Geometrical parametrization of structural elements of deep-water clastic depositional systems: a case study from Pannonian-basin

Szabolcs Borka[1], Janina Horváth[1], János Geiger[1]
[1]University of Szeged, Department of Geology and Paleontology, Egyetem u. 2-6, 6722 Szeged, Hungary, borka.szabolcs@gmail.com

There are several simulation methods - like multiple-point or object-based simulation - which can handle and honour the geometries of depositional structural elements. The parametrized geometry adds an extra but quasi-subjective information to our 3D geological model. Two assumptions must be completed: (1) well-definable geometries corresponding to the architectural elements (2) it is assumed that exactly one sedimentary or lithological facies belongs to each structural element and the flow properties are determined by these structural elements.
The case study takes place in the southern part of the Great Hungarian Plain (Algyő field, Hungary). The formation is a sand/mud-rich submarine fan system.
Five clusters were revealed by Box-Cox transformation, principal component analysis and neural network technique. In addition, well-logs, core samples, 2D maps with discrete variables, sand and porosity contour maps were used to determine the architectural elements and their geometries. The measurement of the latter is well-documented in the literature. For example, in the case of a sinusoid object (channel) one should measure the amplitude, the wavelength, the width, the thickness etc. of the object. Finally, two sinusoid channels were recognizable and measureable related to cluster 4 and 5.
These parametrized geoobjects with their own facies can be used for constructing training images of multiple-point simulation or for direct description of the objects regarding the object-based method.

Key words: *geometry, architectural element, deep-water depositional system, geoobject, geobody*

1. INTRODUCTION

There are several clastic depositional environments which possess sub-environments with well-definable geometries. This parametrical information can be easily revealed in modern environments by orthophotos of fluvial or upper and lower deltaic plain systems, or subaqueous seismic profiles and 3D maps of deep-water submarine fan systems.

The situation is different in case of ancient systems beneath the surface. There are only pointwise data e.g. well-logs, core samples, core plugs as hard data, and seismic profiles and/or (attribute) maps as soft data. Furthermore, usually a theoretical geologic model with architectural elements is available. These theoretical models are derived from observations of modern environments, analogs and experiences of decades of oil and gas exploration.

Integration of the available information (hard data, soft data, theoretical model) gives the conceptual geological model (Pyrcz and Deutsch, 2014). The geostatistical method (i.e. deterministic estimation or stochastic simulation) of the integration determines the ability to honour these inputs.

Probably the most conventional method is the variogram and cell-based algorithm. It can handle continuous variables (sequential Gaussian simulation) and categorical variables (sequential indicator simulation) as well. There isn't any kind of geometrical data in the inputs because the algorithm can't manage it.

Contrary to this, multiple-point (cell-based), object-based and process mimicking (non cell-based) algorithms are able to handle the additional geological information e.g. geometry (**Figure 1**; Pyrcz and Deutsch, 2014). Including these additional parameters as inputs are based on the consideration that the flow properties in a clastic reservoir are mostly determined by the geometries and the lithofacies of ancient sub-environments. The latter means that these methods can use only categorical variables, and exactly one lithofacies belongs to an ancient sub-environment.

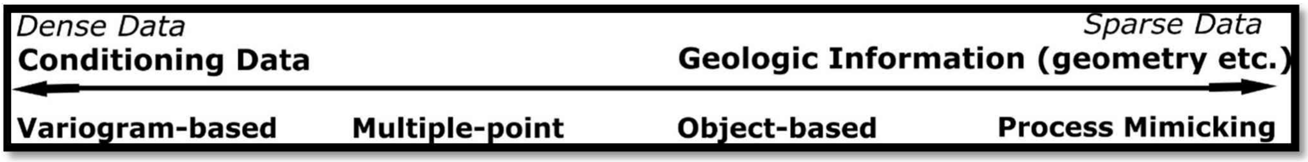

***Figure 1**: Continuum of algorithms indicating the ability of reproduction of Conditioning Data (wells and trends) and/or Geologic information. Variogram-based methods usually fail to handle sparse data and vice versa (modified after Pyrcz and Deutsch, 2014)*

The parameter of geometry can be regarded as a quasi-subjective geological data. Although the method of measurement has widespread literature, the final result moderately depends on the practitioner. Moreover the defined geometry possesses a distribution (mean, minimum and maximum values etc.), but it isn't as verifiable as the parameters and results of variogram-based algorithms.

2. GEOLOGICAL SETTING OF THE AREA OF INTEREST

The case study is located in Algyő sub-basin of the Pannonian-basin in the Great Hungarian Plain.

The following main depositional environments characterized Lake Pannon: (1) fluvio-lacustrine and deltaic plain (2) delta front and delta slope (3) prodelta (4) deep-water systems (5) basin plain (Bérczi, 1988).

The formation of the case study belongs to Szolnoki Formation as a submarine fan system (Gajdos et al., 1983). In the Great Hungarian Plain its thickest sequences (approx. <1000 m) take place in deep sub-basins (Jászság Basin, Derecske Trough, Makó Trough, Békés Basin) (Juhász, 1994).

3. METHODS

To measure a geometry of an architectural element, a visually adequate map showing the geometries in question is needed. If there is enough dense data (wells, 3D seismic lattice or 2D seismic profile), a deterministic or stochastic contour map with continuous variables can be regarded as a good basis.

Another approach is clustering the continuous variables into discrete variables and using them as hard data. Generally the result of this method doesn't give lithofacies related to architectural elements, but 'pure' lithology components. Getting around this, well logs (which reflect the fining - and coarsening vertical trends e.g. GR, SP, RES, shale-content, sand-content) and sedimentologically described core samples were also used to identify the sedimentary facies (i.e. lithofacies).

Currently several parametric shapes (i.e. geobodies, geoobjects) are available. These geobodies are generalized shapes mimicking the true architectural elements.

In case of deepwater submarine complexes, the following geobodies are corresponded to the sub-environments:

- sinusoid objects: braided channels with (very) low-sinousity on the upper part of channelized lobes (coarse-grained systems, CGS) (Normark, 1970); leveed, meandering channels with high-sinousity on the mid-/lower-fan (fine-grained systems, FGS)(Reading and Richards, 1994)
- lobe objects: channelized lobes on the mid-fan (CGS) (Normark, 1970; Mutti, 1985); unchannelized lobes or sand sheets at terminus of meandering channels on the lower-fan (FGS) (Reading and Richards, 1994)
- bar objects: mouth-bar at terminus of main depositional valley on the lower part of upper-fan (FGS) (Normark, 1970)
- ellipsoid objects: crevasse splays attached to channels (Pyrcz et al., 2008; Maharaja, 2008)

Figure 2 shows the measureable parameters of these geobodies.

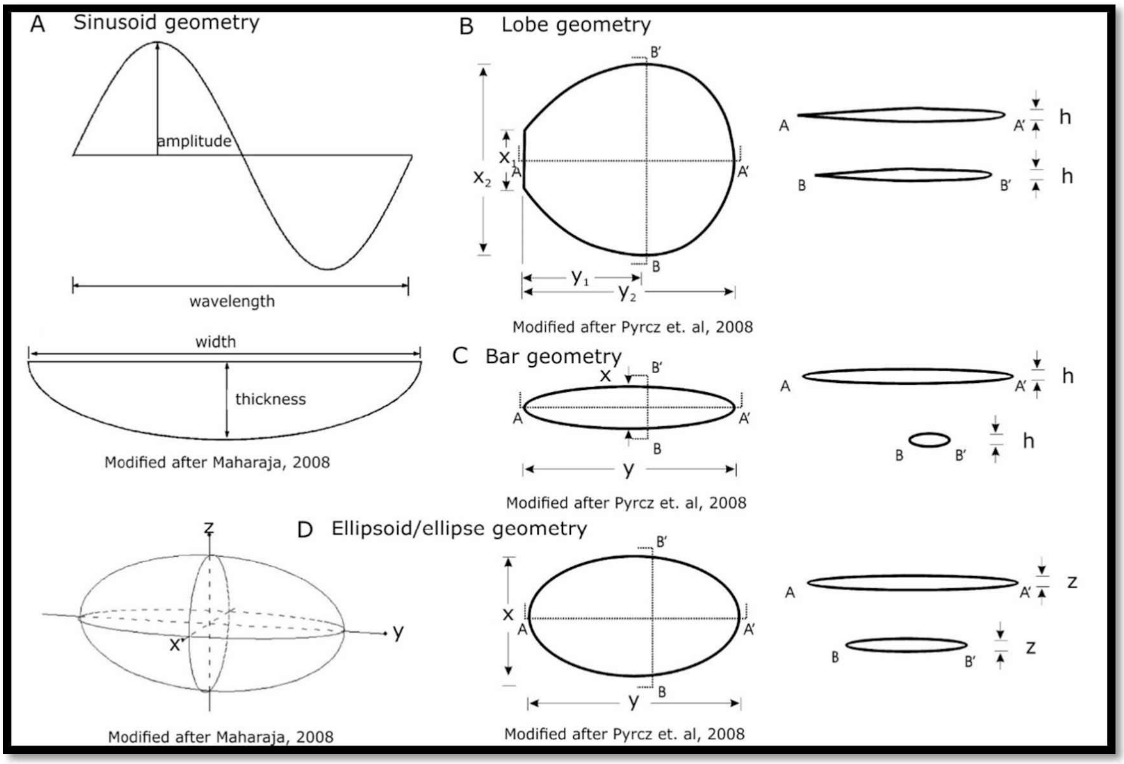

***Figure 2** Parameters of geoobjects (modified after Pyrcz et. al, 2008; Maharaja, 2008)*

(A) sinusoid geometry should be characterized by: amplitude, wavelength, width, thickness and sinuosity (ratio of true streamline length (on the interval of wavelength) and wavelength) of the geobody

(B) lobe geometry: mouth (x_1), width (x_2), length to largest width (y_1), total length (y_2), thickness (h) of the geobody

(C) bar geometry: width (x), length (y) and thickness of the geobody

(D) ellipsoid/ellipse geometry: semi-principal-axes (x, y, z) of a tri-axial ellipsoid.

4. RESULTS

In this study, results of an artifical neural-network clustering technique (data pre-processing: Box-Cox transformation and Principal Component Analysis, data: porosity, permeability, sand- and shale-content from well logs) were used to create 2D maps (slices) with discrete (five lithology clusters) variables. Two out of the five clusters were chosen with the highest porosity, sand-content and permeability (cluster 4-5, **Table 1**). Purpose of visualization (Golden Software's Voxler 3) was to examine what geometries are shown by cluster 4 and 5.

***Table 1**: General statistical character of cluster 4 and 5*

	FIAP		PERM		VSHA		VSND	
Clusters	4	5	4	5	4	5	4	5
N	503	328	503	328	503	328	503	328
Mean	18.39	20.25	32.24	87.16	15.30	8.79	65.93	71.23
Median	18.35	20.23	31.08	79.02	15.45	9.04	65.81	70.31
Std. deviation	0.77	1.00	15.16	41.79	2.76	2.58	3.07	3.84

A quasi-3D model (flatted to the impermeable argillaceous marlstone seal) was constructed by Voxler 3's FaceRender module. In this case cluster 4 and 5 show two sinusoid geobodies at 13 meters under the seal (**Figure 3**). Direct measurement isn't available in Voxler 3, so from the same depth, sand and porosity contour maps using kriging estimation were used to parametrize.

The two results show good similarity (**Figure 3**), although one is based on discrete, and the other one is based on continuous variables. Therefore measurement on the contour maps in Golden Software's Surfer 12 was valid. Measured parameters are shown in Figure 4.

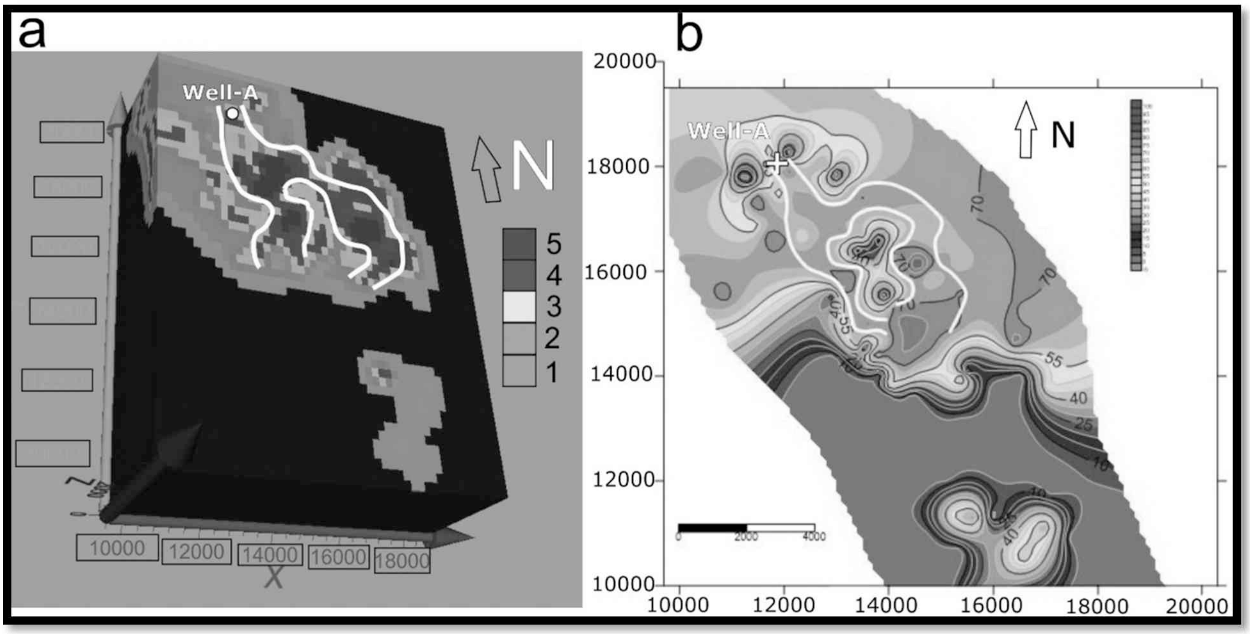

***Figure 3**: Picture 'a' shows two sinusoid geoobjects related to cluster 4 and 5; picture 'b' shows the same shapes in a sand-content contour map. The two slices are from the same depth, at 13 meters beneath the seal*

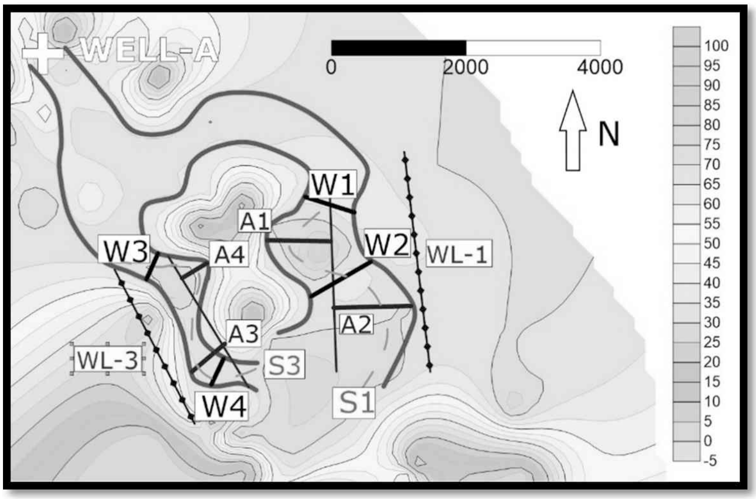

Figure 4: *Notations with number 1 and 2 belong to the right sinusoid geoobject, with 3 and 4 belong to the left sinusoid geoobject; A – amplitude, W – width, WL – wavelength, S – length of streamline*

The geometrical values are summarized in **Table 2**. The sinusoid geoobjects could be well tracked through approximately 45 slices i.e. contour maps (0,4 meters/1 slice). This means that thicknesses of both of the bodies are 18 meters (0,4 m x 45).

Table 2: *Measured values of the sinusoid geoobjects; A – amplitude, W – width, WL – wavelength, S – length of streamline, TH – thickness, SIN – sinuosity. Dimension: meter, except the SIN (ratio)*

Right geobody								Left geobody							
A1	A2	WL1	W1	W2	S1	SIN	TH1	A3	A4	WL3	W3	W4	S3	SIN	TH3
637	775	2156	496	685	2935	1.36	18	310	309	1658	277	286	2358	1.42	18

Core samples of Well-A were available from this depth. These can be characterized by massive, structureless fine sandstones with ripped intraclasts. They are deposits of sandy debris flows (Shanmugam, 2006) related to distributary channels or proximal part of lobes. The GR and SP logs show cylindrical shape which usually denotes channel (Reading and Richards, 1994).

5. CONCLUSIONS

On the basis of well logs, core samples and shapes (sinusoid geometry) of these geoobjects, they can be regarded as sinuous, meandering channels of a sand/mud (i.e. mixed) submarine fan system. Their sinuosities and thicknesses are approx. equals. However, the other parameters are higher in case of the right meandering channel. These values can be used as direct parameters of an object-based algorithm, or to construct training image of a multiple-point simulation.

6. REFERENCES

BÉRCZI, I. (1988): Preliminary sedimentological investigation of a Neogene Depression in the Great Hungarian Plain. –In: ROYDEN, L. H., & HORVÁTH, F. (eds.): The Pannonian Basin: A study in basin evolution, AAPG Memoir 45, 107-116.

GAJDOS, I., PAPP, S., SOMFAI, A. & VÖLGYI, L. (1983): Az alföldi pannóniai (s.l.) litosztratigráfiai egységei, (Lithostratigraphic units of the Pannonian (s.l.) formations in the Hungarian Plain.). MÁFI, Budapest, 70 p.

JUHÁSZ, GY. (1994): Magyarországi neogén medenceré szekpannóniai s.l. üledéksorának összehasonlító elemzése. Földtani Közlöny, 124/ 4, 341-365.

MUTTI, E., (1985): Turbidite systems and their relations to depositional sequences. -In: Zuffa, G.G. (Ed.), Provenance of Arenites. D. Reidel Publishing Company, 65–93.

NORMARK, W. R., (1970): Growth patterns of deep sea fans. AAPG Bulletin, 54., 2170–2195.

MAHARAJA, A. (2008): *TiGenerator*: Object-based training image generator, Computers and Geosciences. Elsevier, 34, 1753-1761.

PYRCZ, M.J. & DEUTSCH, C.V. (2014): Geostatistical reservoir modeling – 2nd edition. Oxford University Print, University of Oxford, 448 p.

PYRCZ, M.J., BOISVERT, J.B. & DEUTSCH, C.V. (2008): A library of training images for fluvial and deepwater reservoirs and associated code. Computers and Geosciences, Elsevier, 34, 542-560.

READING, H. G. & RICHARDS, M., (1994): Turbidite systems in deep-water basin margins classified by grain size and feeder system. AAPG Bulletin, 78, 792–822.

SHANMUGAM, G. (2006): Deep-Water Processes and Facies Models: Implications for Sandstone Petroleum Reservoirs. 1st ed., Elsevier, Amsterdam, The Netherlands, 498 p.