Fluvial elements as potential sources of geothermal energy

MARTA PREKOPOVÁ
Institute of Geosciences, Technical University of Košice, Letná 9, 042 00, Košice, Slovakia
(E-mail: marta.prekopova@tuke.sk)

Abstract
Geothermal energy belongs to the renewable sources connected usually with the development of the regions in the area of tourism. Important precondition of its utilization is identification of aquifers deeper underground. Since aquifers represent elements of certain depositional systems, case studies of surface depositional systems may help us to understand their evolution and can represents analogues of deeper localized sediments. In this paper we present case study of the Quaternary sediments of the Latorica river basin, where 11 hydrogeological wells were used for construction of 3D model of spatial distribution of fluvial elements.

Key words: geothermal energy, fluvial system, aquifer

INTRODUCTION

Geothermal energy belongs to attractive renewable sources because it increases the energetic self-sufficiency as well as tourism development of regions (Timčák, 2011). Utilization of geothermal energy presumes certain geological conditions as existence of appropriate rocks representing aquifers in sufficient depth. Analysis of geological situation in depth is hampered by non-accessibility of the areas therefore studies of surface analogs of depositional systems providing possibility of understanding the general evolution of the depositional system are important. Example of the fluvial depositional system can be represented by sediments deposited in the Latorica River Basin which is part of the East Slovakian Lowland. The majority of the Quaternary sediments are composed of sand. Clays are accumulated only in thin lenses.

FLUVIAL SYSTEM

The fluvial system consists of 8 basic architectonic elements, which can represent potential aquifers: channels, sediment of gravity flows, gravel bars and bedforms, lateral accretion, sand bedforms, laminated sand, foreset macroforms and overbank fines (Miall, 1985; Bridge, 2003). Each of these elements has its own characteristic geometry, structure, composition, which record conditions and processes active during their creation and development. Gravel bars and bedfoms as well as gravity flows dominate by massive gravels. Sands with variable stratifications are typical for channels, sand bedforms, foreset macroforms, lateral accretion and laminated sands. The finest sediments as clays are found in the overbank elements.

The spatial distribution of the fluvial system elements is characteristic by high variability in the vertical as well as in the lateral sequence. The composition of sediments in the zone near the channel is litologically most variegated. With increasing distance the amount of coarse-grained sediments decreases, but the amount of fine-grained sediments deposited mainly from suspension increases. These fines are occasionally interrupted by incursions of thin beds of sandstones which are transported to the flood-plain only during the extreme catastrophic floods (Zwoliński, 1992).

The final spatial distribution of elements depends also on the mobility of the fluvial system that represents a dynamic system sensitive to intrinsic and extrinsic factors. Disturbing of its equilibrium can lead to vertical and lateral mobility of river channels (Werrity, 1997) and thus affects the ultimate emplacement of the sediments. The vertical movement occurs as a raising or lowering of the channel bed. The lowering of the channel bed results from channel incision. Significant incision can widen the channel due to bank collapse. The raising of the bed is caused by sediments aggradation/deposition and facilitates the river horizontal movement. Horizontal migration is represented by channel widening, narrowing and especially by lateral migration of the channel and avulsion. Lateral migration is the result of erosion along the river cut bank that is contemporaneous with deposition inside the meander bend. The avulsion is defined as an abrupt shift of the channel to a new area (Allen, 1965).

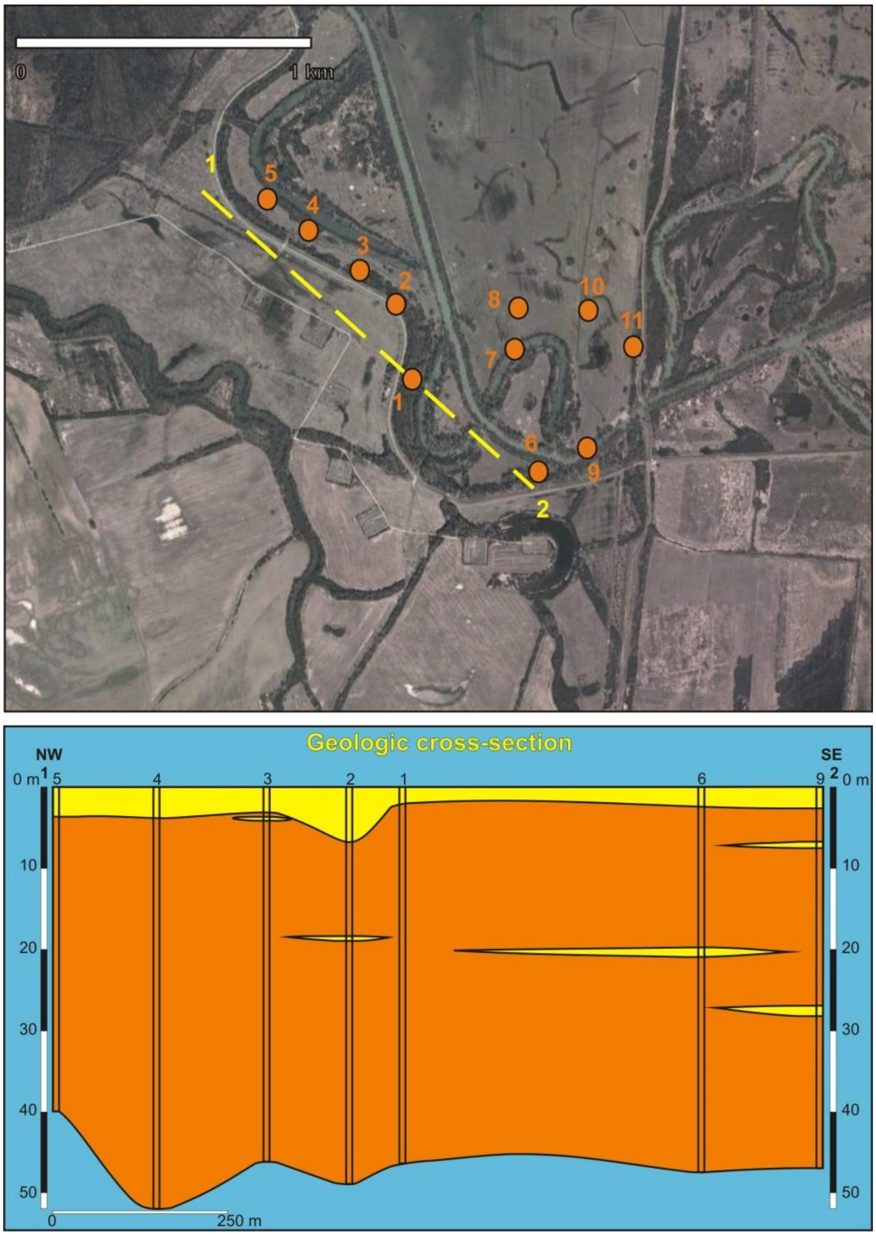

Fig. 1 Location of the hydrogeological wells and their correlation (orange and yellow colours mark the sand and clay respectively).

METHODS

Evaluation of the river migration usually includes sediments analysis and comparison of historical material with material from the present (maps, aerial photographs...). Our study is concerned to the last 150 years of the river migration. The oldest most detailed maps used for determination of the river migration were cadastral maps from 1886 (1:2880 scale). These were compared with younger maps - from 1907, 1950 and 2000. Individual parts of the river were assessed in terms of the places of max. erosion, deposition, movement etc.. Obtained data allowed display the gradual geomorphologic evolution of the studied area in time.

The modelling of spatial distribution of sediments was based on 11 hydrogeological wells, drilled to 52 m depth and collected from 2,9 km^2 area (Fig.1). The input data contain basic information concerning the wells lithology, stratigraphy and location. The sediments are characteristic by prevalence of fine to coarse-grained sands, clays form few max. 2 m thick accumulations and occasionally also gravel is presented. Individual steps of the modelling include the processing of data and interpretation of fluvial elements. The interpretation of facies was reduced only to two basic fluvial elements – channel and floodplain, according which the final 3D model of facies spatial distribution was made (Fig. 3).

RESULTS

Migration of the Latorica river in area of Slovakia (Fig.2) is characterized by downstream movements of the channel. Upstream movements, that occur at the low flow stages, when the locus of maximum flow velocity and bed shear stress impinges upstream of the bend apex (Bridge, 2003) are exceptional. During successive younger time periods the intensity of erosion gradually decreases, conversely to deposition, that was high also during the last observed interval (years 1950-2000)..

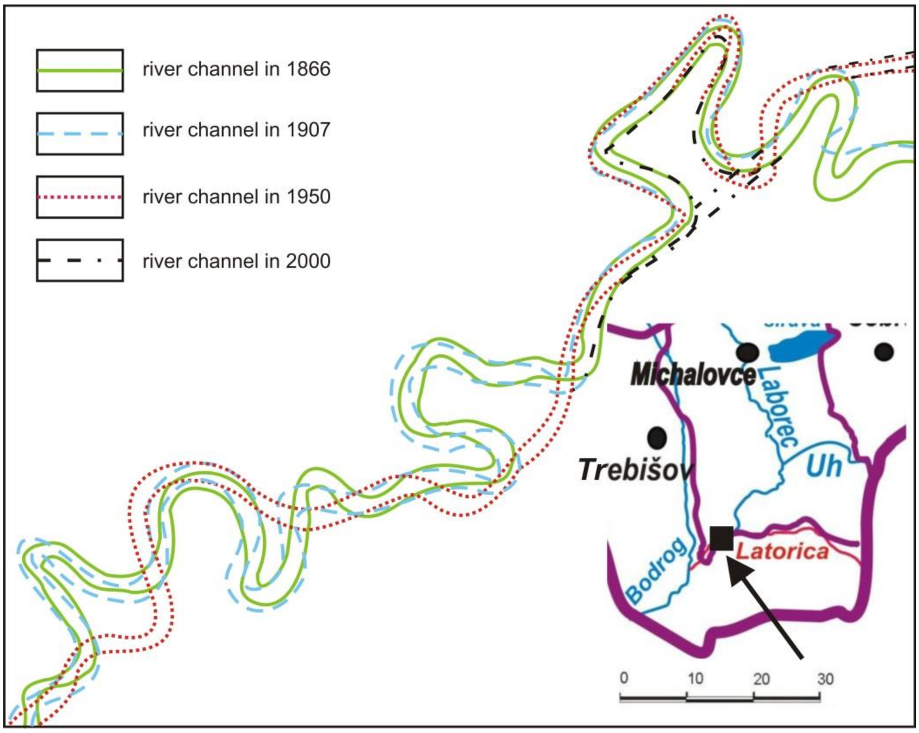

Fig. 2 The course of the Latorica river channel since 1866. Due to the regulation of the Latorica, the river course in 2000 coincides with its course in 1950 in some sections.

We conclude that the rate of erosion and deposition was influenced by decreasing amount of precipitation, but mainly by anthropogenic activities in form of proceeding regulation of the natural channel of Latorica. As the consequence the migration of the Latorica river is minimal today and does not affect the already existing spatial distribution of sediments

Based on the input data we identified 5 facies (grey clay; brown clay; fine- to coarse-grained sand; medium- to coarse-grained pebbly sand and fine-grained gravel) and two facies associations: fluvial channel - characterized by abundance of sand, pebbly sand and gravel representing amalgamated fluvial channels together with point-bars, fluvial levee and crevasse-splaz deposits; and floodplain – characterized by clay that can be assign to overbank or floodplain deposits. Correlation of the water wells documents the prevalence of fluvial-channel association. Amalgamated fluvial channel bodies have high continuity and display sheet-like geometry. Their horizontal dimensions exceed the vertical dimension (Fig.1). We can notice the minor occurrence of overbank facies with lenticular shape. Abundance of fluvial-channel association in the lower part of the profile may indicate a system of laterally migrating rivers. Low accomodation space favour lateral migration of river channels and development of scour-fill episodes (Komatsubara, 2004). The overall thickness of fluvial-channel association suggests continuous creation of accommodation by tectonic subsidence (Amorosi et al., 2008). Occasional lenses of overbank sediments in the middle of the section confirm the high migration rate of the meandering river that probably eroded the major part of the floodplain (Fig. 3). Upper part of the profile displays prevalence of fines thus indicating aggradation of overbank sediments. Accumulation of high amount of fines and its preservation is at present facilitated by human activity. Regulation of the Latorica river and human made embankments surrounding its channel prevents the river migration as well as it prevents the deposition of the sand on a floodplain.

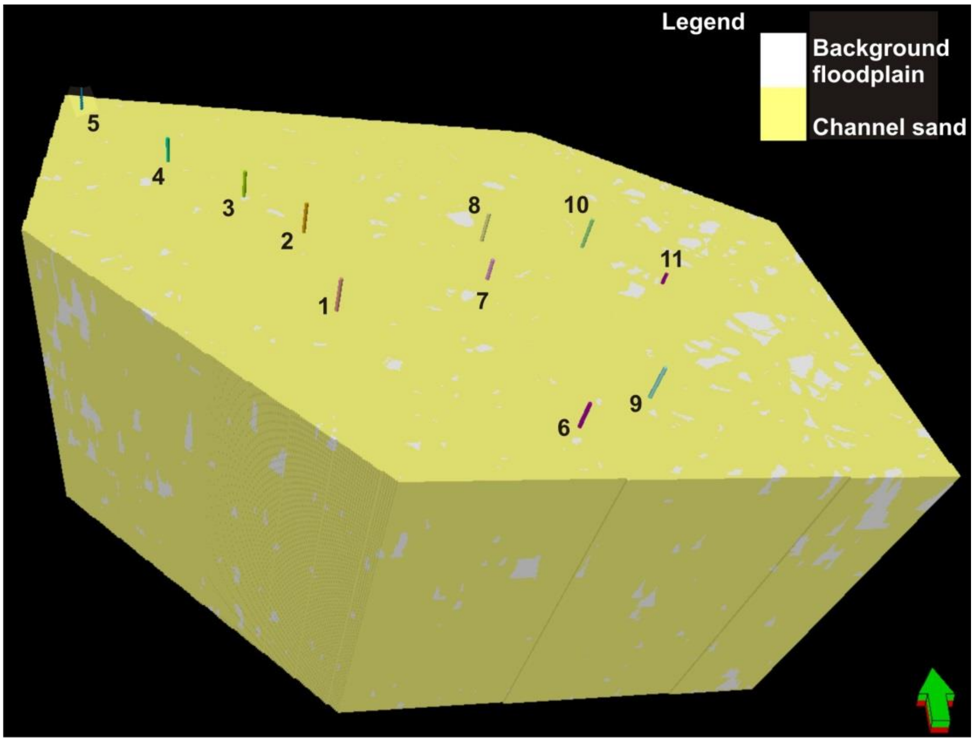

Fig. 3 3D model of spatial distribution of fluvial channel and floodplain facial associations.

LIMITATIONS

The precision of the model was influenced by the quality of the input data. For modelling of certain lithotypes (gravels, clays...) data from hydrogeological wells are sufficient. But for the interpretation of fluvial elements we need information regarding the sediments structure and texture, geometry, that are usually missing in the archive material. Also, the sediments from wells were in many times documented by different geologists and their inconsistent description led to a number of different kinds of facies. Overestimated number of facies could not be correlated from well to well and finally, it was necessary to simplify the facies analysis to two basic elements – channel sand and floodplain (Fig. 3).

CONCLUSIONS

Based on the available data, 3D model of spatial distribution of fluvial Quaternary sediments was created in the studied area. The high content of sandy sediments indicates intensively laterally migrating river system that evolved in area characterized by high continuous subsidence. The uppermost continuous accumulation of clays records the decreasing nature of the lateral migration. This is confirmed by the minimal rate of the horizontal migration of the Latorica river observed from cadastral maps that is caused by regulation of the river by humans.

The results can be applied in the study of fluvial sediments buried deeper underground that can in case of appropriate geological conditions represent sources of geothermal energy. Their detection can significantly increase the development of tourism of certain regions.

Acknowledgements
This publication is the result of the Project implementation: Research centre for efficient integration of the renewable energy sources, ITMS: 26220220064 supported by the Research and Development Operational Programme funded by the ERDF.

REFERENCES

Allen J.R.L. (1965) A review of the origin and characteristics of recent alluvial sediments. Sedimentology, vol. 5, pp. 89-191.

Amorosi A., Pavesi M., Ricci Lucchi M., Sarti G. and **Piccin A.** (2008) Climatic signature of cyclic fluvial architecture from the Quaternary of the central Po Plain, Italy. Sediment. Geol., 209, pp. 58–68.

Bridge J. A. (2003) Rivers and floodplains. Forms, processes, and sedimentary record. Wiley-Blackwell, 504 pages.

Komatsubara J. (2004) Fluvial architecture and sequence stratigraphy of the Eocene to Oligocene Iwali Formation, northeast Japan: channel-fills related to the sea-level change. Sedimentary Geology 168, pp. 109-123.

Miall A. (1986) Architectural – element analysis: A new method of facies analysis applied to fluvial deposits. Earth-Science Reviews, 22, pp. 261-308.

Timčák G.M. (2011) Iceland as a geotourism learning destination. Acta Geoturistica vol. 2, nr. 2, pp. 40-48.

Werrity A. (1997) Short-term changes in channel stability. In: Thorne, C. R., Hey, R. D., Newson, M. D. (Eds.), Applied Fluvial Geomorphology for River Engineering and Management. Wiley, Chichester, pp. 47-65.

Zwoliński Z. (1992) Sedimentology and geomorphology of overbank flows on meandering river floodplains. Geomorphology, 4, pp. 367-399.