MAGNETOTELLURIC SOUNDINGS IN THE MUDDY VOLCANOES AREA, EAST CARPATHIANS, ROMANIA

Rasvan Stochici, Constantin Diacopolos, Marian Popescu
Institute of Geodynamics, Romanian Academy, Romania

Introduction

The Muddy Volcanoes area from Pâclele Mari and Pâclele Mici is located at a distance of 12 km from Berca, situated in the central part of the East Carpathians bend zone. This geological structure exhibits the most famous muddy volcanoes from Romania. This geological phenomenon can be observed in many separate locations, in the proximity of Berca, from which two areas, named Pâclele Mari and Pâclele Mici. The first reference from the geological literature has been made by the French geologist, Coquand (1867), followed by the contribution of the Romanian geologist Cobălcescu (1883); the first to analyze the muddy gas emitted in Berca region was Costăchescu (1906). At the beginning of the 20th century, there have been carried out detailed geological studies by Teissenyre (1910, 1911 and 1924), Krejci-Graf (1935a and 1935b), followed by Ciocardel (1949), who mentioned the hydrocarbon accumulation in geological structures, and the Arbanasi-Berca anticlinal (30 km long). The term muddy volcano refers to formations created by the mud that got to the surface, geological emissions, water mixed with clay and gases. The gas liberated from these structures is methane (approx. 80%) with carbon dioxide, nitrogen and other gases (Baciu et al., 2007; Etiope et al., 2002; Filipescu & Huma, 1979). The evacuated mixture is composed of fine pasta of solids in suspension, which include salty water and eventually fluid hydrocarbons. In fact, muddy volcanoes are miniature craters in front of cracks where natural gases (Paclele Mari) are at a depth of 3000 m that migrate and in their way to the surface, enter in contact with the sedimentary nappes, the clay soil training these fragments that they transport towards the surface. Finally are formed muddy volcanoes with cones that have different shapes and sizes. Sometimes, formations with muddy volcanoes are shaped as elliptical plateaus, covered by ejected pasta (mud lava), of different ages. These are continuously enhanced by tides of water where clay and small fragments of other sedimentary rocks are coalescing. The most active "crater" locations are shifting from time to time, due to the changes in the upper parts of the fracture systems, leaving old eruptive traces of activity and opening new air shafts (Marunteanu and Ioane, 2010). Pâclele Mari (Figure 1) has been studied in detail from a geophysical perspective, with resistivity (VES) and magnetotelluric methods in order to highlight the resistivity anomalies. The article presents the interpretation of the geophysical data and describes information that may contribute to the geological characterization that has been developed until the present.

Figure 1 – MTS locations in the Paclele Mari area

Geological considerations

The involved geological sedimentary formations are Meotian and Pontian bordered by the Dacian, which in their turn are limited towards the exterior in the Romanian formations (Figure 2). The geological formations are overlapped in the muddy volcanoes area, the eruptions bringing to the surface at the height of 322 m (Pâclele Mari) a mixture of geological materials of different ages, Sarmatian, Meotian and Pontian geological materials and dissoluted sodium chloride that originates from the depth (salt breccia). The alignment of crypto-diapir structures includes salt bodies at various depths (Berca-Arbănasi, Ceptura, Urlati, Tinosu-Brazi structures) (Paraschiv, 1975). In this sector have occurred events with different intensities in the tectogenetic phases, the mineral material is lifted through a process of migration by the pressure of ascending gases and as erupted mud is a physical mixture of water, shale and tuff, but also a chemical one (sodium chloride, acid carbonate, sulphates). The mud trained by gases comes out at the surface and flows over the edge of the volcanoes, disperses on their cone or flows. Recent geological studies carried on in the region have described a number of 36 cones in different forms and shapes (Brustur et al., 2015). The chemical analysis of the water from the muddy volcanoes in both protected areas, Pâclele Mari and Pâclele Mici (Sencu, 1985), has shown a very high content in sodium chloride (44,266-64,885 mg/l), medium values of acid carbonates (2,206-3,074 mg/l) and an extremely low content in sulphates (19.72-74.12 mg/l) (Brustur et al., 2015).

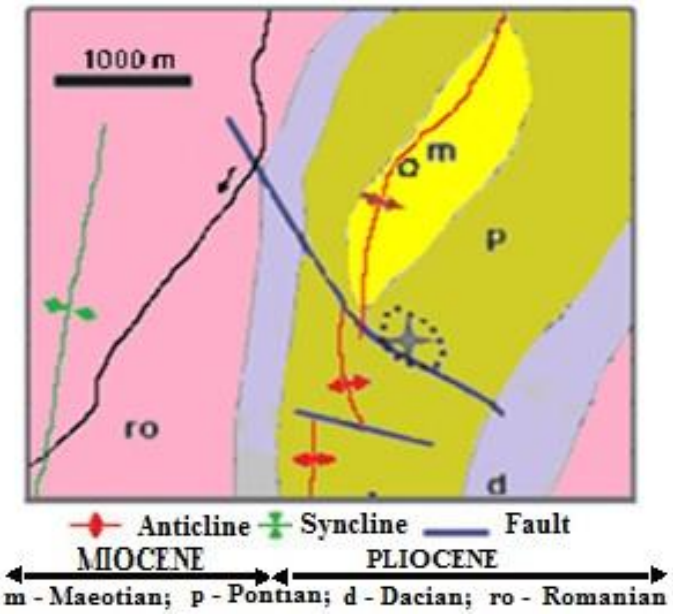

Figure 2 - The geological map of the region Paclele Mari (modified after Ciocârdel, 1949)

Geophysical investigation methods

The geophysical method represents an investigation instrument to examine the resistivity structure from Earth's interior from hundreds of meters until hundreds of kilometers depth. A magnetotelluric survey/sounding (MTS) implies the measurement of the electric and magnetic fields variations (one or more locations).

Interest is shown in the identification of the measure of the geological materials' resistivity in depth, this parameter being strongly influenced by the composition of the electrolytic fluids that transit the cracks and the pores of the geological material. There can be

placed limits on the physical structure and uncovered the processes from the interior of Earth once that the values of the electrical resistivity as a depth function (Figure 3) are known.

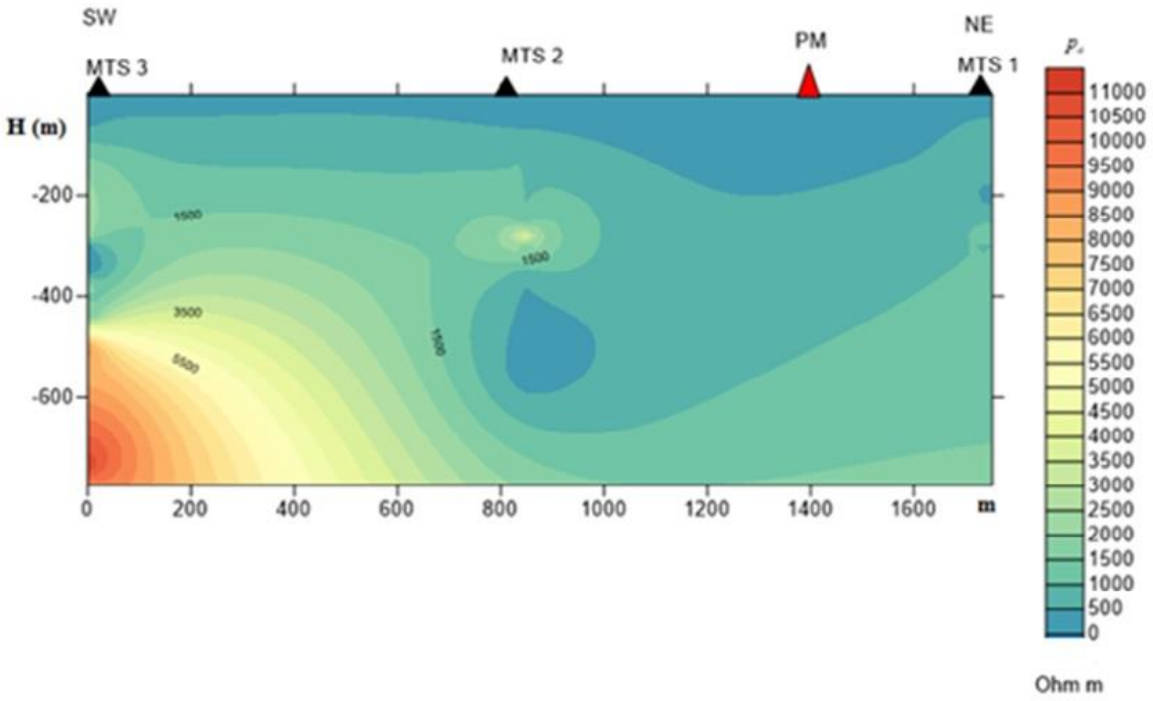

Figure 3 – Resistivity section based on MTS soundings in the Pâclele Mari area

Conclusions

The present paper represents the results of the geophysical investigation carried on at Pâclele Mari where electrometric and magnetoteluric methods have been used, which have succeeded in highlighting the resistivity/conductivity anomaly produced by the saline solutions which contaminated the geological structures.

Muddy volcanoes appear in the center of an anticlinal; the mud is a mixture of water, clay, halite and hydrocarbons migrated along the faulted flanks of these structures, being taken to the surface, this is the cause of existence of a sedimentary cover of over 25 m that presents a low resistivity due to the water salinity. By this method, data referring to the rocks from the superficial strata (clay has a high electrometric potential – it can polarize and its resistivity is low compared to the carbonates, plaster, anhydrite), are obtained.

The method of the magnetotelluric sounding is a good indicator of the lateral lack of homogeneity, registered data have underlined an anomalous area of resistivity, the package of rocks with a higher resistivity (10 000 Ω/m) is bordered by a structural elevation, with a width of approx. 1 km, located between 600 and 500 m depth. Eastern flank appears slightly elevated and has a slight tendency overthrust. Measurements MT performed at Pâclele Mari helped to determine the resistivity of the subsoil to depths up to 2000m.

Bibliography

Baciu, C., Caracausi, A., Etiope, G., Italiano, F. (2007) Mud volcanoes and methane seeps in Romania: main features and gas flux. Annals of Geophysics, 50 (4): 501-511.

Baciu, c., Etiope, G., Spulber, L., Costin, D., Pop, C. (2010) Romanian mud volcanoes – main features and flux to the atmosphere. Geol. Balkanica, XIX Congr. Carpathian-Balkan Geol. Assoc., Abstract volume, p. 35-36, Thessaloniki, Greece.

Brustur T, Tanasescu I , Macalet R , Melinte-Dobrinescu M C. The mud volcanoes from Berca: A significant geological patrimony site of the Buzău land geopark (Romania) , Geo-Eco-Marina - No.21 / 2015, 1-22 pp. (18,3 MB, DOI: 10.5281/zenodo.45066)

Ciocârdel, R. (1949) Regiunea petroliferă Berca-Beciu-Arbănaşi. Com. Geol., St. tehn.-econ., A1, 32 pp.

Cobalcescu, Gr. (1883). Studii geologice şi paleontologice asupra unor terâmuri terţiare din unele părţi ale României. Mem. Geol. ale Scolei Militare Iaşi, 161 pp.

Coquand, H. (1867). Sur le gîtes de pétrole de la Valachie et de la Moldavie et sur l'âge des terrains qui les contiennent. Bull. Soc. Géol. Fr., 2-ème Série, XXIV: 505-570

Costachescu, N. (1906). Les gas contenus dans la sel gemme et dans les volcans de boue de la Roumanie. Anal. Şt. Univ. Iaşi, IV (1): 3-59

Etiope G., Caracausi A., Favara, R., Italiano, F., Baciu C. (2002). Methane emission from the mud volcanoes of Sicily (Italy). Geoph. Res. Lett., 29/8: 561- 564.

Filipescu, M., Huma, I. (1979) Geochimia gazelor naturale. Editura Academiei RSR, 175 pp.

Grigoraş, N. (1961). Geologia zăcămintelor de petrol şi gaze din RPR. Ed. Tehnică, Bucureşti, 235 pp.

Krejci-Graf, K. (1935a). Die Salsen von Beciu-Berca. Geologische Charakterbilder, 40, Borntraeger.

Krejci-Graf, K. (1935b). Die entstehung vulkanartiger Bauformen in Erdölgebieten. Bohrtechniker Zeit., 6.

Marunteanu C., Ioane D. (2010) Muddy Volcanoes, Natural Heritage from East to West, Case studies from 6EU Countries, Springer, 383 pp.

Paraschiv, D. (1975). Geologia zăcămintelor de hidrocarburi din România. Stud. tehn.-econ., A10, 363 pp

Sencu, V. (1985). Vulcanii noroioşi de la Berca. Ed. Sport-Turism, Bucureşti, 21 pp.

Teisseyre, W. (1910). Die Schlammvulkane von Berca-Beciu und die Frageerorterung der Bedeutung derselben fur die Ölzone. C. R. Congrès Internationale du Pétrole Bucarest, III-ème Sess., II: 385-406.

Teisseyre, W. (1911). Die Schlammvulkane von Berca-Beciu. Revue du pétrole, An. IV, no. 1: 4-7; no. 2: 21-25.

Teisseyre, W. (1924). Le phenomene des volcans de boue dans les Carpathes et la loi de migration des hydrocarbures. Kosmos, Bull. Soc. Pol. Nat., 49: 295-298.