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Editorial to the second issue of "International Journal of Terrestrial Heat Flow and Applied Geothermics"

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The second issue of the *International Journal of Terrestrial Heat Flow and Applied Geothermics – IJTHFA* has allowed in bringing together several important works on geothermal research. It is indication that IJTHFA is a step closer to being recognized as the most convenient and useful forum for dissemination research results and information within the geothermal community.

The academic world is increasingly driven by cross-disciplinary visions and models, but the importance of intra-disciplinary approach cannot be underestimated. The approach embraced in IJTHFA is expected to provide a broadened and modern perspective of international geothermal research. With publication of the second issue of we expect to inform scholars of recent advances, evolving trends and new ideas being put forward in our own particular areas of specialty, both for enlivened discussions and for promoting research by next generations of experts.

The papers appearing in this second issue emphasizes the fact that study of Earth's internal heat plays a major role in understanding thermal fields of crustal blocks and energetics of tectonic processes. The results presented reveal that knowledge of terrestrial heat flow is essential for investigating the internal thermal structure of the Earth and demonstrates beyond doubt that research on outflow of thermal energy from the Earth's interior is important. Further, detailed knowledge of thermal interactions in near surface processes is useful for a better understanding of geosphere-biosphere interactions.

The organizers of the International Journal of Terrestrial Heat Flow and Applied Geothermics (IJTHFA) received eight manuscripts, which after due review process were accepted for publication. Given below is a brief overview of the accepted contributions.

Overview of Accepted Contributions

The focus of contributions in this issue has been on understanding of subsurface thermal signals generated by recent climate changes, development of thermal models of crust, qualification of thermal aspects of tectonic processes and assessment of geothermal energy sources. These papers deal with implications of heat flow studies in fields such as paleoclimatology, global warming, exploration geophysics and hydrogeology. The International Heat Flow Commission – IHFC plays a guiding role in development of such investigations.

The work by **Günter Buntebarth, Maria Pinheiro and Martin Sauter** deals with the effect of penetration of diurnal and annual wave temperature into the subsurface. The temperatures have been monitored at an hourly recording frequency at depths of 40, 60 and 78 m between summer 2016 and summer 2018, at the geothermal experimental test site "Neutra" of the Georg-August-University of Göttingen, Germany. It has been asserted that the mean temperature gradient between 40 and 78 m continuously increases, because the temperature decreases at 40 m. The decrease can be explained by an increase in vegetation cover (trees, shrubs, etc.) in the perimeter of the test area, increasing the absorption of solar energy by the leaves. During the phenological growth season the diurnal temperature variation at the surface can be recorded in phase with opposite sign, even at a depth of 40 m, and the drop of the temperature at 40 m, when surface temperature reaches a value of nearly 9 °C, can be observed during small events of eco-dormancy during winter. The annual surface temperature variation of ±10 K induce the same effect with an amplitude of ±2mK at 40 m. It is stated that the dormant state of the vegetation cells is the reason of the annual variation of the residual temperature. At greater depths groundwater flows prevail and influence the temperature according to the structural properties of the encountered lithologies and the precipitation. The vegetation can transfer the daily and seasonal temperature variation to larger depths than expected based on the theory of heat conduction. This timely variation of the temperature gradient demonstrates that the determination of the terrestrial heat flow density is subject to several impacts induced from the surface as well as from the Earth's interior. As a conclusion, temperature gradients determined at shallow depths may be influenced by changes in surface coverage.

Tamara Jimsheladze, Günter Buntebarth and George Melikadze discuss the importance of geothermal studies in understanding recent changes in climate. The focus is on understanding history of the surface temperature at Ajameti/Georgia. as extracted from long-term temperature records in the subsurface. The transient temperature component determined from long-term highly resolved temperature records in a borehole at Ajameti near Kutaisi in Western Georgia during the period between July 2017 and September 2018. Temperatures were recorded at depths of 100, 175 and 250 m with a resolution below the Millikelvin range and a recorded measurement frequency of 3 per hour, resulting in 72 individual measurements daily. At the depth of 100 m, a linear temperature increase of 0.0036 K/year was observed during those 15 months of measurement. At both larger depths, a precise linear trend could not be estimated. Additional impacts of water flow in the subsurface, penetrating from the surface or ascending from deeper layers during the time of measurements, superpose the transient component. The linear trend at 100 m can be understood as an increasing surface temperature at a rate of 0.015 K/year since 80 to 90 years. Two models agree with the data, i.e. a fast rise of the temperature as well as a continuous increase at a temperature diffusivity of $\kappa = 0.9*10^{-6}$ m²/s of the subsurface. The result coincides with the history of the Ajameti village which was founded in 1935, a period in which the settlement trees were probably cut to obtain a larger area of cultivated land, continuously increasing the surface temperature.

Jacek Majorowicz, Marek Grad and Marcin Polkowski discuss the problem of Terrestrial heat flow versus crustal thickness and topography in European continental setting. The relation between heat flow, topography and Moho depth for recent maps of Europe is presented. Newest heat flow map of Europe is based on updated database of uncorrected /heat flow values to which paleoclimatic correction is applied across the continental Europe. Correction is depth dependent due to a diffusive thermal transfer of the surface temperature forcing of which glacial–interglacial history has the largest impact. This explains some very low uncorrected heat flow (HF) values 20–30 mW/m² in the shallow boreholes in the shields, shallow basin areas of the cratons, and in other areas including orogenic belts were heat flow was likely underestimated due to small depth of the temperature logs. New integrated map of the European Moho depth is the first high resolution digital map for European plate understand as an area from Ural Mountains in the east to mid-Atlantic ridge in the west, and Mediterranean Sea in the south to Spitsbergen and Barents Sea in Arctic in the north. For correlation we used: onshore heat flow density data with palaeoclimatic correction (5318 locations), topography map (30 x 30 arc seconds; and Moho map (longitude, latitude and Moho depth, each 0.1 degree). Analysis was done for locations where data from all three datasets were available. Continental Europe area could be divided into two large domains related with Precambrian East European craton and Palaeozoic Platform of the West Europe. Next two smaller areas correspond to Scandinavian Caledonides and Anatolia. Presented results show different correlations between Moho depth, elevation and heat flow for all discussed regions. For each region more detailed analysis of these relation in different elevation ranges is presented. In general, it is observed that Moho depth is more significant to HF than elevation. Depending on region and elevation range, HF value in mW/m² is up to two times larger than Moho depth in km, while HF relation to elevation varies much more.

Sundaram Iyer and Valiya Hamza discuss the problem of paleo heat flow in areas of Sedimentary Exhalative (SEDEX) deposits of eastern Brazil. Representative values of fluid inclusion temperatures and radiogenic heat production values have been compiled as part of an attempt to determine paleo heat flow in areas sedimentary exhalative (SEDEX) deposits in thirteen localities of eastern Brazil. The results obtained indicate heat flow in excess of 80 mW/m² in areas of mineral bearing sulphide ore deposits, during periods of ore forming processes. Such anomalously high heat flow are more than twice the present-day values for stable tectonic units of Precambrian age. There are indications that high heat flow values were sustained by circulation of hydrothermal fluids in the upper crust, during periods not exceeding a few hundred million years. The resulting geothermal episodes may be considered as constituting short-period "heat pulses" occurring in stable tectonic environments, generated by magma emplacements in the upper crust, leading to formation of areas of sulfide ore deposits. Model simulations indicate that subsidence episodes induced by stretching and magma under-plating constitute the mechanisms for high heat flow during the ore-forming processes.

Patricia Descovi and Fábio Vieira discuss characterization of regional geothermal potentials in the State of Tocantins, Central Brazil. They report advances in the determination of geothermal gradients and heat flow in the State of Tocantins, Central Brazil. This region lies between the Amazonas and Sao Francisco cratons, affected by metamorphic folding events (Brasilia and Araguaia) during Proterozoic times. Our investigation has revealed the presence of several areas where geothermal gradients and heat flow have values higher than normal, which is considered atypical of stable tectonic settings. Calculations were carried out for determinations of crustal temperatures, corresponding to surface heat flow values in the range of 40 to 120mW/m². The results indicate that geotherms may intersect the melting curves at intra-crustal depths in regions where heat flow is in excess of 80mW/m². Thus, in the southern parts of the Tocantins province, one may expect zones of partial melting in the lower crust. In areas of anomalous heat flow, results of simulations also point to crustal temperatures in excess of 200°C at depths less than 5 km. Since there is no evidence of magmatic intrusions at intra-crustal depths, thermal energy transfer by carbonic gas flow associated with mineral reactions in the upper crust may be a possible explanation.

Suze Guimarães and Valiya Hamza discuss thermomagnetic features of Pirapora region in central Brazil. They report results of a detailed analysis of aeromagnetic survey data of Pirapora, situated in the São Francisco Craton region. The main residual anomaly span over an area of about 9000 square kilometers and has a maximum intensity of ± 300 nT. The analytic signal of the anomaly is located between 44.5° and 45.5° W and between 16.5° and 18.5 S and has a maximum value of about 0.028nTm^{-1}. Results of spectral analysis, based on matched bandpass filtering method, indicate that the anomaly is composed of signals arising from three different layers. The top layer is at depth shallower than 5 km while the intermediate one extends from 5 to 15 km depth. The bottom of deepest magnetic layer extends over depths varying from 20 to 55 km. Along an east-west belt, south of Pirapora anomaly, the depth to bottom of magnetized crust is less than 35 km and comparable to the thickness of the local crust obtained in seismic surveys. However, the thickness of the magnetized crust can exceed 35 km to the north and to the south of the Pirapora anomaly. This implies that the top layer of the mantle itself is magnetized. Results of geothermal model studies indicate Curie isotherm of 580ºC may lie at depths greater than 35 km, along wide sections of the Pirapora region, within the São Francisco Craton.

Massimo Verdoya, Paolo Chiozzi, Gianluca Gola and Elie El Jbeily report progress in analysis of thermal data from deep oil exploration and geothermal boreholes in the 1000-7000 m depth range to unravel thermal regime beneath the central-northern Apennines chain and the surrounding sedimentary basins. The authors particularly selected deepest bottom hole temperatures, all recorded within the permeable carbonate Palaeogene-Mesozoic formations, which represent the most widespread tectono-stratigraphic unit of the study area. The available temperatures were corrected for the drilling disturbance and the thermal conductivity was estimated from detailed litho-stratigraphic information and by taking into account the pressure and temperature effect. The thermal resistance approach, including also the radiogenic heat production, was used to infer the terrestrial heat flow and to highlight possible advective perturbation due to groundwater circulation. Only two boreholes close to recharge areas argue for deep groundwater flow in the permeable carbonate unit, whereas most of the obtained heat-flow data may reflect the deep, undisturbed, conductive thermal regime.

The paper by **Fabio Vieira and Valiya Hamza** focus on assessment of geothermal resources of South America. The focus of this work is on a new look into the nature and distribution of geothermal resources of South America, on the basis of recent advances in data analysis and regional assessments. Notable in this context is the progress achieved in the use of a procedure based on magmatic heat budget (MHB) that allow estimation of heat flow in areas of recent volcanic activity. In addition, an updated compilation of temperature gradients and heat flow have been completed. Such advances have allowed resource assessments for 6526 localities, spanning over more than 100 crustal blocks, distributed in thirteen countries of the continent. Following this, a 2^ox2^o grid system with homogenized data ensembles were employed for calculating the in-situ heat content. Determinations of resource base based on observational data are now available for 253 out of a total of 418 cells in this grid system. Estimated values of resource base were calculated for the remaining 165 grid elements. Maps based on these results have allowed substantial improvements in assessment of hot dry rock (HDR) and hot wet rock (HWR) resources for several regions. These include tectonically active crustal blocks in southern and central Chile, western Argentina, highland regions of Bolivia, southern parts of Peru, magmatic arcs of Ecuador and cordilleran regions of Colombia and northern Venezuela. Progress achieved in the present work has also allowed a better understanding of low enthalpy (LE) resources in tectonically quiescent platform areas of the eastern parts of the continent.

There are indications that HDR resources, with temperatures higher than 150^{o}C at depths less than three kilometers, occur in 318 localities of the Andean regions. The total resource base (RB) of HDR systems is estimated to be 1329x10^{21}J, while the corresponding weighted mean resource base per unit area (RBUA) is estimated to be 513GJ/m^2. The new results have also been useful in regional scale identification of resources with notable pore fluid circulation, classified as HWR systems. Such systems with temperatures in the range of 90 to 150^{o}C, are inferred to occur at depths less than three kilometers, in 352 localities of the Andean region. The total resource base of HWR systems is estimated to be 586x10^{21}J, while the corresponding value for RBUA is estimated to be 409GJ/m^2. Low enthalpy (LE) resources, with temperatures in the range of < 90^{o}C, are numerous in the remaining parts of Andean regions and also in the eastern parts of the continent. The resource base per unit area of low enthalpy systems with temperatures in the range of 60 to 90^{o}C is estimated to be 240GJ/m^2, while that for systems with temperatures less than 60^{o}Cis estimated to be 210GJ/m^2.

Concluding Remarks

The editors of this journal are indebted to members of the International Geothermal Community who contributed to successful publication of this issue. Special thanks are due to those who helped by reviewing the manuscripts. Their comments and suggestions were most useful in producing this volume.