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HUNGARIAN NATIONAL REPORT ON IAVCEI 2007–2010

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This report covers the research activity belonging to the topics of IAVCEI that has been carried out during the past four years period between 2007 and 2010. The most significant results were obtained in the geochemical, petrological and structural investigation of the young (mainly Miocene and Plio-Pleisticene) volcanism in the Carpathian-Pannonian Region, and in the complex study of the upper mantle xenoliths beneath this region. The research topics and new results will be presented according to the following classification:

1. Palaeozoic and Mesozoic intrusive magmatism in the Carpathian-Pannonian Region including the Variscan granitoids and the Mesozoic Ditrău alkaline complex.
2. Paleogene-Neogene and Quaternary volcanism in the Carpathian-Pannonian Region.
3. The upper mantle and lower crust beneath the Carpathian-Pannonian area based on the study of xenoliths
4. Studies based on international co-operation.

1. Palaeozoic and Mesozoic intrusive magmatism in the Carpathian-Pannonian Region

1.1 Variscan Granitoids

Between 2007 and 2009 the study of the Variscan granitoids occurring in Tisia Composite Terrane (TCT) was continued in the eastern part of the Terrane (Buda Gy in Eötvös University, Budapest). TCT consists of various high-grade metamorphic series and Variscan granitoids which occurs in South Hungary, NE Croatia, N Serbia and W Transylvania, and is surrounded by orogenic belts and faults. The western parts of TCT (Mecsek Mts.) the granitoids are the oldest (340–354 Ma).

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They are characterized by I-type, metaluminous, calc-alkaline, high-K and high-Mg content large granitoid intrusion with small lamprophyre-derived, ultrapotassic, Mg-rich intrusions and/or enclaves (durbachite). Beside of K and Mg, Ca enriched with low Al, Si ($D_{granite}$=Na+K+2Ca/Al(Si+Al)=1.2, $D_{encl.}$=1.7). Because of the Ca activity (high D) apatite, titanite, high amount of allanite crystallised in the enclaves as well as in the enclosing granitoids. Allanite is the major REE-bearing mineral which controls the whole-rock REE patterns ($\Sigma REE_{encl.}$=350 g/t, L/H=19, $\Sigma REE_{granitoid}$=250 g/t, L/H=31). Allanites are oxidised ($Fe^{3+}/Fe^{tot} \approx 0.4$) which is characteristic of the I-type granitoids. In enclaves allanites contain more ΣREE and slightly depleted in Ca compared with allanites occurring in granitoids. Altered allanites are enriched in ΣREE and depleted in Al and Ca. Basic melt originated from the upper mantle, acidic melt formed by partial melting of the continental crust. The two melts crystallised probably in the same time. In peraluminous microgranite dikes allanite was not identified ($D_{microgr.}$=1.1, Σ=120g/t, L/H=20).

The other intrusions (Papuk, Psunj, Battonya, Muntele Mare, Codru) are mostly granodioritic, two micas, peraluminous (A/CNK>1, D=0.9), monazite-type, younger (310–290 Ma) S or S/I-type granitoids with low REE content (ΣREE=112g/t, L/H=9). The only REE rich mineral is monacite and tiny grains of xenotime. REE pattern is controlled by zoned monacite where the core of crystals is slightly richer in HREE than the rim. These granitoids are the result of crust thickening, due to collision of two continental crusts. The granitoid melts originated from the partially melted continental crust after collision (Buda et al. 2009). The TCT belonged to the Moldanubicum zone of the Variscan orogenic belt. Later the TCT was disconnected by eastward movement of S Alps (Pelso Unit) containing peraluminous/peralkaline, S/A-type small intrusions of Permian age (280–275 Ma), indicating the initial rifting (Buda et al. 2010).

The petrological and geochemical study of Mórágy Granite (Mecsek Mts.) in the Geological Institute of Hungary (Király E) supports the hypothesis that these granites have been formed by mixing and mingling of a felsic and a mafic magma instead of previously accepted migmatitic origin (Király 2010).

A current project of Pál-Molnár E at the University of Szeged focuses on the possible genetic relationship of the granitoid intrusions within Tisia Composite Terrane (TCT). In order to obtain correlation studies between granitoid suits from the TCT, an extended field survey is being carried out in the Apuseni Mountains. From 2008 to 2010 five fieldworks were performed, visiting 17 locations and three granitoid suites, collecting more than 100 samples. The main Variscan granitoid suites of the Apuseni Mountains, which are currently under our focus, are: Muntele Mare granitoids (MMG), Codru granitoids (CG) and the Arie granitoids or Codru migmatite complex (CM).

From the MMG and CG suits a total of 14 major and trace element geochemical analyses, and from the MMG and CM suits 370 mineral (including K-feldspar, plagioclase, biotite and muscovite) analyses were carried out to date (Pál-Molnár et al. 2010d). Preliminary results based on currently available data shows granodioritic compositions for the MMG suite, and mostly granitic compositions for the CG suite. In terms of aluminium saturation index (ASI), all the samples are peraluminous, including the CG samples, which formerly were considered metaluminous. All the samples resulted to be of magnesian types, and a slight enrichment in FeO^{tot} could be traced with increasing silica content (András et al. 2010). Trace element data was used to make inferences about the source characteristics of the granitoids, the best distinctions being achieved when the samples were plotted in the Hf-Rb-Ta diagram. The majority of the samples from MMG and CG plot in the late and post collisional field, leucogranites plot in the syncollisional. All the samples are enriched in light RRE and show fractionated distribution (Ce_N/Yb_N=3.50–21.99). The Europium anomaly (Eu/Eu^*) is negative, but variable for both suites (MMG and CG) (András et al. 2010).

Another Variscan granitoid group was also studied, namely the Highis granitoids, outcropping in the southern part of the Highis Mts. These rocks were generated by a short lasting bimodal magmatism at the end of the Permian period and their age had been determined to be 264–267 Ma. These rocks are leucogranites with very high silica content, and relatively high alkali content. According to rock classification based on whole rock chemistry, the samples were alkali granites, with slightly peraluminous, and alkali-calcic geochemical character (Pál-Molnár et al. 2008, 2010c).

1.2 Mesozoic Ditrău Alkaline Massif (DAM)

At the Szeged University during the last few years new mineralogical, geochemical and petrological studies were carried out on the Ditrău Alkaline Massif (DAM) focusing especially on DAM syenites (Pál-Molnár et al. 2010a), nepheline syenites, tinguaite dykes (Pál-Molnár et al. 2010b) and lamprophyre dykes. The DAM is a Mesozoic alkaline igneous complex and situated in the SSW part of the Giurgeu Alps belonging to the Eastern Carpathians (Romania).

DAM peridotites, which stand closest to the parent magma, have either a slightly undersaturated or slightly oversaturated character (Pál-Molnár 2010). By the increase of SiO_2 and alkalies the evolution of this tholeiitic and alkali basalt magma and thermal and fractionation processes ends up in the granite-nepheline-syenite system. The parent magma of the DAM's nepheline syenites became saturated in an alkali-carbonate-rich watery fluidum during the early phase of crystallization. This justifies the fractionational residuum origin of the nepheline syenite melt. The nepheline syenite melt soon after the beginning of crystallization got saturated in volatiles, and most of the DAM nepheline syenites crystallised in an active magmatic hydrothermal system (Fall et al. 2007).

The DAM lamprophyres consist of mainly amphibole (Batki and Pál-Molnár 2009), biotite and plagioclase. The lamprophyre dykes show felsic globular structures up to 11 mm in size filled with carbonatic and/or feldspathic mineral assemblages (Batki and Pál-Molnár 2010a). They are silica- and alumina-undersaturated, alkaline basic, basanitic rocks. They derive from a differentiated melt, and are secondary fractionates of primary melts. They originate from an OIB mantle source containing HIMU and EM I mantle components. The lamprophyre magma derived from a garnet lherzolite mantle source by very low degrees ($\sim$1–2%) of partial melting which means that it must have originated at a great depth, around 60–80 km. The generation of lamprophyres took place in intraplate tectonic setting as late-stage dykes of the ultrabasic body of the DAM (Batki and Pál-Molnár 2010b, 2010c, 2010d).

2. Volcanism

2.1 Geochemistry, petrogenesis and geodynamic relationships of the Neogene to Quaternary volcanic rocks of the Carpathian-Pannonian Region

During the last years further results were published on the genesis of the Neogene to Quaternary volcanic rocks of the Carpathian-Pannonian Region. A new geochemical investigation was focused on the boron content of various volcanic rocks (Gméling et al. 2007a, 2007b, 2007c, Gméling 2010). Variation of the boron concentration in the calc-alkaline volcanic rocks was used to follow the temporal change in the mantle sources. Calc-alkaline volcanic rocks in the western Carpathians do not show significant variation in boron in terms of the position of the volcanoes relative to the supposed collision zone, however a gradual decrease of boron concentration can be observed through time, i.e. from the 16 Ma to the 9 Ma rocks. In contrast, the calc-alkaline rocks show an along arc boron content variation in the eastern Carpathians suggesting an abrupt change in the nature of the source region at he southern parts of Harghita Mts.

Results of detailed volcanological, geochemical and petrogenetical studies of volcanic rocks in the western Carpathians were published by Harangi et al. (2007) and Karátson et al. (2007). Harangi et al. (2007) pointed out that the parental mafic magmas could have been generated from an E-MORB-type mantle source, previously metasomatized by fluids derived from subducted sediment. Initially, the mafic magmas ponded beneath the thick continental crust and initiated melting in the lower crust. Mixing of mafic magmas with silicic melts from metasedimentary lower crust resulted in relatively Al-rich hybrid dacitic magmas, from which almandine could crystallize at high pressure. Crustal involvement in the erupted magmas decreased with time as the continental crust thinned. A striking change of mantle source occurred at about 13 Ma. The basaltic magmas formed during the later stages of the calc-alkaline magmatism were derived from a more enriched mantle, akin to FOZO. Karátson et al. (2007) integrated various methods — volcanological, geophysical, geochemical, palaeontological — to reconstruct the evolution of the Middle Miocene calc-alkaline volcanic rocks of the Visegrád Mts.

A comprehensive review on the genesis and the geodynamic relationships of the Neogene to Quaternary volcanic rocks of the Carpathian-Pannonian Region was presented by Harangi and Lenkey (2007). They emphasized that lithospheric extension had a major role in the generation of the magmas. Dehydration of the subducting slab played only an indirect role in the generation of the calc-alkaline magmas. They suggested that a mantle plume beneath the Pannonian Basin is highly unlikely and the mafic magmas were formed by small degree partial melting in a heterogeneous asthenospheric mantle, which has been close to the solidus temperature due to the lithospheric extension in the Miocene. Harangi (2007) summarized the main features of the youngest volcanic rocks in his region and concluded that rejuvenation of volcanic activity cannot be unambiguously ruled out here, although this will presumably not happen in the near future.

A review of Paleogene–early Miocene igneous rocks of the Alpine-Carpathian-Pannonian-Dinaric Region is presented by Kovács et al. (2007). The authors attempt to reveal the geodynamic link between Paleogene-early Miocene igneous rocks of the Mid-Hungarian zone and those of the Alps and Dinarides. They suggest that these igneous rocks of all these areas were formed along a single, subduction-related magmatic arc. The location and polarity of all potential subduction zones of the area are discussed which may account for the igneous rocks. It is proposed that the Paleogene-early Miocene arc was mainly generated by the Budva-Pindos and Vardar subduction zones, subordinately by Penninic subduction. The present diverging shape of the proposed arc has been achieved by considerable shear and rotations of those lithospheric blocks.

Kovács and Szabó (2008) discussed also the origin of the Middle Miocene calc-alkaline volcanic rocks. Similarly, as proposed previously by Lexa and Konečný (1998) and Harangi et al. (2001, 2007) they suggest that there is no direct relationship between active subduction and the magmatic activity and the magmas were generated by melting of the lithospheric mantle metasomatized by a former subduction event. Melting in the lithospheric mantle of the Alcapa unit was triggered by the extension during the formation of the Pannonian Basin as discussed by Harangi and Lenkey (2007). What is new in the model proposed by Kovács and Szabó (2008) is that they invoke that source-enrichment occurred via the subduction of either the Budva-Pindos or Vardar Oceans. The Alcapa microplate was transferred to its present tectonic position via extrusion and rotations. Geophysical modeling and mantle xenoliths provide evidence that this process occurred at the scale of the lithospheric mantle, indicating that the subduction-modified lithospheric mantle was coupled to the crust. The preserved subduction-related geochemical character of volcanics in intra-plate settings that are otherwise directly unaffected by subduction, can be attributed to tectonic transport of metasomatized mantle from a previous subduction-affected setting.

Tephras of large volcanic eruptions outside the Carpathian-Pannonian Region occasionally reached this area. Sági et al. (2008) described the main petrographic features of the Quaternary Bag tephra and suggested that this might not be a single tephra layer of a single eruption.

The petrology and geochemistry of the Miocene calc-alkaline magmatism at the north-eastern part of the Carpathian-Pannonian region was investigated by Krassay (2010) who concluded that alkali basaltic magma may have been involved in the formation of calc-alkaline igneous rocks.

2.2 Combined petrographical and geochemical studies of volcanic rocks

The Volcanology Group of the Department of Petrology and Geochemistry, Eötvös University has focused on the combined textural and mineral chemical investigation on a wide variety of volcanic rock types. The main aim of these studies is to reconstruct the magma chamber processes occurring prior to eruption in different magmatic system. This kind of study has a particular importance in the case of the youngest volcano, i.e. Ciomadul/Csomád in the southeast Carpathians, of the Carpathian-Pannonian Region. First of all, we determined the age of the latest volcanic eruptions by radiocarbon measurements on charcoal fragments (Vinkler et al. 2007, Harangi et al. 2010). It turned out that the youngest volcanic product, so far we know, can be found at the southeastern margin of the volcano. This is a block-and-ash flow deposit formed at 30 ka cal BC. In contrast, the pyroclastic flow deposit at Tusnád (western part of the volcano), previously thought to be the youngest rock of the Ciomadul/Csomád was dated to 41 ka cal BC. The mineral-scale investigation of pumices and lava dome rocks revealed that the Ciomadul/Csomád dacites are a mixture of antecrysts, phenocrysts and xenocrysts (Vinkler et al. 2007, Kiss et al. 2008, Harangi et al. 2010). The antecryts (hornblende, plagioclase, biotite, apatite, titanite, quartz, K-feldspar, zircon) derived from remobilized dioritic to granodioritic crystal mush, the phenocrysts are hornblende and plagioclase crystallized from a hybrid dacitic magma, whereas the xenocrysts are represented by Mg-rich olivine, clinopyroxene and orthopyroxene. The latter ones could be derived from a fairly primitive mafic magma. Thus, the Ciomadul/Csomád dacite generated by a complex process involving mixing of various magmas and a long-lived, possibly >200 ka, crystal mush.

Silicic magmatic system represents another very complex magma reservoir, where mixing of various crystal mushes and intruding fresh magmas could take place. This complex scenario was detected by a combined petrological and mineral chemical study in the Miocene Bükkalja volcanic field (Lukács 2009, Lukács et al. 2009). One of the important results of this research is the major role of mantle-derived mafic magmas in the evolution of rhyolitic magmatic systems. Volcanological observations and geochemical data could help to correlate and reinterpret scattered pyroclastic deposits and identify pyroclastic units in long, continues drilling cores of boreholes at the eastern margin of Bükkalja (Lukács et al. 2007, 2010, Harangi and Lukács 2009).

Although most people think that basaltic systems are rather simple, Jankovics et al. (2009) demonstrated that it is not always the case. They described a complex evolution for one of the youngest basalts in the Bakony-Balaton Highland volcanic field (the 2.8 Ma Füzes-tó basalt), where the mafic magma could be a mixture of magma batches coming from slightly different mantle sources followed by incorporation of various mineral grains from the upper mantle and lower crust and crystallization at shallow depth. Thus, bulk composition of this basalt cannot be used to infer the source region and partial melting condition, since it is rather a mixture of these various processes. Results of further studies of basalts from the southeastern margin of the Pannonian Basin (the Paleogene Poiana Rusca basalts and the Pliocene basalt at Lucaret) were presented by Tschegg et al. (2010a, 2010b).

The ultrapotassic volcanic rocks are rare worldwide and this is the case also in the Carpathian-Pannonian Region. Klébesz et al. (2009) reconstructed the magma chamber processes of one of the ultrapotassic occurrences found near the Lake Balaton. Here, the Balatonmária-1 borehole penetrated around 200 m thick volcanic suite. Zoning patterns of clinopyroxenes along with the compositional variation were used to identify of mixing of magmas with various differentiation stages.

2.3 Volcanology

On the basis of physical volcanological and petrological studies, Karátson et al. (2007) in the Eötvös Loránd University gave a stratigraphic synthesis on the volcanic evolution of Visegrád Mountains, integrating paleontological, K/Ar and paleomagnetic data. Karátson (2007, 2009) also published detailed field descriptions at outcrop level in a volcanological monograph on Börzsöny-Visegrád and Mátra mountains, as well as volcanic geomorphological studies on the East Carpathians (Tokaj-Slánské and Calimani-Gurghiu-Harghita Mountains). The volcanic structure and a new volcano geomorphological interpretation on Mátra Mountains was given by Karátson (2010), pointing out mid-scale volcanic cones instead of a large caldera proposed in the earlier literature. In Harghita Mts, the stratigraphy of the youngest (∼30 ka) volcanic activity of the Carpathians at Sf. Ana (Szent Anna) crater lake was investigated by a paleolimnological approach (Magyari et al. 2009).

Volcano geomorphological research has been done in other countries as well. A comparative study of Etna's scoria cones using high-resolution LiDAR digital elevation (DEM) data was published by Favalli et al. (2009). The regular shape of stratovolcanoes was analysed by SRTM DEM data by Karátson et al. (2010a). Late-stage volcano evolution of the Pleistocene San Francisco Mountain, Arizona, was deciphered by Karátson et al. (2010b) using high-resolution DEM and Ar/Ar data.

A special volume of the Central European Journal of Geosciences on the physical volcanology of the Carpahian-Balkanian Region (including Carpathian-Pannonian Region was organized by Németh and Pécskay (2010). In this volume Lexa et al. (2010) overviewed the main characteristics of the volcanic forms found in the Carpathian-Pannonian Region that is completed a number of case-studies (Németh 2010, Németh et al. 2010, Keresztúri et al. 2010) highlighting that this area could be a natural laboratory for volcanologists.

2.4 Geochronology

Systematic chronological work on the Miocene calc-alkaline and Plio-Pleistocene alkalic rocks in the Carpathian-Pannonian Region have been carried out in the Institute of Nuclear Research (Hungarian Academy of Sciences) in Debrecen.

Geochronology of the Neogene subvolcanic and volcanic rocks in the Eastern Carpathians and Apuseni Mts (Romania) is presented by Pécskay et al. (2009), Canstantina et al. (2009) and Seghedi et al. (2010).

Results of a $^{40}Ar/^{39}Ar$ chronological study of Pliocene alkali basalts from Transdanubia have been compared with previous K-Ar ages. Both method resulted about 8 Ma for the onset and around 2.5 Ma for the end of volcanic activity (Wijbrans et al. 2007). However, remarkable difference has been obtained for the basanite of Hegyestű hill. A systematic study has shown, that this bias is caused by the poor Ar-retentivity of the basanite: it loses 30–40% of it ^{40}Ar(rad) content during baking the extraction line below 250°C before extracting the radiogenic Ar from the rock. It has been found that leucite content of the rock is responsible for this effect, which is not caused by the very poor Ar retentivity of the leucite in this rock, but by a structural change of leucite at $150 - 300$°C temperature. It is emphasized, that this effect has been found for Hegyestű, but likely not only for this rock. Method is given for discovering this possible feature of leucite (Balogh et al. 2010).

3. Upper mantle and lower crustal xenoliths

The investigation of the upper mantle and lower crustal xenoliths in the Carpathian-Pannonian Region have been in the focus for several years. Between 2007 and 2010 important new results were obtained especially in the study of fluid inclusions and carbonate veins in the xenoliths, the effects of host basalt–xenolith interactions, the trace element contents of clino- and orthopyroxenes and the crystal chemistry of clinopyroxenes in the spinel peridotite xenoliths. Unusual upper mantle xenolith types have been discovered. Besides the well known occurrences of Bakony-Balaton Highland and Persani Mts + xenoliths from Upper Cretaceous lamprophyres have also been studied.

3.1 Upper mantle xenoliths from the Bakony-Balaton Highland Volcanic Field

Many different kinds of mantle and lower crust-derived xenoliths have been studied in the Lithosphere Research Group, Department of Petrology and Geochemistry of the Eötvös Loránd University.

An unusual quartz-bearing orthopyroxene-rich websterite xenolith has been found in alkali basaltic tuff at Szigliget. The xenolith is interpreted to represent a fragment of an orthopyroxene-rich body that crystallized in the upper mantle from a hybrid melt that formed by interaction of mantle peridotite with a quartz-saturated silicate melt that was released from a subducted oceanic slab (Bali et al. 2008a). The study of other two orthopyroxene-rich olivine websterites from the same volcanic region (Bali et al. 2007), in addition, revealed material formed from Mg-rich silicic (boninitic) melts at mantle depths. Spinel peridotite xenoliths frequently contain silicate melt pockets. Textural, geochemical and thermobarometric data indicate that the melt pockets formed at relatively high pressure through breakdown of mainly amphibole as a result of temperature increases accompanied, in most cases, by the influx of external metasomatic agents. The compositional character of the external agents might have been inherited by melting of a hydrated and probably carbonated deeper lithospheric component, which itself was metasomatized by melts with significant slab-derived components (Bali et al. 2008b). Coexisting fluid inclusions and silicate melt inclusions, trapped as primary inclusions in clinopyroxene rims and as secondary inclusions along healed fractures in orthopyroxene, were studied in two amphibole-bearing spinel lherzolite peridotite xenoliths (Hidas et al. 2010). It is confirmed that the parental melt for both silicate melt and fluid inclusions was the same and suggested that the trace element content of the CO_2-rich end-member, containing some dissolved melt, resulted from high P-T immiscibility in deep lithospheric environments and is controlled by the trace element content of the parent silicate melt (Hidas et al. 2010). Results of study on fluid inclusions mantle fluids contain small but significant amounts of H_2O (Berkesi et al. 2009). This conclusion, in turn, has important implications concerning the geochemical and geodynamic evolution of the Earth's deep lithosphere.

Peridotite xenoliths showing unusual tabular equigranular textures, addressed as flattened tabular equigranular, were found in the same volcanic field. The occurrence of flattened domains in the upper mantle may considerably influence the percolation and residence time of the mantle melts and fluids, which could promote or prevent melt/wall-rock interaction (Hidas et al. 2007).

Clinopyroxene structural parameters (cell, M1 and M2 volumes) from a suite of peridotite xenoliths have been investigated by X-ray single-crystal diffraction in order to evaluate the response of cpx crystal chemistry to textural changes and increasing deformation, and to estimate equilibrium pressure conditions of texturally heterogeneous spinel-peridotite xenolith series (Nédli et al. 2009). The inverse relationship between pressure and deformation can be explained geodynamically by the presence of a mantle diapir beneath the region, which could have caused significant deformation and lithosphere thinning in the centre of the CPR.

Spinel peridotite xenoliths from Pliocene alkali basalts of the western Pannonian Basin have alsp been investigated in the Institute for Geochemical Research (Hungarian Academy of Sciences) and in the Hungarian Natural History Museum. The origin and evolution of CO_2 inclusions and calcite veins in peridotite xenoliths from the same area were investigated by means of petrographic investigation and stable isotope analyses. The stable isotope and trace element results support the conclusions of earlier studies that the carbonate melt droplets found on peridotite xenoliths in the alkaline basalts represent mobilized sedimentary carbonate. The large $\delta^{13}C$ range and the ^{12}C-enrichment in the carbonates can be attributed to devolatilization of the migrating carbonate or infiltration of surficial fluids containing ^{12}C-rich dissolved carbon (Demény et al. 2010a).

Clino- and orthopyroxenes in anhydrous spinel peridotite xenoliths have been analysed for trace elements by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Clinopyroxenes show highly variable mantle normalized REE (rare earth elements) patterns but basically can be classified into three major groups: LREE-depleted, LREE-enriched and U-shaped patterns. LREE-depleted xenoliths generally have undeformed protogranular textures, while the more deformed xenoliths with porphyroclastic and equigranular textures have LREE-enriched trace element patterns. The U-shaped pattern is very distinctive and is generally associated with poikilitic textures. The HREE content of the clinopyroxenes suggest that most of the xenoliths experienced less than 15% partial melting.

Cryptic metasomatism frequently accompanies deformation. Metasomatic enrichment of incompatible trace elements can be observed not only in clinopyroxenes but also in coexisting orthopyroxenes. The metasomatic agents were probably alkaline mafic melts of asthenospheric origin and some may relate to upper Cretaceous alkali lamprophyre magmatism. Geochemical signatures of subduction-related melts or fluids have not been found in the anhydrous LREE-enriched xenoliths, although poikilitic xenoliths with U-shaped normalized REE patterns may indicate the influence of subduction-related melts (Dobosi et al. 2010).

3.2 The subcontinental lithospheric mantle beneath the Persani Mountains, Eastern Transylvanian Basin

Peridotite xenoliths with a broad range of textures provide evidence for consistent microstructural evolution in a vertical transect of the shallow lithospheric mantle (35–55 km depth) beneath the Persani Mountains, due to ongoing plate convergence in the Carpathian Arc nearby. Seismic anisotropy estimated from the measured olivine and pyroxene crystal preferred orientations suggests that the strike-parallel fast SKS polarization directions and $\sim$1 s delay times measured in the Eastern Carpathians are likely the consequence of convergence driven belt-parallel flow in the lithospheric mantle (Falus et al. 2008).

3.3 Upper mantle xenoliths from Late Cretaceous lamprophyres

Spinel lherzolite xenoliths hosted in Late Cretaceous lamprophyre dyke in the Villány Mts (S Hungary) have been studied mainly in University of Szeged. It has been concluded that the lamprophyres from the Villány Mts and NE Transdanubia could have originated from the same or similar enriched asthenospheric mantle sources (Nédli and Tóth 2007). Additionally, in accordance with the volcanological and sedimentological constraints from the Villány Mts and the neighbouring Mecsek Mts, we suggest that the uprise of the subcontinental mantle material was related to a Cretaceous rifting event and lithospheric deformation of the southwestern part of the Tisza unit. Mantle upwelling and formation of lamprophyre melts can be related to generation or reactivation of deep fractures of the lithosphere, during a period of lithospheric extension between the major nappe emplacements (Albian-Cenomanian and Paleocene) of the region (Nédli et al. 2010). Moreover, studies of clinopyroxene and spinel crystal chemistry in the Villány Mts mantle xenoliths show low closure temperatures and low pressure re-equilibration, near to the plagioclase stability field (Nédli et al. 2008). These low PT values are in agreement with the recrystallized texture of the xenoliths.

The Lithospheric Research Group in the Eötvös Loránd University reported the results of LA-ICP-MS analyses of rock forming minerals in clinopyroxene-apatite-K feldspar-phlogopite (CAKP) metasomatic xenoliths and primary carbonatite melt inclusions (CMI) hosted in apatite (Ap) and K feldspar (Kfs) (Guzmics et al. 2008a, 2008b) from the Transdanubian Central Range, Hungary. The melts found in CMI in Ap and in Kfs likely formed by liquid-liquid separation from an originally carbonate and phosphorous-rich melt. Our findings suggest that the studied CAKP rocks were formed by carbonatite melt metasomatism, which occurred in an open system in the upper mantle.

3.4 Xenolith – host basalt interactions in lower crustal mafic granulite xenoliths

The effects of xenolith – host basalt interaction were investigated in lower crustal mafic granulite xenoliths from the Bakony-Balaton Highland Volcanic Field, Central Pannonian Basin by means of high resolution electron beam techniques and LA-ICPMS analyses. It was found that Fe-Ti-oxides (Dégi et al. 2009) and fine-grained silicates (Dégi et al. 2010) formed in the lower crust were modified to a significant extent by the host basalt. Complex chemical zoning patterns were detected using high-resolution element mapping in ilmenites and in lamellar titanomagnetite-ilmenite intergrowths (Dégi et al. 2009). The chemical alteration of the Fe-Ti-oxides was diffusion-controlled and, hence, time and temperature dependent. On the basis of diffusion profiles in titanomagnetite the duration of xenolith-host basalt interaction was estimated to be at least 9–20 hours, which is a maximum estimate for the ascent rate of the hosting alkali basalts in Káptalantóti (Sabar-hegy) and Szigliget (Rókarántó-domb).

Ultrafine-grained symplectitic reaction rims formed after garnet were partly molten and/or recrystallized in the vicinity of melts infiltrated to the xenoliths from the host basalt resulting in complex chemical zoning patterns in the symplectite phases (Dégi et al. 2010). The trace element composition of the symplectites systematically changes from the garnet cores towards the former garnet grain boundaries showing increase in Na, K, Ti and several trace elements related to the host basalt. According to this, bulk rock composition of xenoliths containing significant volume of symplectites may be strongly modified.

4. International collaboration

In the framework of a co-operative program between the Spanish Research Council and the Hungarian Academy of Sciences the geochemistry and evolution of the magmatic rocks of the Canary Islands have been investigated. This study includes the investigation of the carbonatite xenoliths from La Palma (Demény et al. 2008a), the carbonatites in Basal Complex of Fuerteventura (Casillas et al. 2008), the study of the isotope compositions and fluid/rock interaction processes in the seamount series of La Palma (Demény et al. 2008b) and the geochemical and H-O-Sr-Nd isotope investigation of magmatic processes and meteoric-water interactions in the basal complex of La Gomera (Demény et al. 2010b).

The origin of carbon was determined in the "kimberlite" of Wekusko Lake, Canada (Chakhmouradian et al. 2009). The petrology and geochemistry of the Yungul carbonatite dykes (Speewah, Kimberley, Australia) have been investigated by Gwalani et al. (2010). These carbonatites are associated with a significant epithermal fluorite deposit. The C isotope data from Yungul indicate that the carbonatites are mantle-derived have had a complex history involving enrichment in $\delta^{18}O$.

Garnets and clinopyroxenes, intergrown with diamonds in 37 diamondites ("bort", "polycrystalline diamond aggregates", "polycrystalline diamond", "framesite"), presumably from southern Africa, were analyzed for trace element contents by LA-ICP-MS (Dobosi and Kurat 2010). Model equilibrium fluids for peridotitic garnets suggest crystallization from magnesian carbonate-bearing fluids/melts, which were very rich in incompatible trace elements – similar to kimberlites. The variation of the Cr, mg-values and incompatible trace elements in the hypothetical equilibrium fluids indicate fluid-rock fractionation processes rather than igneous fractional crystallization processes being responsible for the evolution of the diamondite-forming fluids.

Czuppon and his co-workers measured the noble gas isotopic and elemental compositions in mantle derived xenoliths from North Queensland (Czuppon et al. 2009) and Tasmania (Czuppon et al. 2010) (Australia). They suggested that the identified noble gas components are likely related to the main tectonic/magmatic events of Eastern Australia (e.g. Paleozoic subduction, opening of the Tasman Sea, plume activity). In addition, they showed that the noble gas isotopic heterogeneity in the studied samples reflects different tectonic evolution in northeastern and southeastern Australia indicating the existence of isotopic heterogeneity at regional scale in the subcontinental lithospheric mantle beneath eastern Australia.

Nitrogen and C isotopic ratios, N contents and aggregation states have been determined in a set of diamondite samples. The diamondites exhibit mean values for δ^{13}C of $-16.9 \pm 7.2‰$ and for δ^{15}N of $+11.9 \pm 8‰$ for all samples in this study. This organic-looking carbon and nitrogen isotope composition can be explained by the involvement of re-worked crustal organics, or by isotope fractionation processes in the mantle (Mikhail et al. 2010).

In East Cuba, near Holguin town, polimetallic injections containing precious metals associated with basic, neutral and acidic igneous rocks has been found. Samples from boreholes exposed these bodies were studied at the University of Debrecen. Based on grain-size distribution of the samples volcanic or shallow subvolcanic origin of the igneous bodies can be suggested; trace element spectrum of the andesite samples indicates similarities to that of the lower continental crust. The authors suggest that volcanism formed the ore bearing magmatic bodies is associated to the Loma Blanca Formation, i.e., the "final phase" of the Cretaceous island-arc (Kozák and Rózsa 2007).

Systematic geochronological studies have been carried out in the Institute of Nuclear Research in Debrecen (Hungarian Academy of Sciences). These studies include:

— Cenozoic anorogenic volcanism of the Bohemian Massif (Filip et al. 2007, Ulrich et al. 2008, 2010)

— Tertiary alkaline basaltic volcanic activity of Lower Silesia, Poland (Birkenmajer et al. 2007)

— Geochronological study of the crater basalt volcanic field (CBVF), Northern Patagonia (Pécskay et al. 2007).

— Tertiary granitoid rocks from the Dinarides (Cvetkovic et al. 2007)

— King George Island, Antartica, Polish Arctowski Station (Kraus et al. 2008).

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