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Combined geophysical (magnetotellurics) and geochemical results for determination of the Lithosphere-Asthenosphere Boundary (LAB) beneath the Nógrád-Gömör Volcanic Field

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SUMMARY

The LAB depths can be estimated by different geophysical methods (seismology, magnetotellurics), however these depths are controversial. It has been emphasized in the literature that combined geophysical and geochemical approach may lead to a better understanding of these depths.
The magnetotellurics (MT) is very powerful method because it indicates the sudden increase in conductivity at the LAB. The mantle xenoliths (small fragments of the lithospheric mantle) provide direct information on the texture and composition of the lithospheric mantle.
In the Carpathian-Pannonian region (CPR) five, well-studied occurrences of mantle xenoliths-bearing Plio-Pleistocene alkali basalts are known, which makes the CPR a very promising area for investigating the inconsistency in the LAB estimates. As a test area Nógrád-Gömör Volcanic Field (NGVF) has been chosen.
The host basalt erupted at the NGVF collected mantle xenoliths from a small volume of the upper mantle in a depth of about 40-50 km. The major element geochemistry of the studied xenoliths indicates that most of them represent a mantle domain that did not go through any major geochemical processes, whereas others show evidence for wehrlitisation. This metasomatism is supposed to be caused by a migrating mafic melt agent, resulting in the transformation of a large portion of lherzolite to wehrlite beneath the NGVF, possibly just below the crust mantle boundary.
In aim to detect the LAB at the research area and find the correlation with petrologic results, we carried out MT deep soundings. The campaign contained 12 long period MT stations with 3-5 km average spacing along ~50 km long profile NNW to SSE direction. This presentation summarizes the preliminary results of the combined geophysical and geochemical approaches to determine the LAB depths.

Keywords: magnetotelluric, lithosphere, asthenosphere, geochemical, LAB

INTRODUCTION

The LAB depths can be estimated by different geophysical methods (seismology, magnetotellurics) controversially, therefore, emphasized by literature, the combined geophysical (magnetotelluric) and geochemical approach may lead to a better understanding of these depths. In the Carpathian-Pannonian region (CPR) several well-studied occurrences of mantle xenoliths-bearing volcanoes are known. As a test area Nógrád-Gömör Volcanic Field (NGVF) has been chosen, which seems a very promising area for studying the inconsistency in the LAB estimates (Figure 1).
Here we provide preliminary result of a magnetotelluric survey across an NNW-SSE profile combined with the data of the petrologic and geochemical studies of xenoliths to determine the LAB and the supposed wehrlite body in lithospheric mantle depth. Considering the existing results, we have taken a presented map of the depth of the conductive asthenosphere for comparison, which was estimated by Ádám and Wesztergom (2001) in the Pannonian Basin using magnetotelluric data.

GEOCHEMICAL RESULTS

Mantle xenoliths are small fragments of the subcontinental lithospheric mantle, brought to the surface by alkaline basalts at the Carpathian-Pannonian region. Mantle xenoliths at the Nógrád-Gömör Volcanic Filed display a wide range in texture and composition (e.g. Szabó and Taylor, 1994; Liptai et al., 2013).
Most of the xenoliths are spinel lherzolites, consisting of olivine, clinopyroxene, orthopyroxene and spinel. However wehrlite xenoliths were also observed which contain large amount of clinopyroxene than the lherzolite. The composition of the wehrlite xenoliths and presence of silicate melt inclusions in clinopyroxene indicate metasomatism by upward migrating alkaline melts, which trapped in the uppermost mantle (Patkó, 2014). Petrographic evidence may suggest that

there still might be melt present below the Moho (Patkó, 2014; Figure 2).

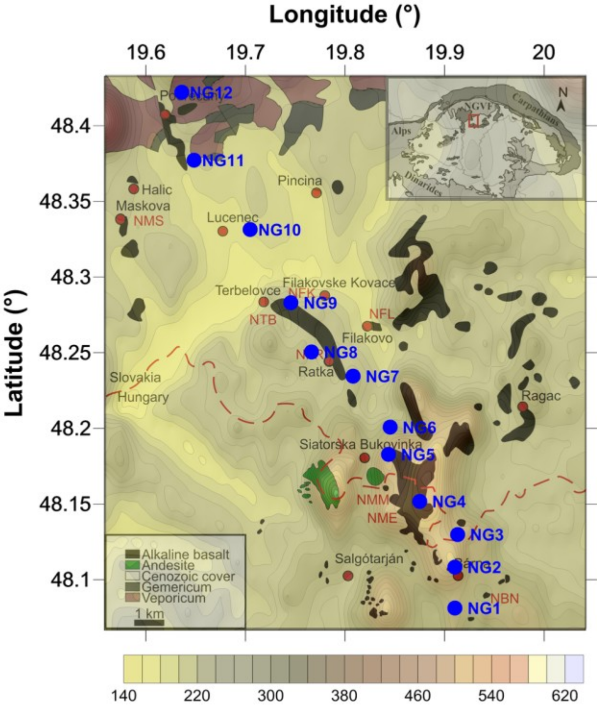

Figure 1. Location of studied area on relief map with magnetotelluric stations (2014) and occurrences of the xenoliths and alkali basalts of studied area. Elevation is in meter.

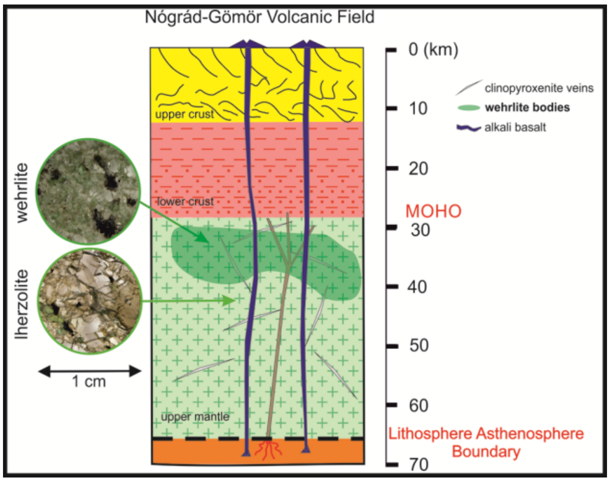

Figure 2. Proposed lithologic cross-section of the studied area based on petrologic and geochemical data obtained from xenoliths (Patkó, 2014)

MAGNETOTELLURIC RESULTS

Long period magnetotelluric (MT) data were collected at 12 locations along a ~50 km long NNW-SSE profile with the aim of characterization of the electric conductivity behavior of the lithospheric rocks and determine the LAB (Figure 1). LEMI-417 acquisition system is used with an average spacing of 3-5 km for magnetotelluric measurements. The average recording time was approximately 4-5 days at a station and electromagnetic time variations were observed between 0.25-100,000 sec period ranges. The data were processed using robust single-site and in some cases remote reference processing code to eliminate artificial noises and estimate MT transfer functions with different approach (Egbert and Booker 1986, Egbert and Livelybrooks, 1996).

Prior to the inversion and modeling process we checked the strike direction of the data which was estimated by impedance (Swift angle – Swift, 1967). In function of period the strike direction represents the complex structure. At short periods the main geological strike is appeared as N40°E and with period it turns to between north and N10°E direction which only at the center frequencies differ from.

Control the defined strike direction we used another options to analyze electrical strike by induction arrows (calculated from the tipper (Wiese 1962), and phase tensor ellipse (Berdichevsky and Dmitriev, 1976; Caldwell et al, 2004). The directionality of induction arrows between 1000-3000 sec periods represents an equal orientation to east. At longer periods the vectors aligned toward little bit to southeast direction. Consequently, by induction arrows can be established that the geology structure consider probably as 2D.
The phase tensor ellipses are in good correlation with the induction arrows represent 2D structure where the elongations of the ellipses show the geological strike (next to the approximately zero values of the βp skew). In few cases the chaotic behavior of induction arrows and phase tensor ellipses is probably caused by the presence of numerous shallow anomalies.
Since the above mentioned parameters are classified the characteristic of the studied area as 2D we made certain with dimensionality analyses to decide the dimension for the following data processing and inversion method. For characterizing the measuring area we considered Bahr-Q (WAL) invariant dimensionality indicators (Bahr, 1991; Marti I. Castells, 2006; Prácser and Szarka, 1999; Weaver et al, 2000). The dimensionality indicators show this area mainly two-dimensional beside some cases with 3D/2D and 3D character, caused by crustal conductive anomalies or the main tectonic line as Rába–Hurbanovo–Diósjenő Line between NG3 and NG4 MT sites.
For preliminary results of MT data we used 1D inversion to determine the depth of conductive asthenosphere.

We defined the depth of resistivity decreases and identified as crustal/lithospheric and asthenospheric depth cases by inversion layers. On the Figure 3a can be seen values of the depth at all MT sites for magnetotelluric polarizations (TE, TM) and an invariant parameters (root mean square, Geosystem, 2000). At higher scattering of polarization solutions, by invariant the indication on average depth between 30-40 km probably refer to the supposed wehrlite body in the lithospheric mentle, and the estimated depths of asthenosphere are in good agreement with the geochemical results and Ádam and Wesztergom map of conductive asthenosphere (70-80 km) as well. The other MT stations, which locates close to the studied area correlate well the calculated asthenosphere depth values as: Zabar = 65 km, Ipolytarnóc = 70 km and Litke = 80 km. Beside the depth information of 1D inversion results we illustrated the resistivity values, too. The Figure 3b represents that the estimated resistivity where the resistivity in relation with asthenosphere is an order of magnitude lower (~0.11 Ωm) than the crustal/lithospheric conductor(s) (~10 Ωm).

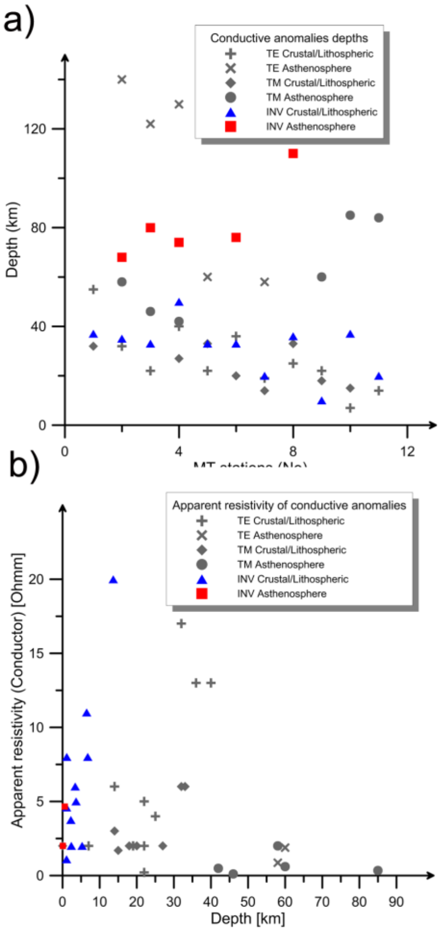

Figure 3. a) Conductive anomalies depth (Crustal/Lithospheric and asthenosphere) along the profile by 1D inversion results; b) apparent resistivity values at crustal and asthenosphere depths

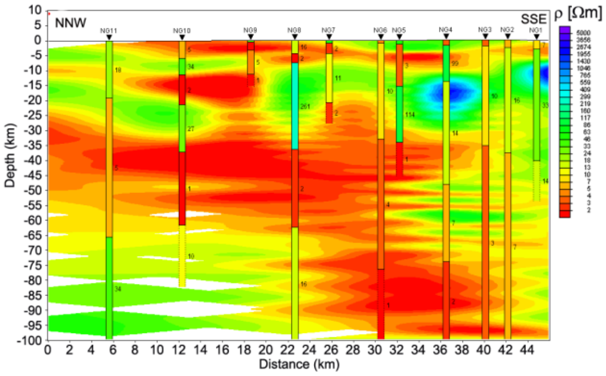

Figure 4. 1D inversion results by Occam (smooth, Constable et al., 1987) and layer inversion (layer model, Geosystem, 2000) for invariant apparent resistivity (root mean square).

In order to specify the resistivity distribution of the supposed crustal/lithospheric conductive body - which could be relateds to the suspected migrating mafic melt agent which transformed a large portion of lherzolite to wehrlite - we computed both the Occam (Constable et al., 1987) and layer inversion (Geosystem, 2000). The Figure 4 shows the inversion results along the NNW-SSE profile. The section demonstrates the smooth Occam and the layer inversions also with value of the resistivity of layers. At 30-45 km depth between NG5-NG11 MT sites, the low resistivity anomaly indicate the conductive body for which petrographic evidence suggests that there still might be melt present below the Moho (Patkó, 2014). On the section, the depth of conductive asthenosphere appears only at the beginning of the section.

CONCLUSION

Using two different approaches, the controversial estimates of the LAB depths by different geophysical methods may be better understood. With addition geochemical information by mantle xenoliths it leads to better understanding of these depths and geophysical indications.
In a test area we determined the LAB depth and find good correlation between the new results, xenolith data and earlier presented depth of the conductive asthenosphere. This presentation summarizes only the preliminary results but in additional processing should be necessary as 2D inversion.

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