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Geology

New Data on the U-Pb Zircon Age of the Pre-Alpine Crystalline Basement of the Black-Sea-Central Transcaucasian Terrane and their Geological Significance

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ABSTRACT. The available data on the composition, interrelation, age and formation conditions of the pre-Alpine crystalline basement constituting rocks of the Black Sea-Central Transcaucasian terrane are considered. It is shown that the main stages of regional metamorphism and granite formation are fully corroborated by new U-Pb LA-ICP MS dating. The investigations carried out to fill up the gaps existing in isotope-geochronological data of the crystalline basement of the Black Sea-Central Transcaucasian terrane and considerably specify the age of pre-Alpine endogenic processes. *© 2011 Bull. Georg. Natl. Acad. Sci.*

Key words: *the Caucasus, regional metamorphism, magmatism, U-Pb zircon age.*

Introduction

The Caucasus represents a complicated polycyclic geological structure involving mountain fold systems of the Greater and Lesser Caucasus and adjacent foredeeps and intermountain troughs.

Paleomagnetic and paleokinematic, as well as traditional geological data (character of sedimentation and magmatism, geology and age of ophiolites, paleoclimatic and paleogeographic data) indicate that within the oceanic area of Tethys (with a typical oceanic crust), which separates the Afro-Arabian and Eurasian continental plates, in geological past relatively small continental or subcontinental plates (terranes) were situated, having diverce geodynamic nature and characterized by specific lithologic-stratigraphic section and magmatic, metamorphic and structural features.

During the Late Precambrian, Paleozoic and Early Mesozoic time these terranes experienced horizontal displacement in different directions within the oceanic area of Proto-Paleo- and Mesotethys (Neotethys) and underwent mutual accretion and ultimately joined the Eurasian continent.

In the Caucasian segment of the Mediterranean mobile belt the Greater Caucasian, Black Sea-Central Transcaucasian, Baiburt-Sevanian and Iran-Afghanian terranes, which in geological past represented island arcs or microcontinents, are identified (Fig. 1) [1].

In terms of modern structure they represent accretionary terranes of the first order separated by trustworthy or supposed ophiolite sutures of different age. Terranes of the first order, in their turn, consist of a great number of subterranes delimited as a rule by deep faults

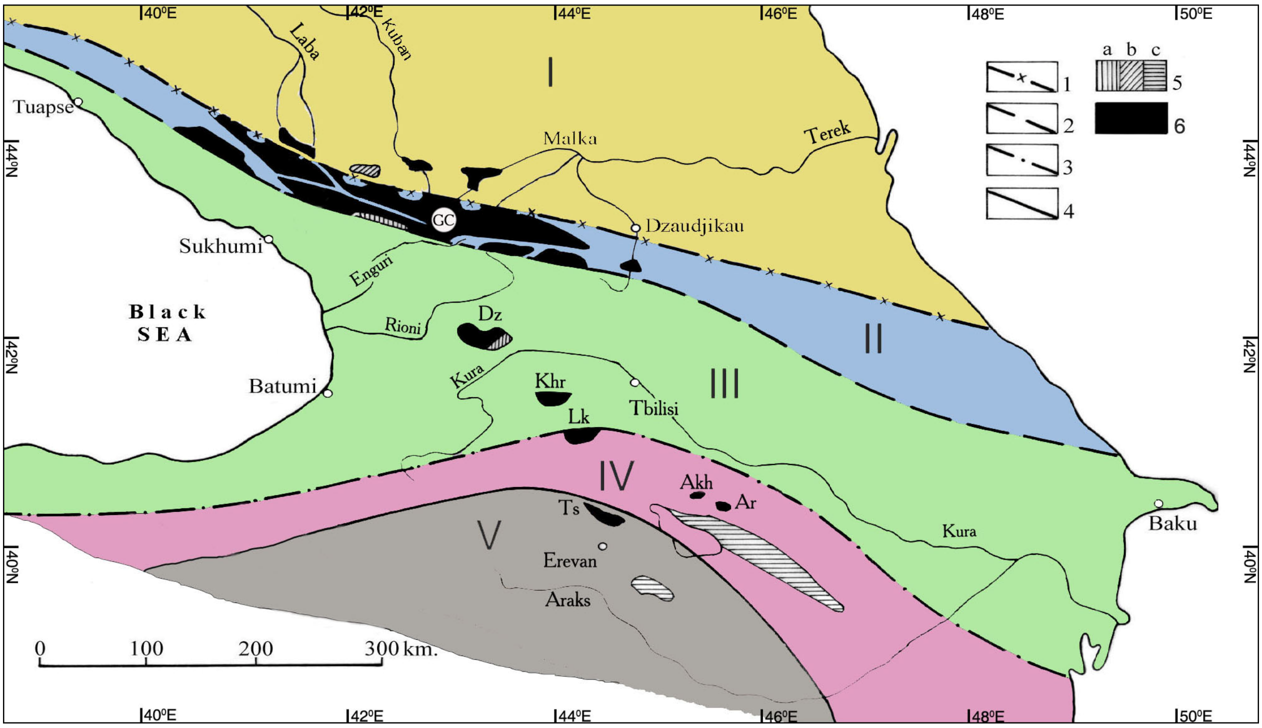


Fig.1. Tectonic subdivision of the Caucasus on the basis of the terrane analysis [4], simplified.

I. The Scythian platform; Accretionary terranes of the first order: II - Greater Caucasian terrane; III - Black Sea-Central Transcaucasian terrane; IV - Baiburt-Sevanian terrane; V - Iran-Afghanian terrane

1-4 - ophiolite sutures, marking the location of small and large oceanic basins: 1 - of Early? - Middle Paleozoic age, 2 - of Late Precambrian - Paleozoic age, 3 - of Late Precambrian-Early Mesozoic age, 4 - Mesozoic age; 5 - ophiolite terranes (obduction sheets): 5_a - Late Precambrian age, 5_b - Paleozoic age, 5_c - Mesozoic age; 6 - exposures of pre-Alpine crystalline basement.

Lettered separate exposures: GC - Greater Caucasian; Dz - Dzirula; Khr – Khrami; Lk - Loki; Akh - Akhum; Ar - Asrikchai; Ts - Tsakhkunyats.

or regional thrusts. Earlier they were considered as separate tectonic units (zones) of the Caucasus. Besides, in many places of the Caucasian region there are ophiolite terranes - relicts of the oceanic crust of small or large oceanic basins overthrust (obducted) from the above-mentioned ophiolite sutures.

It should be specially noted that the Earth's crust of the Caucasus is tectonically layered [2-5]. Similar tectonic layering has recently been reported from many regions of the world. It has also been traced throughout the whole central segment of the Mediterranean mobile belt [2].

The paper aims to fill up the gaps existing in isotope dating of the crystalline basement of the Black Sea-Central Transcaucasian terrane.

Review of the available data on composition, interrelation, age and formation conditions of pre-Alpine crystalline rocks

The largest exposure of the pre-Alpine basement of the Black Sea–Central Transcaucasian terrane is the Dzirula massif (subterrane) with the area 1200m^2 (see Fig. 1, 2).

The Dzirula massif consists of: Precambrian gneiss-migmatite complex, three generations of metabasites and quartz-diorite orthogneisses; Cambrian (?) metabasites of the fourth generation; Late Baikalian granitoids of plagiogranite-granite series and Late Variscan granite-gneisses and granites (see Fig.2, 3).

In the south-eastern part of the Dzirula massif the so-called Chorchana Utslevi allochthone complex is observed as well. These allochthonous plates are represented by Cambrian-Middle Paleozoic metapelites, metabasites and Precambrian and Paleozoic metaophiolites (metabasites and ultrabasites) associated with them, which represent fragments of the Proto-Paleotethys oceanic crust [4, 6, 7] (see Fig. 2).

Within the Dzirula massif multistage regional metamorphism is established [3, 4, 8-10]. Three stages of regional metamorphism are distinguished: Grenville prograde, Late Baikalian high temperature diaphthoresis and Late Variscan retrograde. At the same time, rocks of the gneiss-migmatite complex bear signatures of the earliest (Grenville or even older) regional metamorphism in the Dzirula massif. The rocks of the complex are cut by Precambrian quartz-diorite orthogneisses that carry the

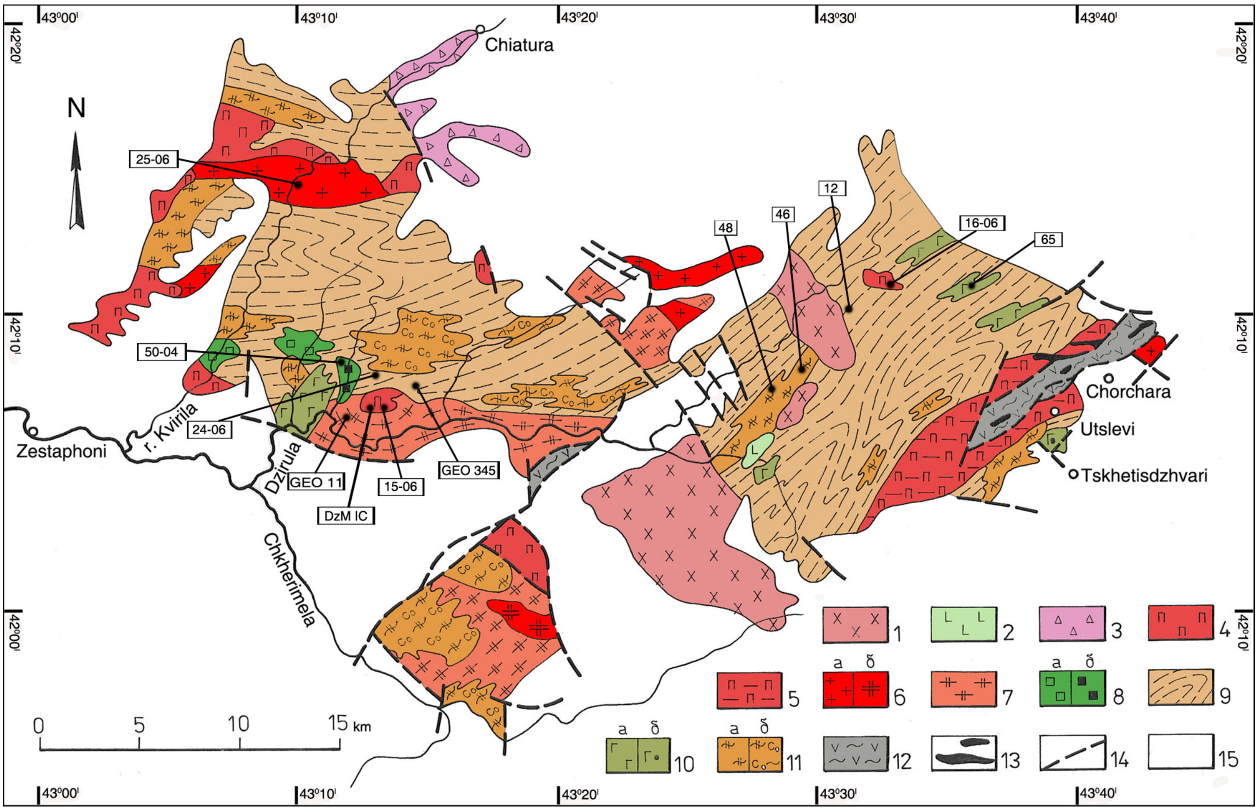


Fig.2. Schematic geologic map of the Dzirula crystalline massif.
1 – granitoids (Middle Jurassic); 2 – feldspar gabbro, (Early-Middle Jurassic?); 3 – rhyolite volcanics (Late Paleozoic); 4–7 – Late Variscan: 4 – microcline granites; 5 – foliated (dynamometamorphosed) granites and mylonites; 6 (a) porphyritic microcline granites of the Rkvia intrusion, (b) porphyry granites; 7 – microcline granite gneisses and migmatites; 8: a – massive tonalities and granodioprites (Late Baikalian) in the Kvirila and Macharula river canyons, b – massive gabbro–gabbro-diorite (Cambrian?) in the Gezrula river canyon; 9 – quartz-diorite ortho gneisses (Late Precambrian); 10 – metabasites (gabbro, gabbro-amphibolites): (a) Precambrian (?), (b) Cambrian; 11 – Precambrian gneiss-migmatite complex: (a) crystalline schists, amphibolites, amphibole-biotite schists, plagiogneisses, and plagiomigmatites, (b) cordierite plagiogneisses and plagiomigmatites; 12 – metavolcanic-phyllite complex (Cambrian – Early-Middle Paleozoic); 13 – serpentinite protrusion (part of the Precambrian – Paleozoic metaophiolite terrane); 14– faults; 15 – sedimentary cover (Mesozoic-Cenozoic); 16 – in rectangles - sample numbers.

xenoliths of already metamorphosed rocks of the complex, including strongly deformed plagiomigmatites and crystalline schists (see Fig. 4).

The oldest (Grenville) (700-720ºC; 2.6-2.7 kb) regional metamorphism of the gneiss-migmatite complex is represented by critical parageneses: Cor+Pl+Bt(1)+Sill±±Qtz±Spi+Zir and Hbl(grayish-green)+Cpx+Pl±Grt. According to S. Korikovsky et al. [10], Bt1 has a high-Ti content (TiO_2 4.5 mas.%, X_{Fe} 0.56-0.57) and spinel (hercynite) contains ZnO up to 1-4 mas.%. In paraplagiogneisses K. Chikhelidze [11]established rolled detrital zircons as well as facet crystals of zircon. The latter was formed as a result of magmatism and regional metamorphism and is characterized by short prismatic crystals with numerous facets of bipyramidal indices.

The second stage - Late Baikalian high temperature diaphthoresis – (500-650ºC; 2.7 kb) [4, 11] of the regional metamorphism of gneiss-migmatite complex is represented by the following parageneses: Bt(2)+Ms+Grt+Pl+Qtz+Zir, Bt(2)+Andl(Sill)±Grt±Zir, Hbl(green)+Pl±Bt(2), Hbl(green)±Cum±Cpx+Pl. Replacement of high-temperature paragenesis - Cor+Pl+Bt(1)+Sill±Ksp+Pl±Spi+Zir of Grenville regional metamorphism with lower-temperature paragenesis – Grt+Bt(2)+Andl(Fibr)+Ms+Pl+Qtz+Zir of Late Baikalian regional metamorphism is established. It is noteworthy that collective crystallization and neo-mineralization of early existing biotites Bt(1) also takes place, accompanied by the occurrence of zircon grains in a newly formed biotite Bt2 [4]. According to S. Korikovsky et al. [10], Bt(2) is low-Ti (TiO_2 0.48-054mas.%, X_{Fe} 0.43-0.48). Zircons formed at this stage of metamorphism are grown around the detrital and facet crystals of zircon formed at the first-Grenville stage of metamorphism.

The latest manifestation of regional metamorphism coincides with the formation of Late Variscan granites. At this stage of regional metamorphism in the pre-Variscan crystalline formations of the Dzirula massif the process of regional microclinization is recorded [12]. Due to this proc-

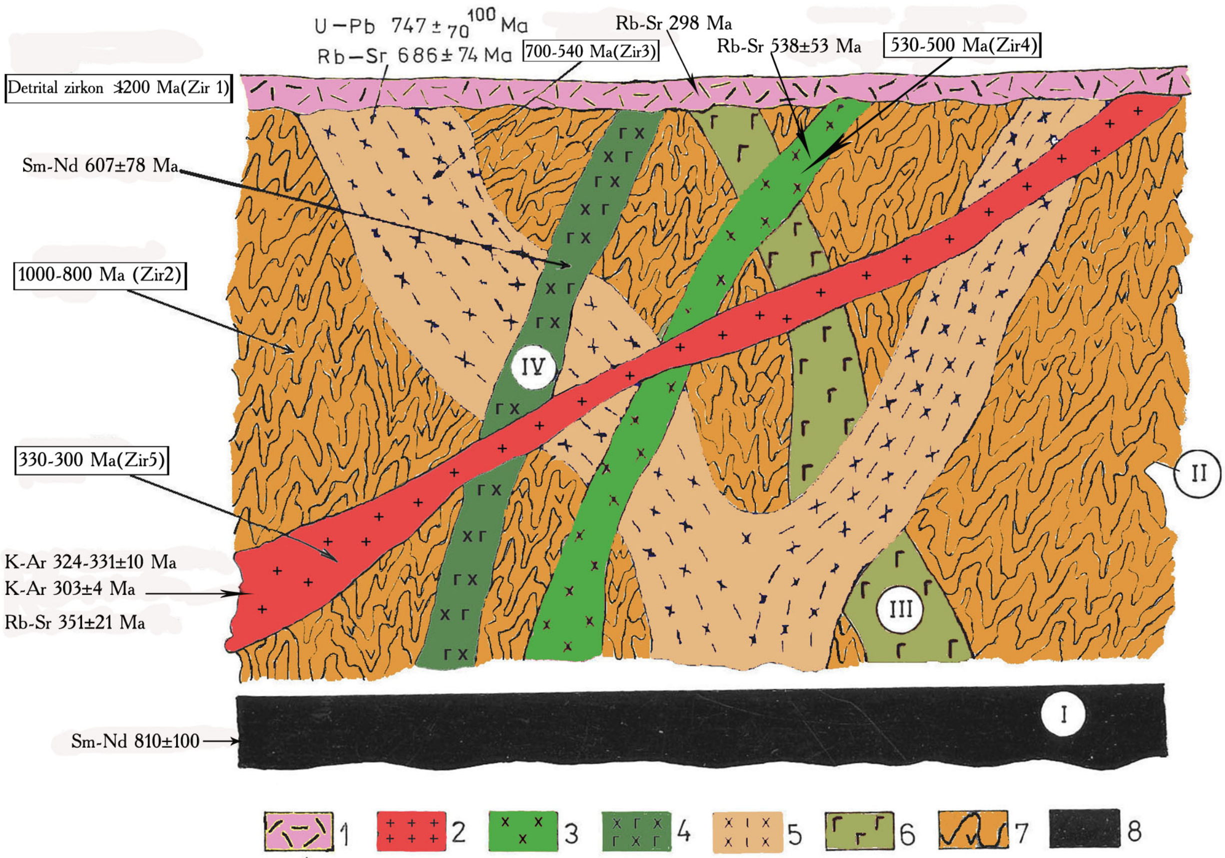


Fig. 3. Scheme of the principle of interrelation of the Dzirula crystalline massif constituting rocks.
1 - rhyolite tuffs (Upper Visean-Bashkirian); 2 – microcline granites (Late Variscan); 3 – granitoids of plagiogranite (tonalite)-granite series (Late Baikalian); 4 – gabbro–gabbro-diorite intrusions (Cambrian ?); 5 – quartz-diorite orthogneisses (Baikalian); 6 – metabasites (gabbro, gabbro-amphibolites) (Late Precambrian); 7 – gneiss-migmatite complex: crystalline schists, amphibolites, amphibole-biotite schists, plagiogneisses and plagiomigmatites (Neoproterozoic); 8 – melanocratic basement. Figures in circles: I, II, III, IV generation of basites. Figures in rectangles – new U- Pb zircon age determinations.

ess microcline porphyroblasts and other low-temperature minerals are developed as well: muscovite, albite, chlorite, actinolite, minerals of epidote group, and zircon of new generation. The latter occurs also in Late Variscan granites.

Until the 1990s the pre-Alpine magmatism and regional metamorphism of the Dzirula crystalline massif were considered as events connected with the epoch of Late Variscan orogeny. The first isotope-geochronological studies were carried out by K-Ar dating of muscovites and biotites, giving the precise age of Late Variscan granites as well as that of a widespread process of regional microclinization in all the pre-Alpine formations of the Dzirula massif [13]. The latter was genetically connected to the centre of the Late Variscan granite protolite. K-Ar age of granites and microclinized substrate of various compositions was defined as 325-336±10 Ma [12, 13].

Since the 1990s, according to geologic [4, 7-9, 14] and isotope-geochronological data, the Lower Paleozoic and Precambrian age of some magmatites and metamorphites has been established in the Dzirula massif [7, 13, 15-17] (see Fig. 4).

On the basis of geologic and petrologic data the following petrogenetic conclusions are evidenced:

(1) The Precambrian quartz-diorite gneisses were formed in an ensimatic immature island arc during sub-

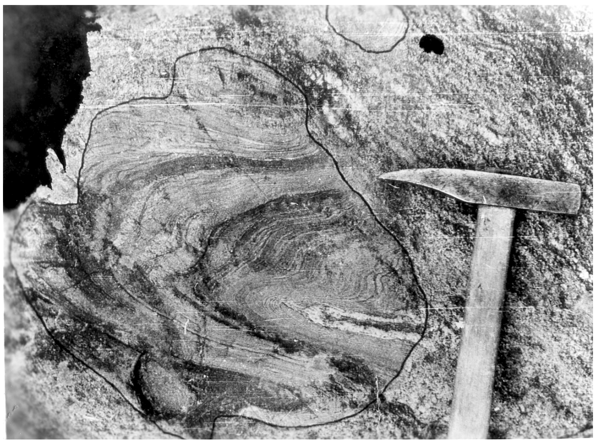


Fig. 4. Xenolith of migmatized and post crystallization folded biotite crystalline schists in Precambrian (Baikalian) quartz-diorite orthogneiss [4]

duction. Petrochemical, geochemical and geological data [4, 18, 19] indicate that they mostly belong to granites of I and partly of S type but after mineralogic-petrographical classification – to MPG and ACG groups.

(2) The rocks of the gabbro–gabbro-diorite series are the melting products of the mafic rocks of the oceanic crust and, partially, of the Precambrian quartz-diorite gneisses. They were formed from ensimatic crust without the contribution of continental material. The rocks of plagiogranite (tonalite) – granite series were generated from intensive plagiomigmatization of the Precambrian plagiogneiss-plagiomigmatite complex as a result of Late Baikalian regional metamorphism. They were formed from the rocks of immature continental crust and fully correspond to granites of S type and MPG group.

(3) The Late Variscan granites are typical products of the selective melting of the sialic crust (third inversion layer, according to geophysical data). These granitoids were emplaced immediately after the thrusting of the mafic (second) and sialic (first) layers. They were formed at various depths within this layer, probably without any considerable contribution of mantle heat and material. The source of heat was mainly the mechanical energy of tectonic deformations, particularly, the tectonic doubling of the crust. These granites belong to I and S types and MPG group of granites [4, 19].

Geologic, petrologic and geophysical data attest horizontal tectonic layering of the Earth's crust within the Black Sea-Central Transcausian terrane, taking place in Variscan (Saurian) orogeny [4]. On the surface this is expressed by juxtaposed fragments of various terranes formed in different geodynamic settings: the fragments of the upper mantle, the oceanic crust and a volcanoclastic lens accumulated on an ancient continental slope. Prior to Late Variscan granite emplacement these rocks were thrust together with the spatially associated pre-granite crystalline basement of femic composition (second layer) and sialic rocks (first layer) as indicated by geophysical data [20].

Pre-Alpine crystalline rocks within the Black Sea-Central Transcaucasian terrane crop out also in the Khrami massif.

The Khrami Precambrian complex contains two main rock types (Fig. 5, [21]): biotite-cordierite-bearing plagiogneiss complex and biotite-hornblende-bearing quartz-diorite gneisses. The main mineral paragenesis of biotite-cordierite plagiognesses is: Cor+Bt+Pl^{20-30-} +Qtz±Ort. They have a chemistry of S type granites and correspond to the CPG (cordierite-bearing peraluminous) group. Mineral paragenesis of biotite-hornblende-bearing quartz-diorite gneisses is: Hbl+Bt+Pl^{30-40-}± Qtz. They belong to granitoids of I type and ACG group.The parent rocks of biotite-cordierite plagiogneisses were volcanogenic-sedimentary rocks but of biotite hornblende quartz-diorite gneisses – basic magmatic rocks.

PT conditions of Grenville (?) regional metamorphism corresponds to P=2.6-2.7kb, T=700-720^0. During the Late Variscan orogeny, granite formation and subsequent granitization and retrograde metamorphism of the Precambrian complex took place. In the Precambrian gneiss-migmatite complex veined bodies of metagabbro of Paleozoic age are observed. They underwent only Late Variscan regional metamorphism [4]. All the above mentioned rocks are cut by biotite-bearing, two-feldspar K-rich Variscan granites poor in muscovite. They belong to I type granites formed in the ensimatic island arc occupying an intermediate position between the MPG and ATG groups of granitoids. They yield biotite K-Ar ages of 330 – 340 ± 10 Ma [13, 22].

New data on the U-Pb zircon age of the pre-Alpine basement rocks of the Black Sea-Central Transcaucasian terrane

To determine the age of the crystalline rocks U-Pb LA-ICP MS method of zircon grains, collected from different rocks of the Dzirula and Khrami massifs, was applied.

U-Pb LA-ICP MS dating was performed at the laboratories of the Department of Geosciences of National Taiwan University, Institute of Earth Sciences of Academia Sinica (samples №№46, 48, 24-06, 12, 65, 50-04, 16-06, 15-06, DZM 10, 25-06) [23] and at the Institute für Geowissenschaften of Johann-Wolfgang-Goethe University (samples №№ GEO 11, GEO 345).

The study of zircons from different rocks of the pre-Alpine crystalline basement showed morphological and optical inhomogeneity of zircon populations. In some crystals there occur relic cores of an earlier zircon including the detrital zircons with the later envelope. Consequently, in the studied crystals of zircon endogenic events of different age are encoded. Heterogeneity of the zircon crystals is conditioned by the presence of several generations of zonal crystals with different characteristics [23,24].

U-Pb LA-ICP MS zircon age dating was fulfilled: in Neoproterozoic gneiss-migmatites and quartz-diorite orthogneisses of the Black Sea-Central Transcaucasian terrane; in Cambrian (?) metabasites; in all the above-mentioned rocks diaphthorized during the Late Baikalian orogeny and feldspathized in the Late Variscan time as well as in Late Variscan granitoids. 290 measurements were carried out in 245 zircon crystals.

The greatest number of U-Pb LA-ICP MS age deter-

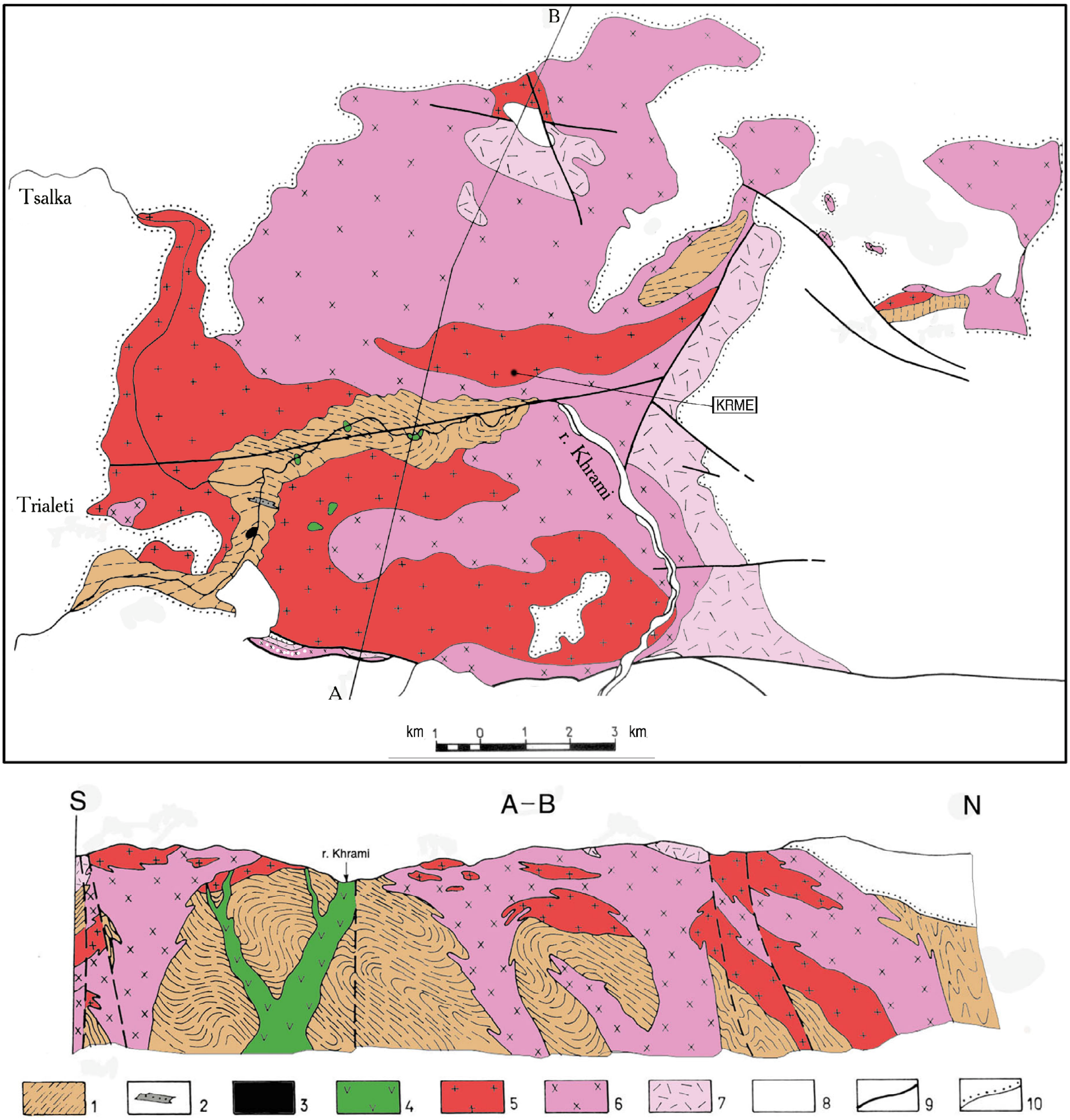


Fig. 5. Geological map of the Khrami crystalline massif after O.Khutsishvili [22] with changes.
1-7 - formation of the basement: 1-Precambrian gneiss-migmatite complex; 2-packet of Lower-Middle Paleozoic (?) metasandstones in gneiss-migmatite complex; 3-protrusion of mantle serpentinites (enlarged); 4-Paleozoic metagabbroids; 5-Late Variscan microcline granites; 6-Upper Paleozoic quartzporphyric-graniteporphyric complex; 7-Upper Paleozoic volcanogenic-sedimentary complex; 8-Mesozoic-Cenozoic sedimentary cover; 9-Faults; 10-transgressive overlapping; 11-trustworthy and presumable contours between geological units; 12 - in rectangle - sample number.

mination was carried out in the pre-Alpine basement of the Dzirula massif. In particular, in its metamorphic and magmatite rocks. 218 zircon crystals have been analyzed. In most cases, the pre-Variscan age is established in the crystal cores of zircon, and the Late Variscan age in the peripheral parts.

Genetic and five age-types of zircons are established: zircon (Zir1) - detrital zircon (>1200 Ma); zircon (Zir2) is formed at the Grenville stage of polymetamorphism (~ 1000-800 Ma), zircon (Zir3) corresponds to the crystallization age of quartz-diorite orthogneisses (~ 700 -540 Ma); zircon (Zir4), formed at the Late Baikalian stage of polymetamorphism and during the crystallization of tonalite-granitic series (550-500 Ma); zircon (Zir5), formed during the crystallization of Late Variscan granitoids (~ 330-300 Ma).

The results of U-Pb local dating of 4 heterogeneous zircon crystals from paraplagiogneisses of the Neoproterozoic gneiss-migmatite complex show the real pattern of multi-stage development of zircon crystals in the Dzirula massif (Sample # GEO 11, Fig.6). External configurations of the crystals are similar and have a prismatic-bipyramidal appearance. They are built up of a combination of prism (100) and bipyramids (111) and (311) often with asymmetrically developed facet combinations. Elongation of hyacinth type crystals is K=3-3,5. Despite their similar appearance, these zircons sharply differ by their inner structure and local isotope age. In the crystal core of evidently detrital zircon (Zir1) the age 1218±38 Ma was determined (crystal 1). A well-developed zoned envelope dated to 538±18 and 552±14 is grown around the detrital core. It corresponds to the Late Baikalian stage of regional metamorphism (Zir4). The latter is overgrown with a narrow transparent rim of late generation zircon (presumably Zir5). In the same sample, the age of the second crystal (2) core of zircon is 976±40 Ma (Zir2) and apparently, it corresponds to the oldest Grenville regional metamorphism attested in the Dzirula massif. This weakly zoned corroded crystal of zircon 2 is overgrown by bipyramidal-prismatic crystal, which is regenerated with a later transparent presumably Late Variscan (Zir5) unzonal rim. Crystal 3 is characterized by a prismatic-bipyramidal appearance, idiomorphism and well-expressed zonality. Here in the core the Late Baikalian age is established as 525±14 Ma and 528±12 Ma (Zir 4). This crystal is overgrown by a transparent un-zoned rim, presumably of the Late Variscan age. The core of crystal 4 is dated to 537±14Ma (Zir4) and it corresponds to the Late Baikalian stage of metamorphism but the external rim of this crystal is asymmetric and its age 334±8 Ma (Zir5) corresponds to the Late Variscan endogenic processes. It is noteworthy that K. Chikhelidze [11] distinguishes detrital, magmatic and metamorphic zircons as well as composite heterogeneous ones in the Neoproterozoic paraplagiogneisses of the Dzirula massif.

Here are also analyzed zircons from paraplagiogneisses which are intensely injected by late granite material (Samples 46, 48) (Fig.7). Zircons of sample 46 are sharply heterogeneous and here detrital zircon is dated to 1954±34 Ma (Zir1). The age 719±13 Ma is presumably that of the protolith of quartz-diorite orthogneiss Zir3 and also the age of the Late Baikalian stage of regional metamorphism 542±10, 559±11 and 579±11Ma (Zir4) is also determined. The Late Variscan mean age 323±3 Ma (Zir 5) is obtained in sixteen cases. For the zircon sample #48, only in one case the Baikalian age of quartz-dioritic orthogneiss protolith is defined as 673±12.6 Ma (Zir 3). All the other 20

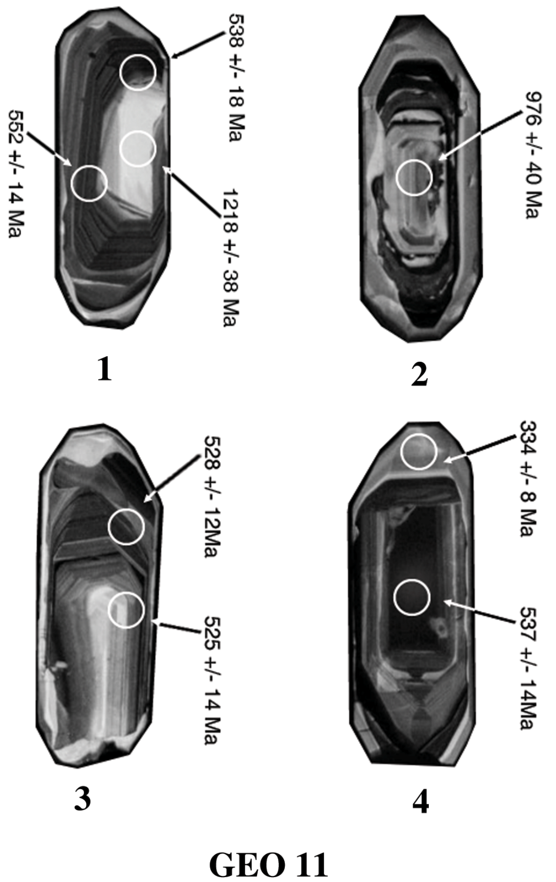
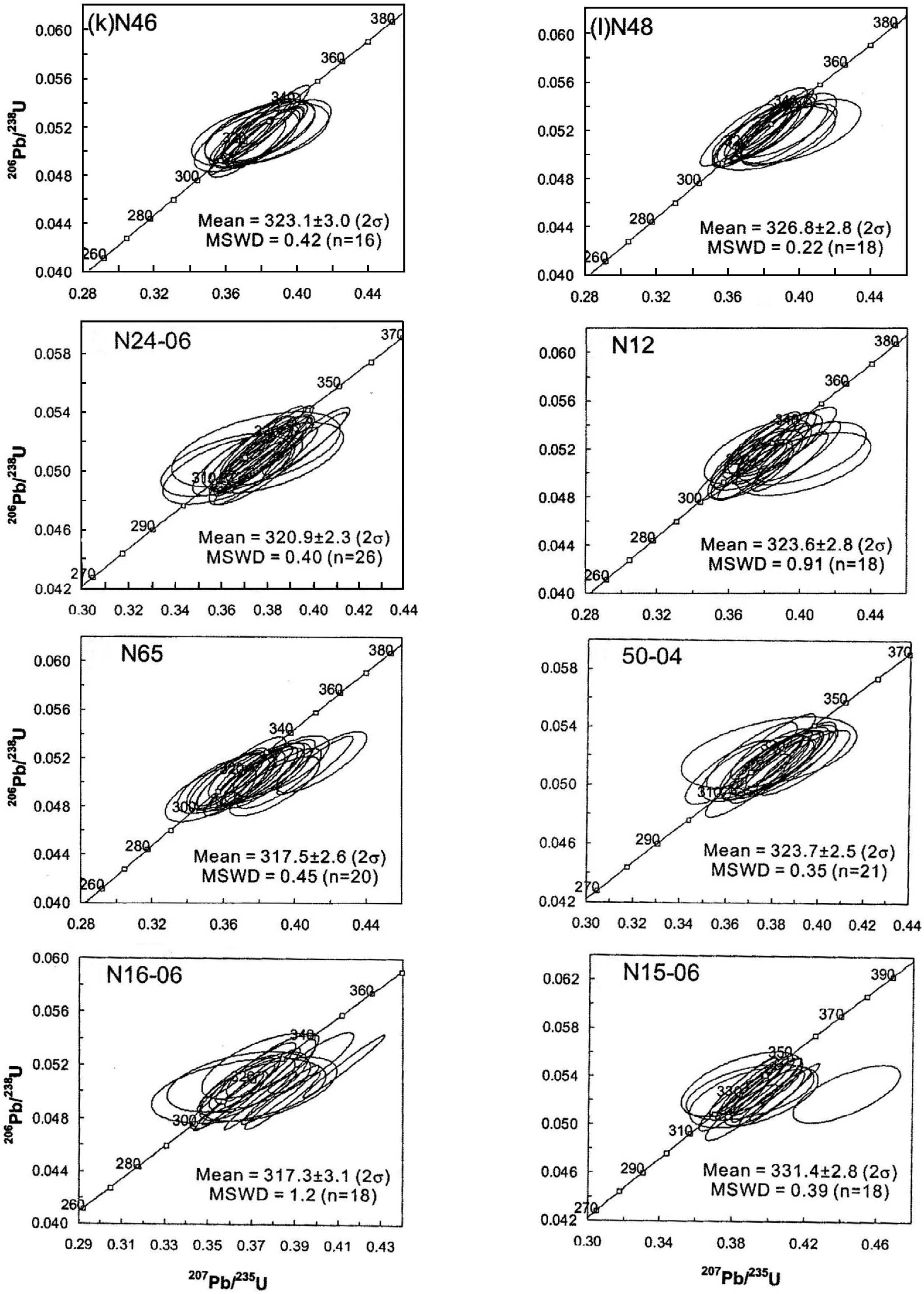


Fig. 6. Zircons from Neoproterozoic plagiogneisses (sample №GEO 11) of the Dzirula massif

determinations yield the mean age 326.8 ± 2.8 (Zir5) of the Late Variscan endogenic process.

As is known, quartz-dioritic orthogneisses are younger, as they cut crystalline schists, paraplagiogneisses, plagiomigmatites and amphibolites formed at the Grenville stage of regional metamorphism. In sample # GEO345 four zircon crystals from quartz-diorite orthogneisses, which were reworked by the Late Variscan granites, have been analyzed (see Fig.8). Crystal 1 is of prismatic-bipyramidal appearance, it is long, prismatic (elongation K=5-6) and idiomorphic, with weakly expressed zonality and asymmetry. The crystal is transparent. Crystal 2 is of similar morphology. But unlike the previous crystal it is of rather clearly expressed hyacinth type of zircon and flat-tabular structure. Less elongation of crystal K=2.5-3 is also observed. A prismatic-bipyramidal configuration and hyacinth type of crystal in the fragment of crystal 3 is observed. The bipyramidal part is built up of bipyramids (111), (311), (331) with different indices. It is distinctly zonal, inner jointing is expressed. In all three crystals only Late Variscan age is established: 337±10 Ma, 323±9 Ma and 328±8 Ma, 335±13


(k)N46
Mean = 323.1±3.0 (2σ)
MSWD = 0.42 (n=16)
(l)N48
Mean = 326.8±2.8 (2σ)
MSWD = 0.22 (n=18)
N24-06
Mean = 320.9±2.3 (2σ)
MSWD = 0.40 (n=26)
N12
Mean = 323.6±2.8 (2σ)
MSWD = 0.91 (n=18)
N65
Mean = 317.5±2.6 (2σ)
MSWD = 0.45 (n=20)
50-04
Mean = 323.7±2.5 (2σ)
MSWD = 0.35 (n=21)
N16-06
Mean = 317.3±3.1 (2σ)
MSWD = 1.2 (n=18)
N15-06
Mean = 331.4±2.8 (2σ)
MSWD = 0.39 (n=18)
206Pb/238U
207Pb/235U

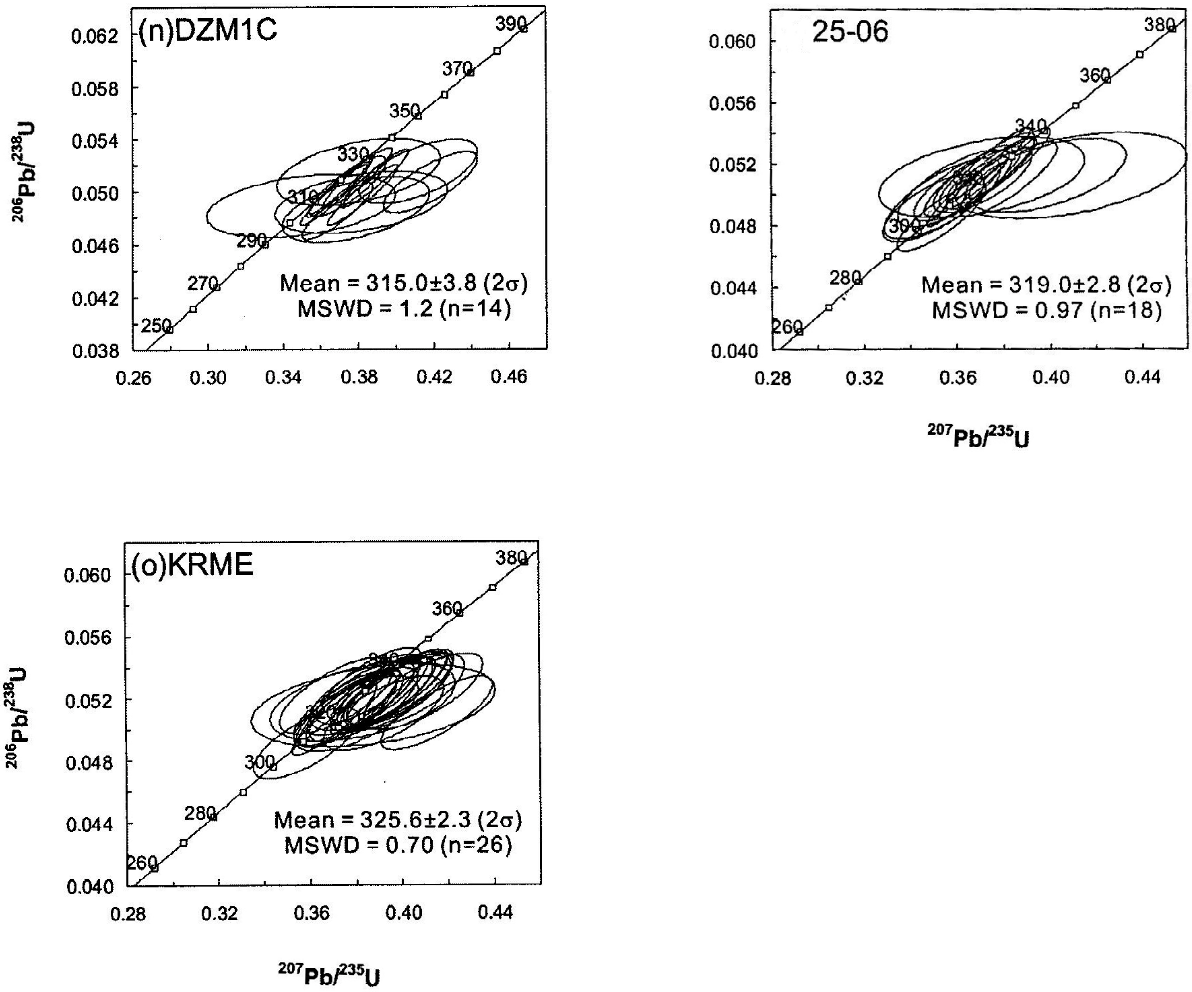


Fig.7. Concordia diagrams of zircon U-Pb LA-ICP MS dating results for the pre-Alpine crystalline basement of the Black Sea-Central Transcaucasian terrane

Ma. Crystal 4 is semi-transparent, distinctly zoned, very asymmetric and has bipyramidal-prismatic appearance. In its core, which is partially rounded, the Late Baikalian age 531±16 Ma (Zir 4) has been determined and in the peripheral zoned transparent envelope - the Late Variscan age 337±11 Ma.

Sample 24-06 is an intensely feldspathized quartz-dioritic orthogneiss. For this sample 29 zircon crystals have been analyzed. Here in 25 cases the Late Variscan mean age is determined (320.9±2.3 Ma; see Fig. 7). Both crystals of the zircon, shown in Fig. 8, have short prismatic appearance. Edges of prism facets are flat and slightly deformed. The ribs of the bipyramid facets are almost smoothed and faces are rounded. In the prismatic face plane, zonality is observed. In the core (Zir3) of the crystal 1 626±11 Ma (presumably the age of orthogneiss protolith) is determined and in its periphery - 320±6 Ma (Zir5). In the core and peripheral cover of the second crystal (2) identical age 319±6 Ma is observed, which corresponds to the Late Variscan endogenic process.

The age of detrital zircon 1000±18 Ma (Zir1) is determined, only in one case, in the zircon crystal core of the granitized quartz-dioritic orthogneiss (sample №12). But in the remaining 20 cases the Late Variscan figures - mean 323.6±2.8 Ma are obtained (see Fig.7).

Now we shall consider the extraordinary results of isotope determinations of pre-Variscan metagabbroids (see Fig. 3). Zircons were analyzed from separated from each other gabbroids of Dedaberastskali (sample 65) and Gezrula (sample 50-04) outcrops (see Fig.7). The results of isotope dating of zircons from the metagabbro turned out to be unexpected. It should be noted that the Late Variscan age is obtained for these rocks. In all the twenty determinations of the Dedaberastskali metagabbro outcrop mean 317.5±2.6 Ma covering the interval 309-325±6 Ma is obtained and for the metagabbro of the Gezrula outcrop, in all 24 crystals, including the core, mean 327±2.5 Ma is determined (316-340±6 Ma). The Late Variscan age established in geologically well-dated Cambrian metabasites is conditioned by their intensive feldspathization and biotitization, which is connected with the intrusion of Late Variscan granites. The advent of zircons in these gabbros was induced by the impact of secondary processes. It should be noted that in the Dedaberastskali and Gezrula gabbros, unaffected by secondary processes, Late Variscan zircons are almost missing.

Four samples of Late Variscan granites have also been analyzed – three equigranular (sample #16-06, 15-06 and DZMIC; see Figs. 7 and 9) and one porphyry-like variety (sample #25-06). In sample #16-06 in 22 zircon crystals 27 local analyses were made in total, and in 18 cases the Late Variscan age was determined as mean 317.3±3.1Ma (see Figs.7 and 9). In Fig. 9 two crystals of sample #16-06 are given. Zircon crystal 1 is of bipyramidal appearance (see Fig.9). Internal zonality is observed in the center. The age of the crystal core 879±16 Ma presumably corresponds to the Grenville stage of the endogenic process and the age of the peripheral part is 313±6 Ma (Zir2), reflecting the age of crystallization of Late Variscan granites. Zircon crystal 2 is of prism-bipyramidal appearance. The bipyramid faces are rounded and semi-transparent. Here, a non-uniform inner structure is observed. The crystal is homogeneous: the ages of its core (317±6 Ma) and the peripheral part (311±5 Ma) correspond to the crystallization age of the Late Variscan granite. The measurements, carried out for homogeneous 18 zircon crystals from sample N 15-06, show constant Late Variscan figures mean 331.4±2.8 Ma (see Fig.7). 18 measurements were undertaken for sample # DZMIC; it is homogeneous as well and for the entire crystal including its core in 16 instances Late Variscan figures were obtained – mean 315.0±3.8 Ma (see Fig.7) and only in two cases 405±8 and 396±7 Ma was determined. Zircons of porphyric granite (sample #25-06) are extremely heterogeneous (see Figs. 9 and 7). In Figure 9, two crystals are represented. These are hyacinth type prism-bipyramidal crystals with elongation K=1.5-2. Their internal zonal structure is faintly visible. The core of crystal 1 (Zir2) is dated to 816±15 Ma and most likely corresponds to the Grenville stage of endogenic process. In the peripheral rim (320±5 Ma) as well as in zircon crystal 2 (318±6 and 319±6 Ma) the Late Variscan age is established. 28 zircon crystals of the same sample are also analyzed. In 18 of them the Late Variscan age – mean 319.0±2.8 Ma (Zir5) was determined (see Fig.7); for 4 crystals – the pre-Grenville age (in our view detrital zircons) – 2392±37, 1840±30, 1578±26 and 1441±24 Ma (Zir1). In 2 cases fig-

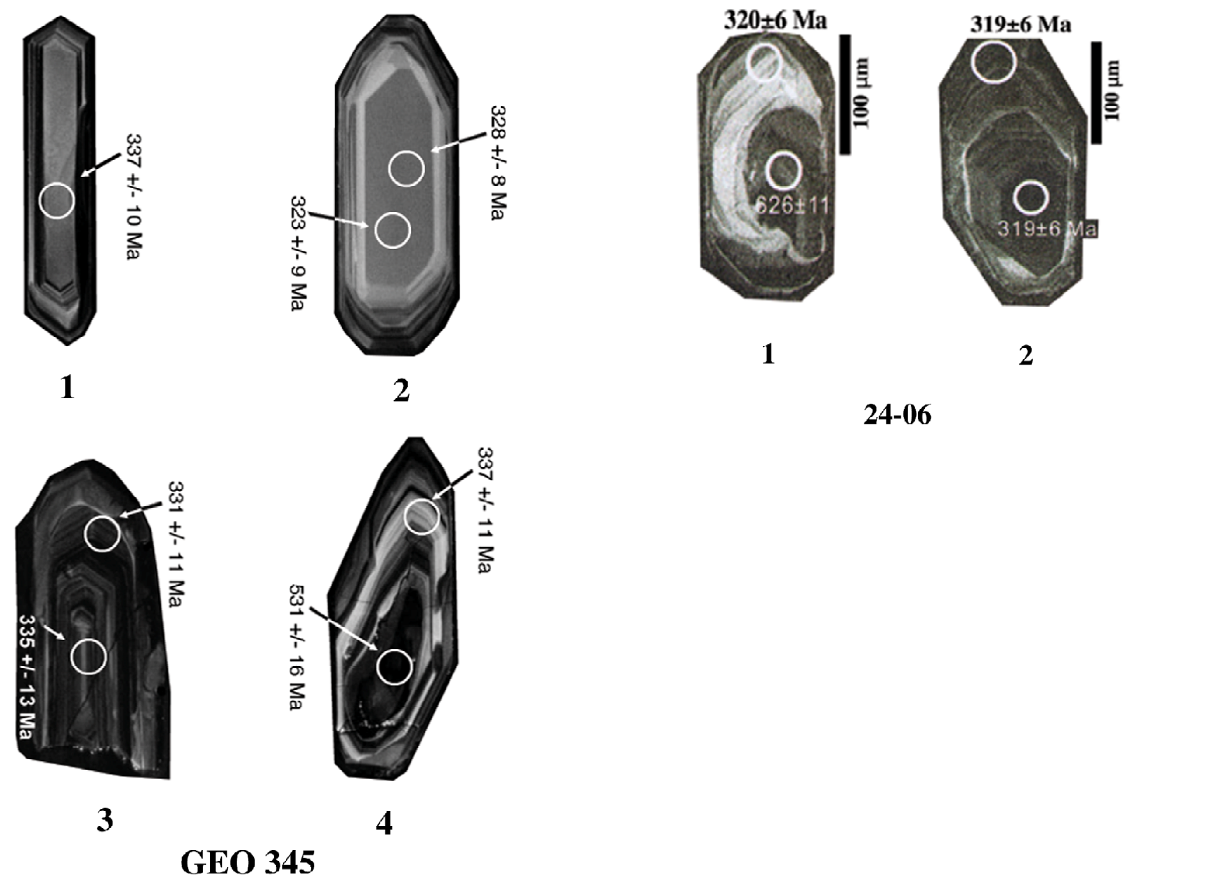


Fig. 8. Zircons from Baikalian quartz-diorite orthogneisses of the Dzirula massif (samples №345, №24-06).

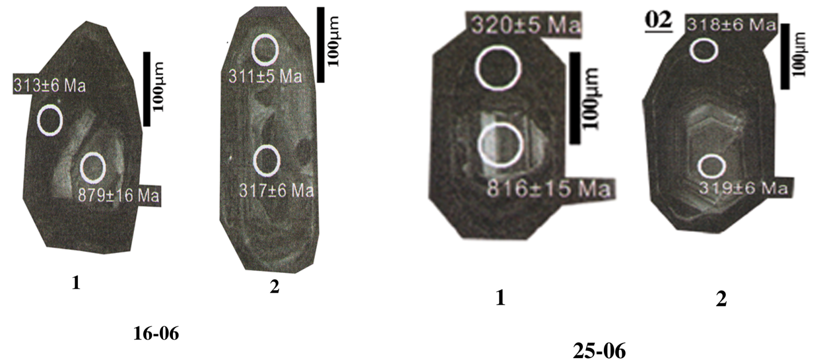


Fig. 9. Zircons from Late Variscan granitoids of the Dzirula massif (samples № 16-06, № 25-06).

ures corresponding to the Grenville stage of regional metamorphism are obtained - 804±10 and 816±15 Ma (Zir 2). The results of 6 local determinations (Zir3) fall within 584-638 Ma (584±10, 593±11, 594±11, 638±12, 662±12 and 691±12 Ma) and they mainly correspond to the Baikalian (Neoproterozoic) age. In sample #25-06 the presence of zircons of four generations is clearly observed.

The results of age determination of 26 zircon crystals from the Late Variscan potassic granitoids of the Khrami crystalline massif by U-Pb LA-ICP MS dating show the mean age 325.6±2.3Ma (see Fig.7) covering the interval 319-332±6Ma. Only in one case, in the crystal core the hereditary age 931±6Ma is determined. It presumably corresponds to the Grenville stage of regional metamorphism of the Neoproterozoic gneiss-migmatite complex.

Conclusions

During the Neoproterozoic and Paleozoic time under suprasubduction conditions on the peripheries of large and small oceanic basins, established on the basis of paleomagnetic paleokinematic and geological data, regional metamorphism and granite formation took place in the Caucasus. At the same time geological (structural) and geophysical data indicate that the Earth's crust of the Black Sea-Central Transcaucasian terrane, as well as of the Caucasus as a whole, is tectonically layered. This layering, side by side with other sources of heat, causes the generation of supplementary thermal energy for metamorphism and granite formation processes.

The main stages of regional metamorphism and granite formation are bound up with the Grenville, Baikalian (Pan-African), Late Baikalian (Salairian) and Variscan orogenies. These epochs of tectogenesis and corresponding endogenic activity, established earlier mainly with the help of geological data, are fully corroborated with new U-Pb LA-ICP MS data.

The heterogenous structure of zircons found in the pre-Alpine crystalline rocks of the Dzirula massif has been established. In separate crystals a relic core of the early zircon with the late envelope is evidenced. Heterogeneity of zircons is induced by the presence of crystals of several generations and different age. The zircons bear the signs of detrital, magmatic and metamorphic genesis.

Genetic and five age-types of zircons are distinguished: 1) detrital zircon >1200 Ma; 2) zircon formed presumably at the Grenville stage of metamorphism - 1000-800 Ma; 3) zircon developed during the crystallization of quartz-diorite orthogneisses - 650-540 Ma (Baikalian stage); zircon 4) formed presumably during the crystallization of tonalite-granitic series - 530-500 Ma (Late Baikalian stage of metamorphism) and 5) zircon formed during the crystallization of Late Variscan granitoids and also under the impact of high-temperature fluids over pre-Late Variscan rocks – 330-310 Ma.

The age of regional metamorphism of gneiss-migmatite complex of the Khrami crystalline massif is determined as 930Ma (Neoproterozoic). The Late Variscan granitoids are dated within the interval – 319-332Ma.

The studies conducted substantially fill up the gaps existing in the isotope-geochronological data of the pre-Alpine crystalline basement of the Black Sea-Central Transcaucasian terrane and specify to a considerable extent the age of pre-Alpine endogenic processes.

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გეოლოგია

ახალი მონაცემები შავი ზღვა-ცენტრალური ამიერკავკასიის ტერეინის ალპურისწინა კრისტალური სუბსტრატის U-Pb ცირკონული ასაკის შესახებ და მათი გეოლოგიური მნიშვნელობა

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განხილულია არსებული მონაცემები შავი ზღვა-ცენტრალური ამიერკავკასიის ტერეინის ალპურისწინა კრისტალური სუბსტრატის ამგები ქანების ურთიერთდამოკიდებულების, ასაკის და ფორმირების პირობების შესახებ. ნაჩვენებია, რომ რეგიონული მეტამორფიზმისა და გრანიტწარმოშობის ძირითადი ეტაპები დაკავშირებული იყო გრენვილურ, ბაიკალურ (პანაფრიკულ), გვიან ბაიკალურ (სალაირულ) და გვიან ვარისკულ ოროგენეტურ ეპოქებთან. ტექტოგენეზისის ეს ეტაპები და შესაბამისი ენდოგენური აქტიურობა, რომლებიც ადრე დადგენილი იყო ძირითადად გეოლოგიური მონაცემებით, მთლიანად დასტურდება ახალი U-Pb. LA YCP MS დათარიღებით.

შესრულებული კვლევები არსებითად ავსებს შავი ზღვა-ცენტრალური ამიერკავკასიის კრისტალური სუბსტრატის იზოტოპურ-გეოქრონოლოგიურ მონაცემებში არსებულ ხარვეზს და მნიშვნელოვნად აზუსტებს ალპურისწინა ენდოგენური პროცესების ასაკს.

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