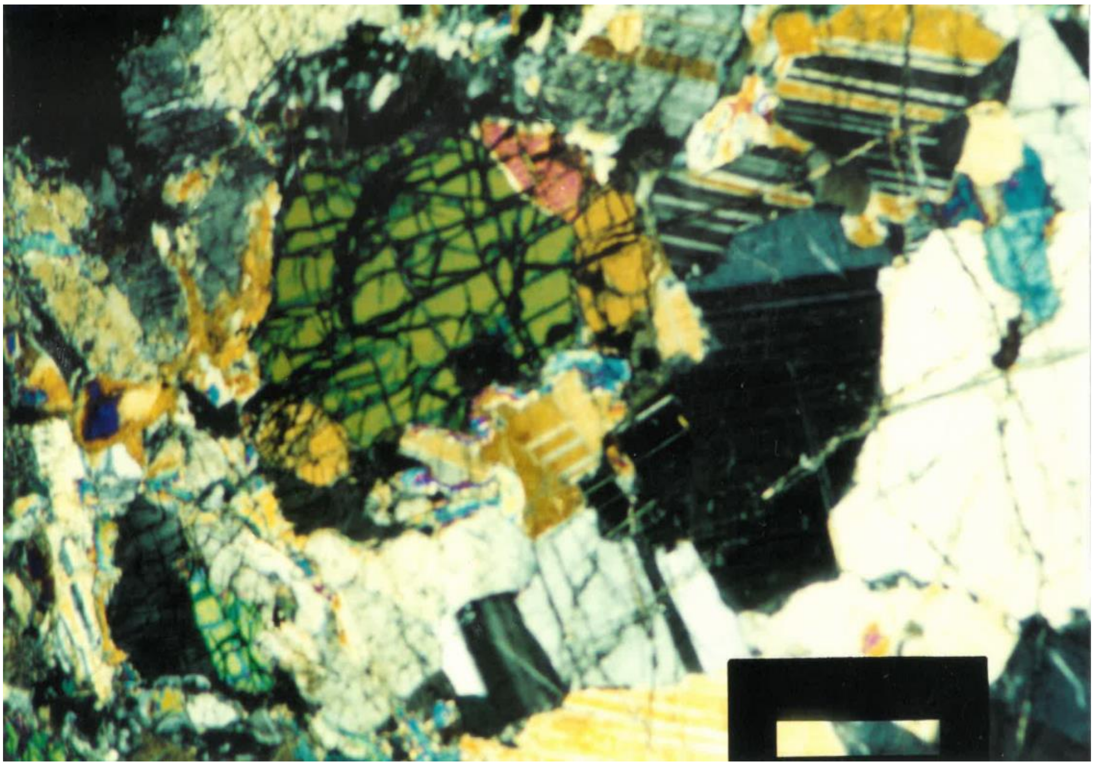

Fig. 4. Microscopic photograph of olivine gabbro (crossed Nicols)

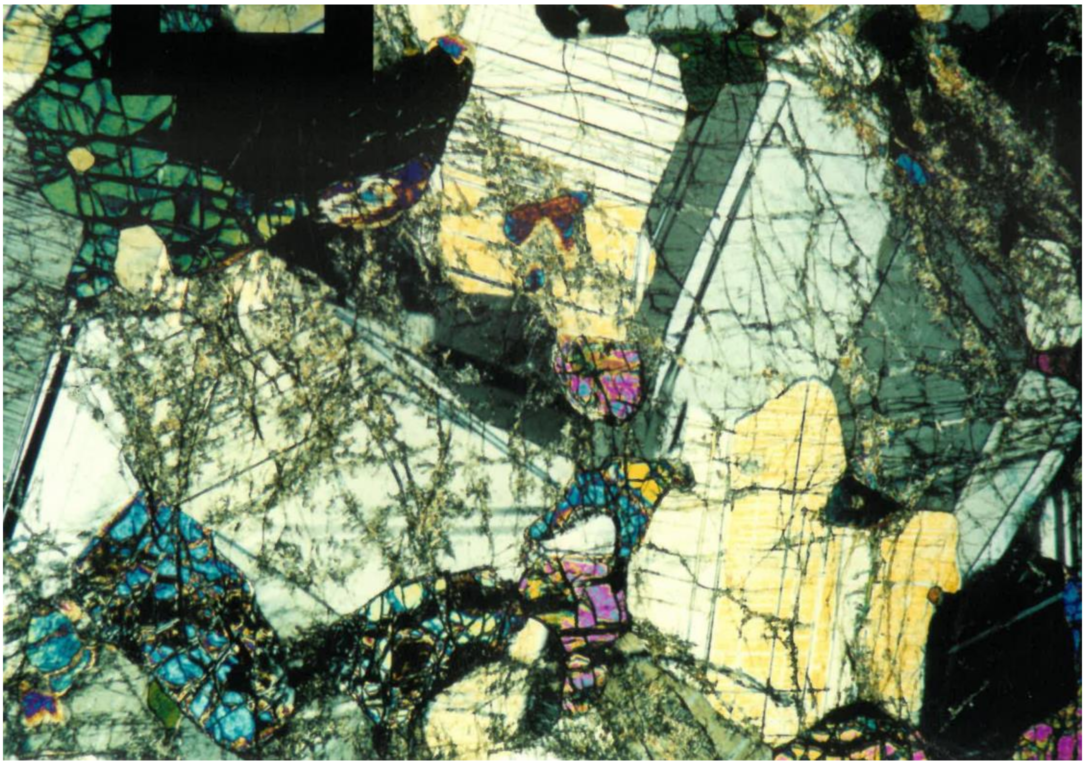

Fig. 5. Microscopic photograph of gabbro (crossed Nicols)

Pyroxene, based on its microscopic characteristics, can be determined as augite (dijalag). It occurs in allotriomorphic grains, often in groups. Prismatic cleavage is weakly pronounced.

There is no olivine in the modal composition, while in the normative composition (Table 1, analysis 4) there is olivine, which is understandable if we have in mind the method of calculations according to the CIPW method. The amount of anorthite determined in the normative composition is in accordance with the modal composition (microscopically determined composition).

It should be mentioned that in the field within the ophiolitic complex Demir Kapija-Gevgelija there are certain zones in which there are pronounced metamorphic changes of the gabbros. These metamorphic changes are represented by a process of uralitization (the occurrence of a uralite that develops with a change of pyroxene). Pyroxene, augite (dijalag)) gradually turns into fibrous or compact amphibole along the edges of the augite or on the surfaces of the augite cleavage.

5. *Uralite gabbro*

Within the complex, the gabbro affected by metamorphic changes occurs in several places, and it has turned into uralite gabbro. In the microscopic preparation it can be seen that the rock has a gabbroic structure (made of pyroxenes and plagioclases). Pyroxene is intensively modified into uralite which has the properties of actinolite. Plagioclases are slightly more acidic, mainly having a lamellar structure.

The normative composition (Table 1, analysis 5) does not fully correspond to the modal composition. Pyroxene appears in the normative composition and amphibole in the modal composition. The normative composition of the plagioclase has a higher percentage of anorthite, while in the modal composition the plagioclase has optical characteristics that indicate a more acidic plagioclase (with a smaller amount of anorthitic component).

6. *Diorite*

It is made of plagioclase, hornblende, quartz, and magnetite. It has a hypidiomorphic granular structure. Plagioclases appear in hypidiomorphic to idiomorphic crystalline shapes and in elongated forms. They have a pronounced zonal structure as a consequence of rapid cooling of the magmatic melt. The rock is made of plagioclases, hornblende, quartz and magnetite. Plagioclases appear in hypidiomorphic to idiomorphic shapes, and they have a pronounced zonal structure.

7. Basalt

This rock can also be called anorthitic-uralite basalt. It is dark gray to black in color, it has a characteristic fine porphyric structure in which in places there are larger phenocrysts of plagioclase. The basic mass is holocrystalline, composed of basic plagioclases and pyroxene of the pigeonite- augite type, which are involved in the uralitization processes. Plagioclases appear in twined individuals and are elongated in the direction of the main axis, idiomorphic in shape. Around the pyroxenes in some places there are kelephite edges made of amphibole-actinolite. Magnetite and epidote occur as accessory minerals.

8. Diabas

The rock is dark green, it is very hard and is made up of rod-shaped albites and amfiboles that occur in the form of sticks and irregular grains, epidote, magnetite, and a little quartz (Figure 6).

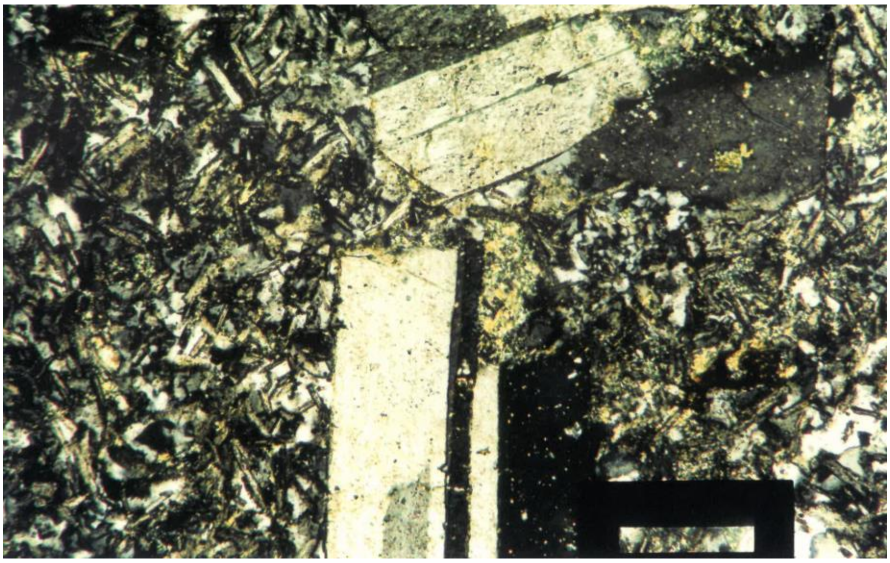

Fig. 6. Microscopic photograph of diabase (crossed Nicols)

9. Quartzdiorite

The rock is dark gray in color and it occurs in the form of veins that in places intersect the ophiolitic complex. Under a microscope the rock has pseudo-porphyric structure with plagioclase phenocrysts and sometimes amphiboles. In addition to these minerals, quartz also occurs in the rock. In its optical characteristics, amphibole corresponds to hornblende. Magnetite and epidote occur as accessory minerals (Figure 7).

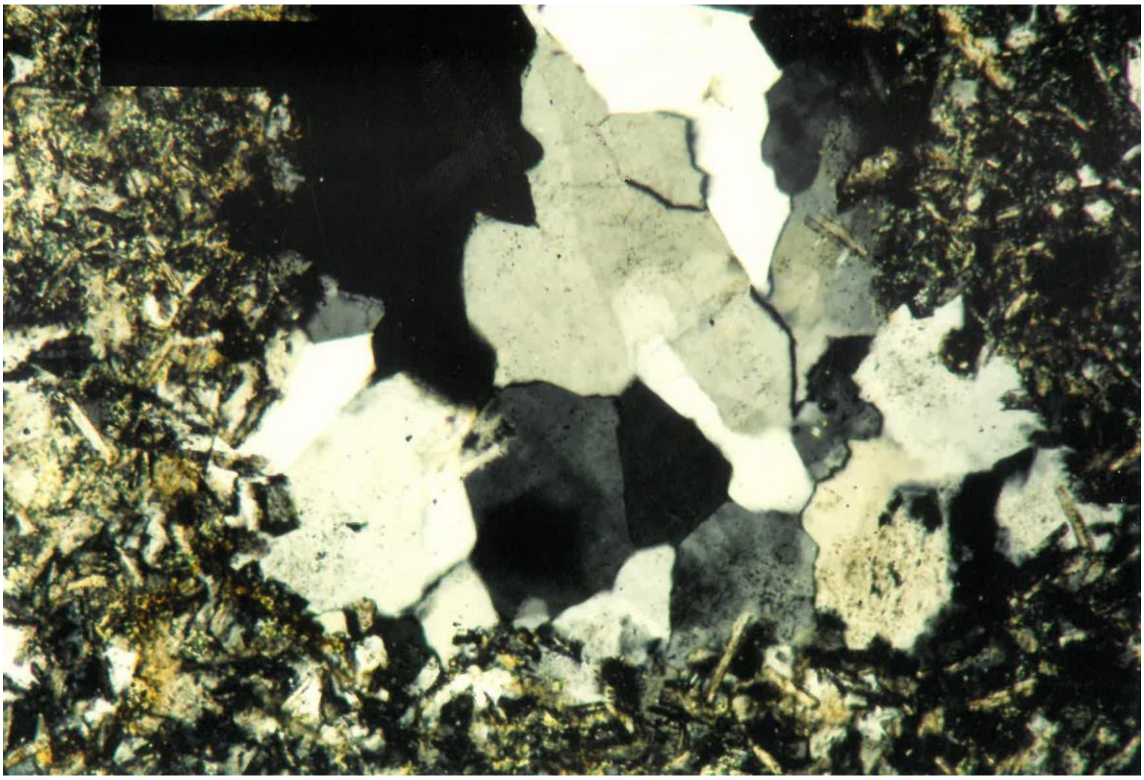

Fig. 7. Microscopic photograph of quartzdiorite (crossed Nicols)

CLASSIFICATION OF ROCKS

The classification of magmatic rocks from the Dren-Bohula section is made based on the Middlemost nomenclature (1994) (Figure 8), as well as on the nomenclature of calculation of the normative mineral composition (Norm Calculation) (Table 1).

From the diagram in Figure 8 it can be concluded that this is a differentiation of a basic magma which in a continuous sequence of differentiation gave the following magmatic rocks: peridotite gabbro-gabbro-gabbrodiorite-diorite-granodiorite.

These rocks are part of the sequence of oceanic crust that developed during the Jurassic in this part of Tethys (the Tethyan Eastern Vardar ophiolitic unit in the Eastern Mediterranean).

From the data presented on the normative composition of rocks (Table 1), it can be concluded that there is a typical continuous differentiation of one ultrabasic to basic magma with a classic series of differentiation from basic plagioclases-intermediate plagioclases-acid plagioclases-feldspar to quartz and differentiation from olivine-pyroxenes-amphiboles-mica.

CONCLUSION

Within the ophiolitic complex Demir Kapija Gevgelija, its western part called the Dren-Bohula massif is built of the same rocks from which the other part of the ophiolitic complex is built: verlites, gabbros, troctolites, gabbro-diorites, diorites, quartzdiorites, grandoirites. The classification made and the nomenclature of rocks indicate a continuous differentiation of an ultrabasic magma to basic magma.

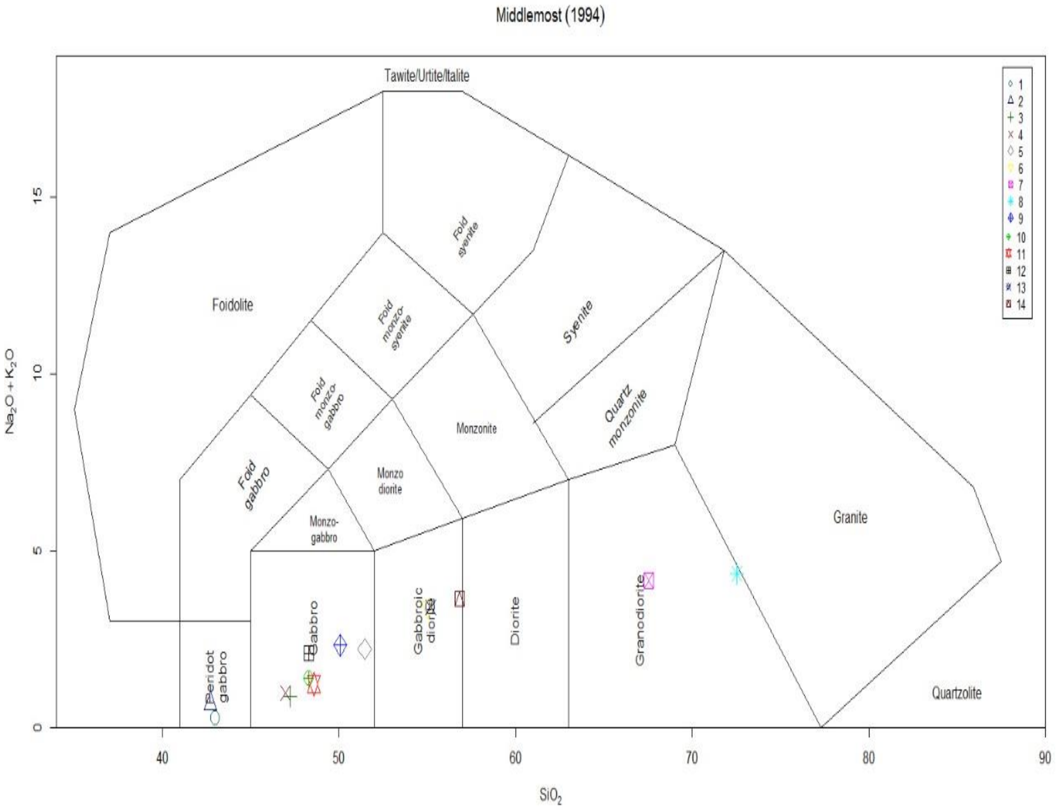

Fig. 8. Total alkali vs. silica (TAS) intrusive rock plot (Middlemost, 1994)

REFERENCES

Boev, B. & Lepitkova, S. (2002). The age of the ophiolite rocks on the territory of the Republic of Macedonia. *Proceedings of XVII. Congress of Carpathian-Balkan Geological Association,* Bratislava, September 1, 4pp. Available from: http://eprints.ugd.edu.mk/id/eprint/1430 (lastaccessed April 2013).

Boev, Blazo and Prelevic, Dejan and Bozovic, Milica and Eric, Suzana and Cvetkovic, Vladica (2013) *Olivine websterite veins cutting the Rabrovo serpentinites (South Macedonia): new evidence of the arc setting of the east Vardar ophiolites?* Contributions, Section of Natural, Mathematical and Biotechnical Sciences, MASA, **34** (1-2). pp. 69–81. ISSN 1857-9027,

Bozovic, Milica and Prelevic, Dejan and Romer, Rolf and Barth, Matthias and Boev, Blazo and Bogaard, Paul (2010) *A Segment of Oceanic Crust, in Macedonian (FYROM) Ophiolites, seen through Sheeted Dyke Diabases, Keratophyres and Adakite-like Volcanics.* EGU General Assembly Conference Abstracts, 12. p. 7996.

Karamata, S. (2006). The geological development of the Balkan Peninsula related to the approach, collision and compression of Gondwanan and Eurasian units. In: Robertson, A. H. F. & Mountrakis, D. (eds) Tectonic Development of the Eastern Mediterranean Region. Geological Society, London, Special Publications 260, pp. 155–178.

Lepitkova, S. (2002). *Petroloski, geohemijski i izotopski proucuvanja na peridotitite od vnatresniot dinarski ofiolitski pojas vo Republika Makedonija*. PhD dissertation, Kiril and Metodij University of Skopje, 333 p.

Middlemost, E.A.K. (1994) Naming materials in magma/igneous rock system. *Earth Sci Rev.* **37**, pp. 215–224,

Prelevic, Dejan and Wehrheim, Simon and Reutter, Magnus and Boev, Blazo and Bozovic, Milica and Bogaard, Paul van den and Cvetkovic, Vladica and Schmid, Stefan M. (2017) *Th*e Late Cretaceous Klepa basalts in Macedonia (FYROM)— Constraints on the final stage of Tethys closure in the Balkans. *Terra Nova*, **29**. pp. 145–153.

Prelevic, Dejan and Wehrheim, Simon and Bozovic, Milica and Romer, Rolf and Boev, Blazo (2014) *The origin of volcanic section of the Vardar ophiolitic zone: a comparative petrological and geochemical study of latecretaceous volcanics from Macedonia with their jurasic counterparts from Balkans*. Optimal research and sustainable usage of the geological resources.

Saric, K., Cvetkovic, V., Romer, R. L., Christofides, G. & Koroneos, A. (2009). Granitoids associated with EastVardar ophiolites (Serbia, F.Y.R. of Macedonia and northern Greece): Origin, evolution and geodynamic significance inferred from major and trace element data and Sr-Nd-Pb isotopes. Lithos 108, 131–150.

Schmid, S., Bernoulli, D., Fu« genschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M. & Ustaszewski, K. (2008). The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolutionof tectonic units. *Swiss Journal of Geosciences,* **101**, 139–183

Zachariadis, P. (2007). *Ophiolites of the eastern Vardar Zone, N. Greece*. PhD dissertationMainz: Johannes Gutenberg-Universita«t, 131 p.