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BasinVis 1.0 - A MATLAB®-based Program to visualize Sedimentary Basin Fill and Subsidence

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BasinVis 1.0

- BasinVis to analyze and visualize sedimentary basin in a comprehensive workflow.
- It is particularly aimed at 2D/3D stratigraphic and subsidence visualization of sedimentary basins with well data or stratigraphic profile (e.g. synthetic wells). This allows users with programming experience to edit and customize all provided functionalities to fit their own research area.

MATLAB®

- This study choses MATLAB® as a numerical computing environment for programming and provides 2D/3D visualization functions. MATLAB is a powerful tool for software development and the language is relatively easy to learn.
- BasinVis 1.0 is implemented entirely in MATLAB® version 8.4 (R2014b) and requires the 'Symbolic Math' and 'Curve Fitting' Toolboxes (Math, Statistics, and Optimization package). It can be operated under Microsoft Windows (XP or higher), Mac OS X (10.7.4+ or higher), and recent Linux distributions (e.g. Ubuntu 14.04).

Main Window

- 'mainwindow.m'
- The main window acts as central hub to all functions and process stages of BasinVis 1.0.
- Function buttons are arranged to follow the order of the work flow.

Figure 1. *Main menu of BasinVis 1.0.*

Workflow

- This workflow outlines the main scripts and functions within the workflow of BasinVis and describes their high-level goals.
- BasinVis incorporates three main processing steps
- The graphical user interface guides users through the workflow.

Figure 2. *Flow chart of BasinVis 1.0's main script files and their high-level functions.*

Example Application and Data Background

- The Vienna Basin located in central Europe was selected as an example for the evaluation of BasinVis 1.0.
- c. 30x40 km^2 of the central Vienna Basin, lying mainly on the hanging wall of the Steinberg fault.
- a total of **110 wells** reaching Miocene sediment were examined. Wells reaching the pre-Neogene basement were selected for subsidence analysis.

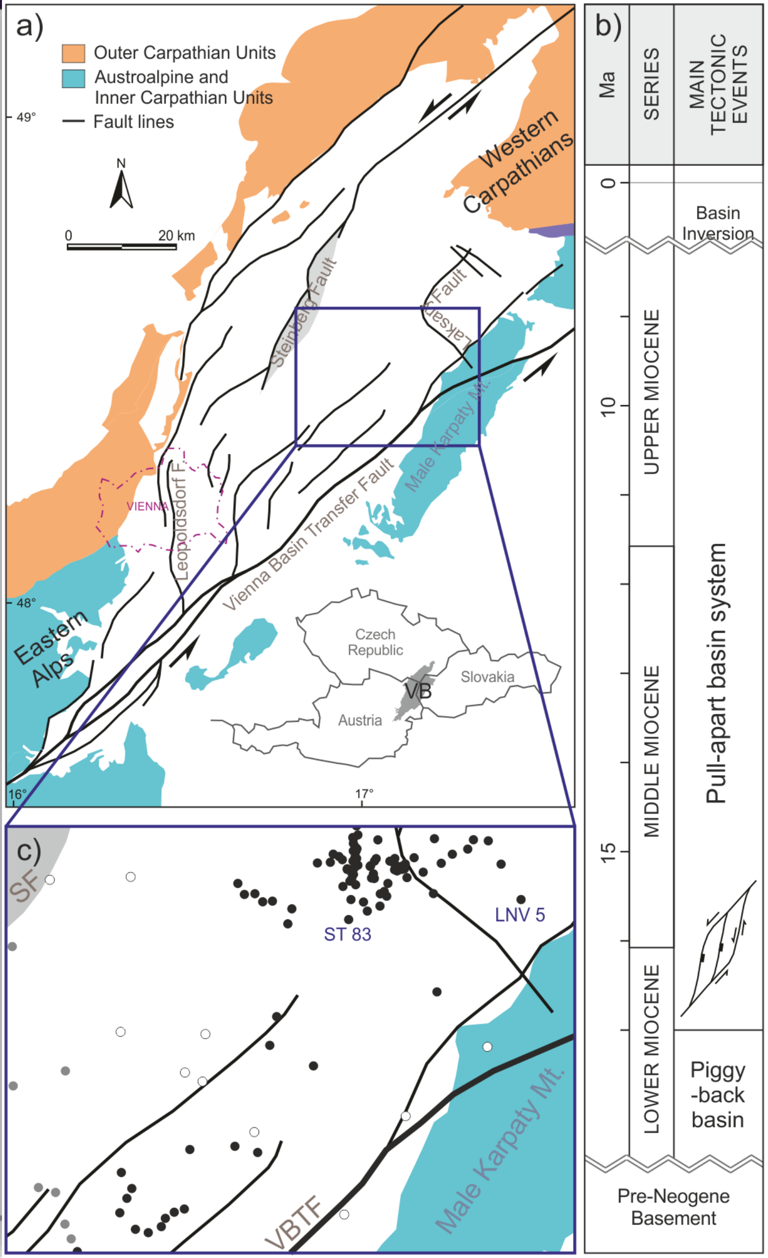


Figure 3. a) Structural outline of the Vienna Basin and location of the study area (Wessely et al., 1993), b) General tectonic outline of the Vienna Basin (Decker, 1996; Hölzel et al., 2008b; Lee and Wagreich, 2016; Strauss et al., 2006), c) locations of the studied wells ***(filled circles: wells from the Dionyz Štur Institute, shaded circles: wells from Hölzel (2009), and*** *open circles:* ***synthetic wells****).*

Interpolation methods

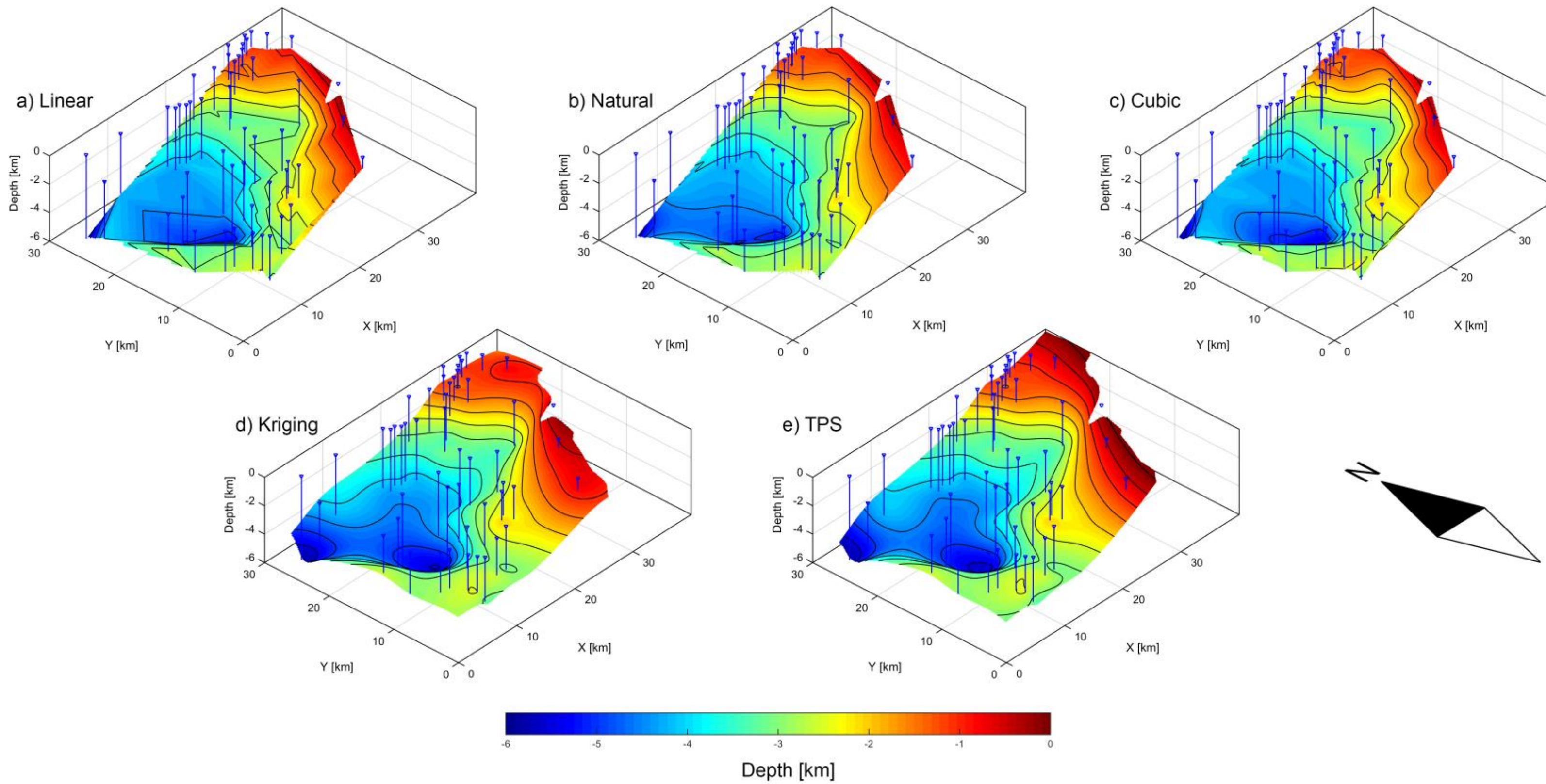


Figure 4. *Interpolation methods; a) linear, b) natural, c) cubic spline, d) Kriging, and e) thin-plate spline. The example shows the depth model of the pre-Neogene basement in our case study area.*

Subsidence Analysis

- Subsidence analysis is performed using **decompaction and backstripping techniques**, respectively, for basement(total) subsidence and tectonic subsidence.
- The subsidence is computed at locations where a well or stratigraphic profile can provide detailed data.

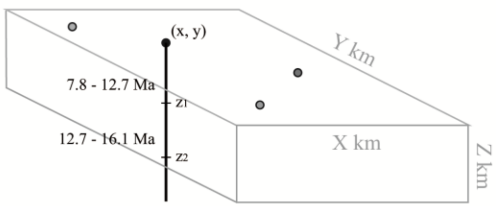
Parameter	Symbol	Description	Example
Study Area Location Depth Geologic Age	X, Y, Z x, y z_1, z_2, ... Ma, ka, yr	a size of mapping and modeling area x, y coordinators top depth of each stratigraphic unit geologic age of each stratigraphic unit	
Initial Porosity Coefficient Densities	$\varnothing_0$ c ρ_s ρ_m ρ_w	initial porosity of porosity-depth relation (%) coefficient of porosity-depth relation (x 10^{-5}) average density of sediment grain (g/cm^3) average density of mantle (3.3 g/cm^3) average density of water (1.0 g/cm^3)	from Sclater and Christie (1980) | $\varnothing_0$	c	ρ_s Shale 63 0.51 2.72 Sand 49 0.27 2.65 Shaly Sand 56 0.39 2.68 Chalk 70 0.71 2.71
Water-depth Sea-level	W_d Δ_{SL}	paleowaterdepth paleosealevel	

Table 1. *Required input data in BasinVis 1.0*

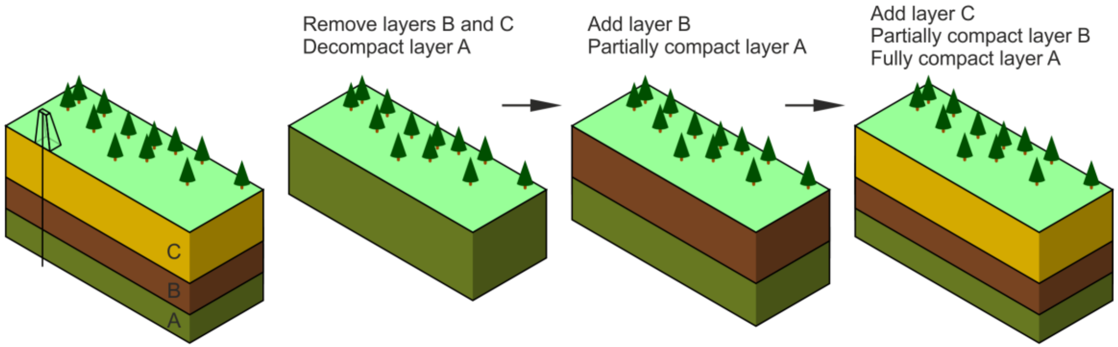


Figure 5. *Concept of the successive stages in the decompaction analysis*

- **Decompaction technique** calculates the thickness of a sediment layer at any time in the past by moving the layer up the appropriate porosity-depth relation curve (Allen and Allen, 2013). A typical porosity-depth relation is exponential (Sclater and Christie, 1980), where ϕ is the porosity at depth (z) and coefficient *(c).*

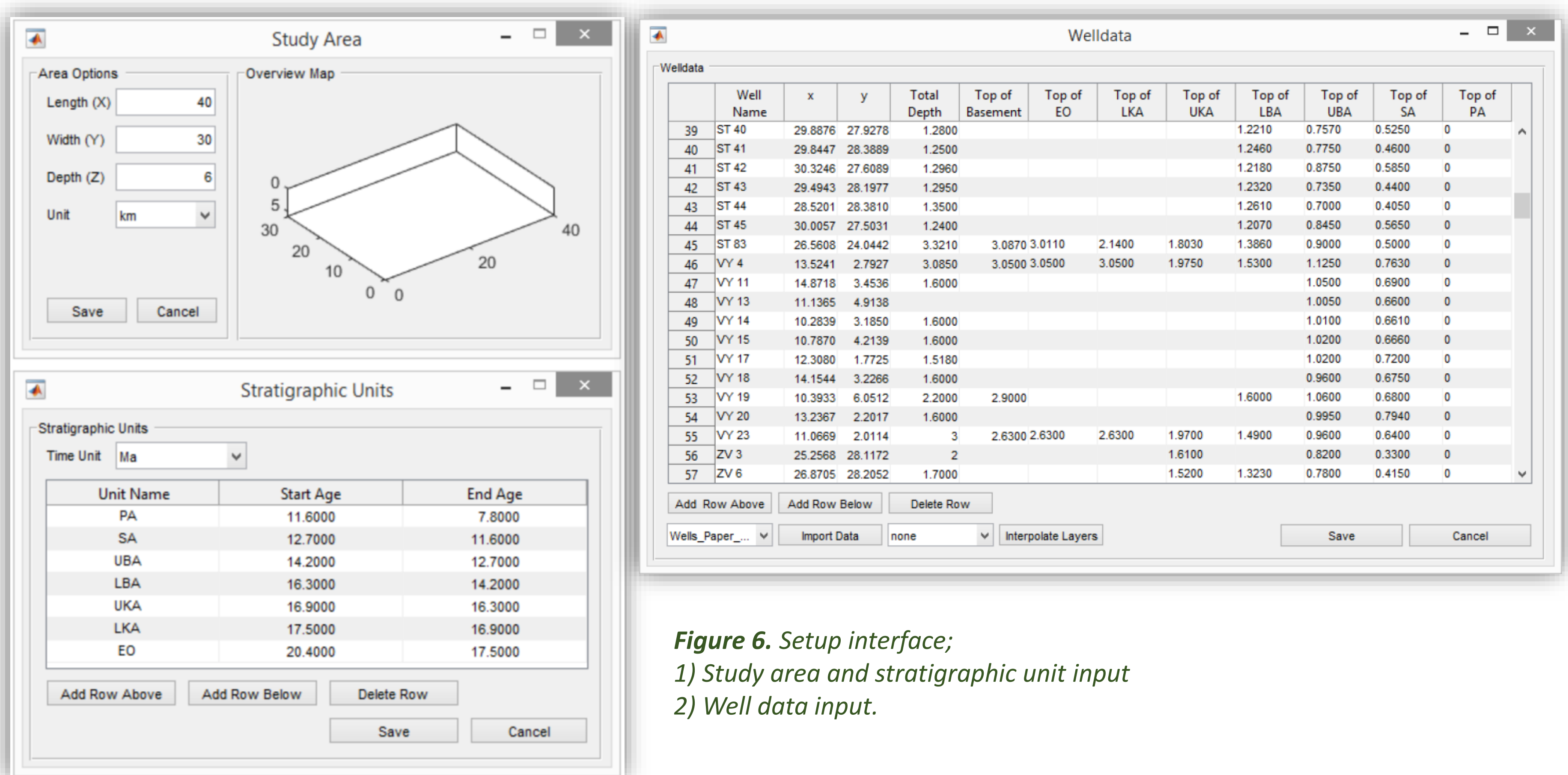
$$\phi(z) = \phi_0 e^{-cz}$$

- **Backstripping technique** removes progressively the sedimentary load from a basin, correcting for compaction, paleobathymetry (W_d), and sea-level change (Δ_{SL}), in order to reveal the tectonic driving mechanisms of basin subsidence (Miall, 1999). It can be calculated by using the following equation (Steckler and Watts, 1978),

$$Z = S\left(\frac{\rho_m - \rho_s}{\rho_m - \rho_w}\right) + W_d - \Delta_{SL}\left(\frac{\rho_m}{\rho_m - \rho_w}\right)$$

where Z is the water-loaded depth of the basement resulting from tectonic forces only, and S is the decompacted thickness of the sediment column.

SetUp – study area, stratigraphic units, and well data

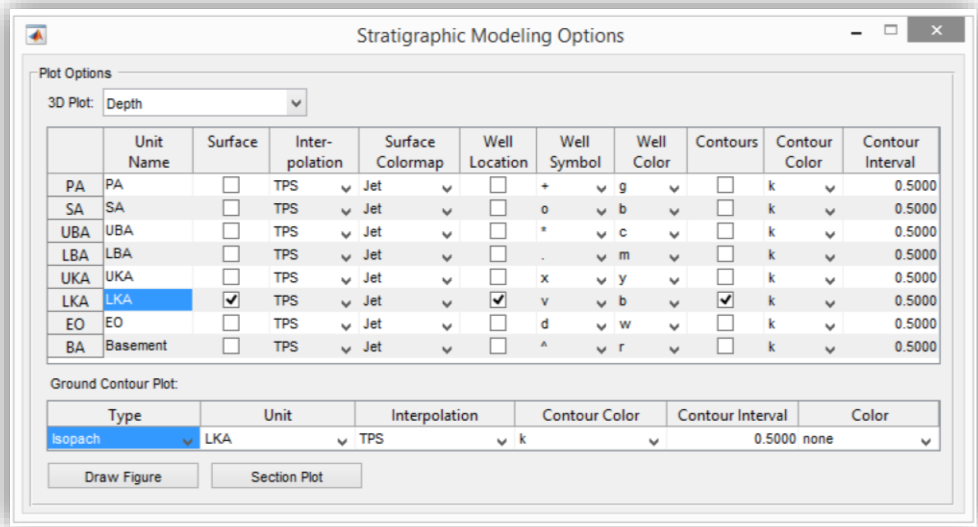


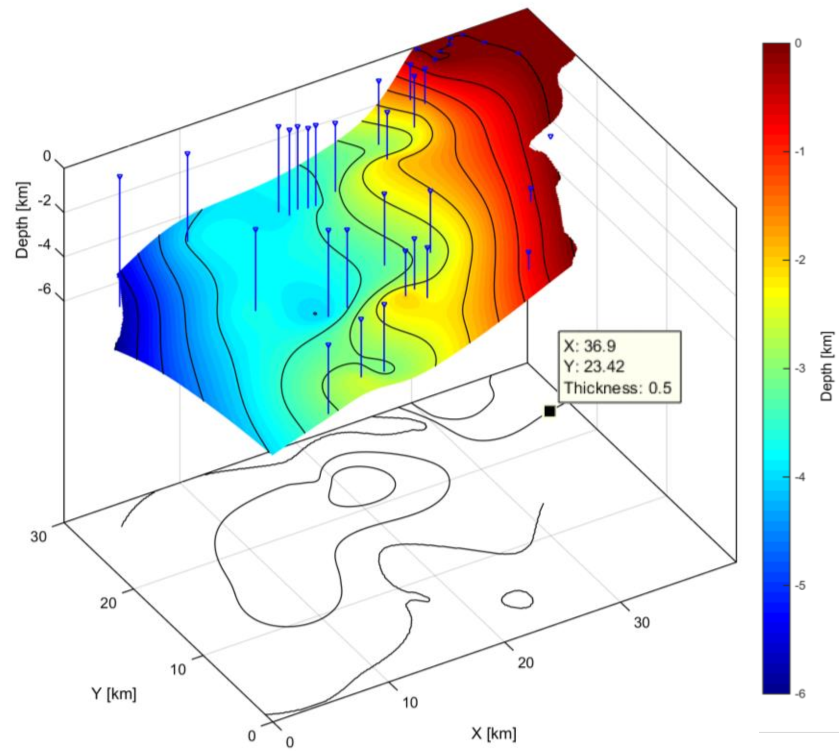
Unit Name	Start Age	End Age
PA	11.6000	7.8000
SA	12.7000	11.6000
UBA	14.2000	12.7000
LBA	16.3000	14.2000
UKA	16.9000	16.3000
LKA	17.5000	16.9000
EO	20.4000	17.5000

	Well Name	x	y	Total Depth	Top of Basement	Top of EO	Top of LKA	Top of UKA	Top of LBA	Top of UBA	Top of SA	Top of PA
39	ST 40	29.8876	27.9278	1.2800					1.2210	0.7570	0.5250	0
40	ST 41	29.8447	28.3889	1.2500					1.2460	0.7750	0.4600	0
41	ST 42	30.3246	27.6089	1.2960					1.2180	0.8750	0.5850	0
42	ST 43	29.4943	28.1977	1.2950					1.2320	0.7350	0.4400	0
43	ST 44	28.5201	28.3810	1.3500					1.2610	0.7000	0.4050	0
44	ST 45	30.0057	27.5031	1.2400					1.2070	0.8450	0.5650	0
45	ST 83	26.5608	24.0442	3.3210	3.0870	3.0110	2.1400	1.8030	1.3860	0.9000	0.5000	0
46	VY 4	13.5241	2.7927	3.0850	3.0500	3.0500	3.0500	1.9750	1.5300	1.1250	0.7630	0
47	VY 11	14.8718	3.4536	1.6000						1.0500	0.6900	0
48	VY 13	11.1365	4.9138							1.0050	0.6600	0
49	VY 14	10.2839	3.1850	1.6000						1.0100	0.6610	0
50	VY 15	10.7870	4.2139	1.6000						1.0200	0.6660	0
51	VY 17	12.3080	1.7725	1.5180						1.0200	0.7200	0
52	VY 18	14.1544	3.2266	1.6000						0.9600	0.6750	0
53	VY 19	10.3933	6.0512	2.2000	2.9000				1.6000	1.0600	0.6800	0
54	VY 20	13.2367	2.2017	1.6000						0.9950	0.7940	0
55	VY 23	11.0669	2.0114	3	2.6300	2.6300	2.6300	1.9700	1.4900	0.9600	0.6400	0
56	ZV 3	25.2568	28.1172	2				1.6100		0.8200	0.3300	0
57	ZV 6	26.8705	28.2052	1.7000				1.5200	1.3230	0.7800	0.4150	0

Figure 6. *Setup interface;*
1) Study area and stratigraphic unit input
2) Well data input.

Stratigraphic setting and Visualization

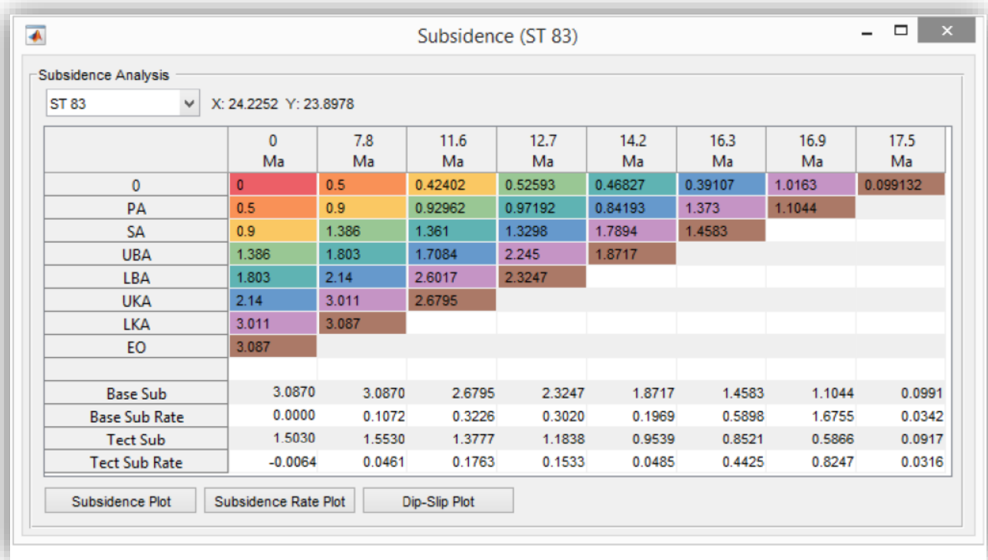




- From the available data, the stratigraphic setting of the study area can be analysed through visualizations of depth and thickness of each stratigraphic layer.
- Results can be visualized as combination of multiple plots: well locations, contours, and surfaces in 2D and 3D.

Figure 7. *Stratigraphic setting interface and visualization. An example visualization of the stratigraphic unit Lower Karpatian (c.17.5 - 16.9 Ma); 3D top-depth distribution surface model (above) and isopach map (below).*

Subsidence analysis and Visualization



	0 Ma	7.8 Ma	11.6 Ma	12.7 Ma	14.2 Ma	16.3 Ma	16.9 Ma	17.5 Ma
0	0	0.5	0.42402	0.52593	0.46827	0.39107	1.0163	0.099132
PA	0.5	0.9	0.92962	0.97192	0.84193	1.373	1.1044	
SA	0.9	1.386	1.361	1.3298	1.7894	1.4583		
UBA	1.386	1.803	1.7084	2.245	1.8717			
LBA	1.803	2.14	2.6017	2.3247				
UKA	2.14	3.011	2.6795					
LKA	3.011	3.087						
EO	3.087							
Base Sub	3.0870	3.0870	2.6795	2.3247	1.8717	1.4583	1.1044	0.0991
Base Sub Rate	0.0000	0.1072	0.3226	0.3020	0.1969	0.5898	1.6755	0.0342
Tect Sub	1.5030	1.5530	1.3777	1.1838	0.9539	0.8521	0.5866	0.0917
Tect Sub Rate	-0.0064	0.0461	0.1763	0.1533	0.0485	0.4425	0.8247	0.0316

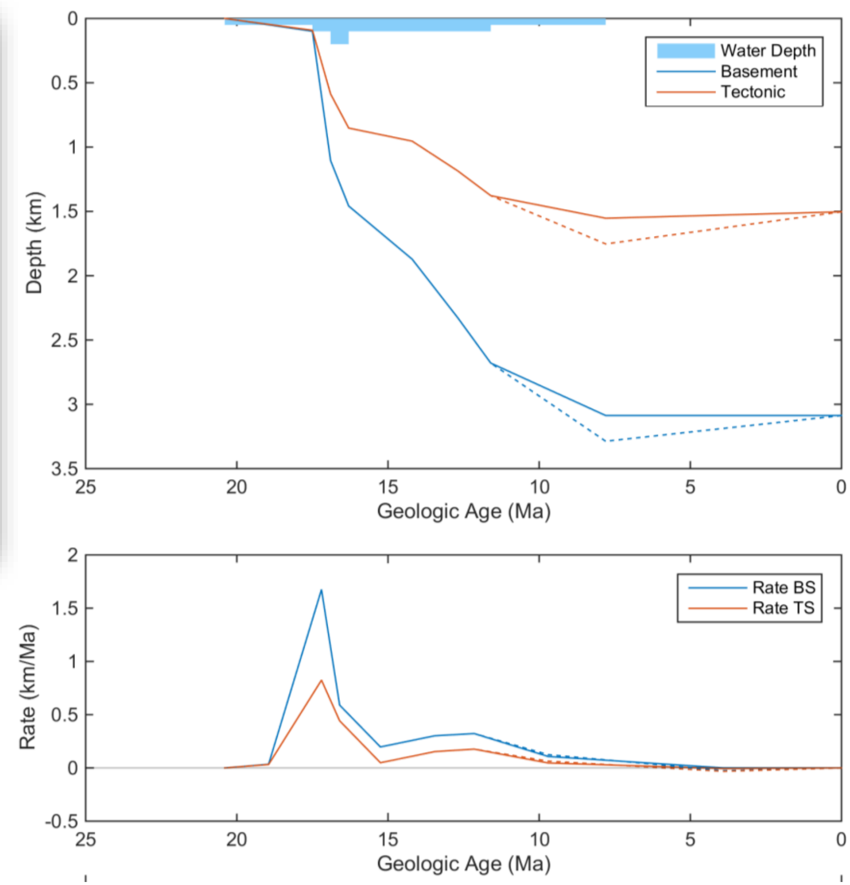


Figure 8. *Subsidence analysis.*
Numerical subsidence results and 2D graph plots for basement and tectonic subsidence depths (km) and rates (km/Ma) from the well ST 83. The dotted lines present subsidence depths and rates including eroded thickness and uplift (c. 200 m) from c. 7.8 Ma to present.

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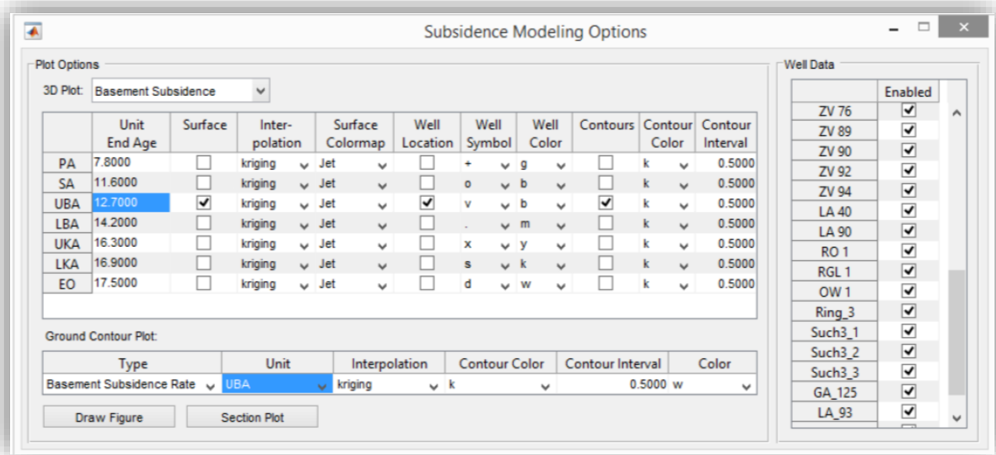
Subsidence analysis and Visualization



- Subsidence modelling is achieved by interpolating basement and tectonic subsidence data at different geologic ages. To generate surface results, we provide the same set of interpolation and plotting methods as used in the stratigraphic setting analysis.

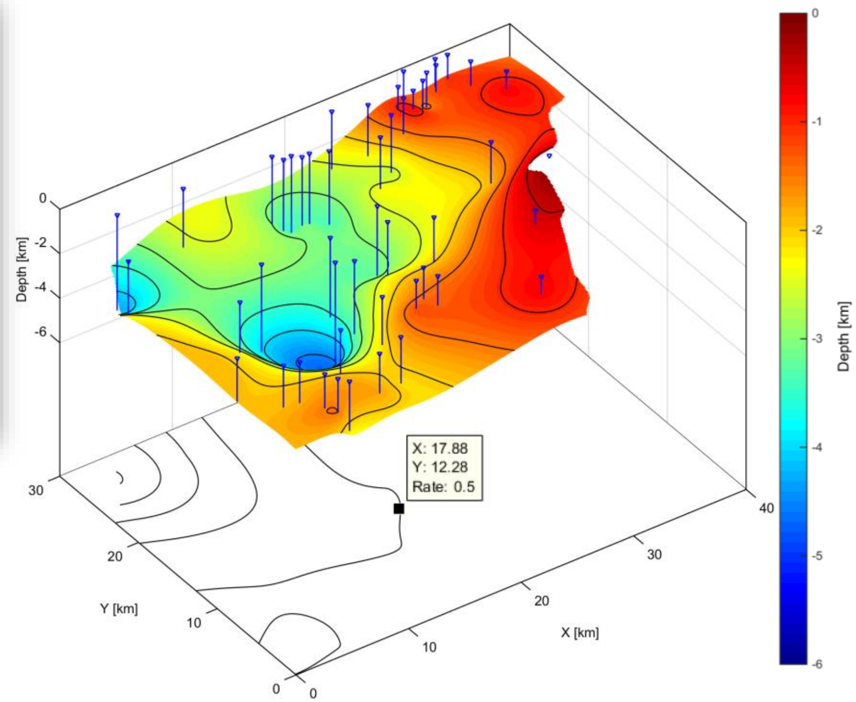


Figure 9. *Subsidence modeling interface and visualization. An example visualization for subsided basement depths (km) at 12.7 Ma (above) and basement subsidence rates (km/Ma) during 14.2 – 12.7 Ma (below).*

Cross-section and Fault backstripping

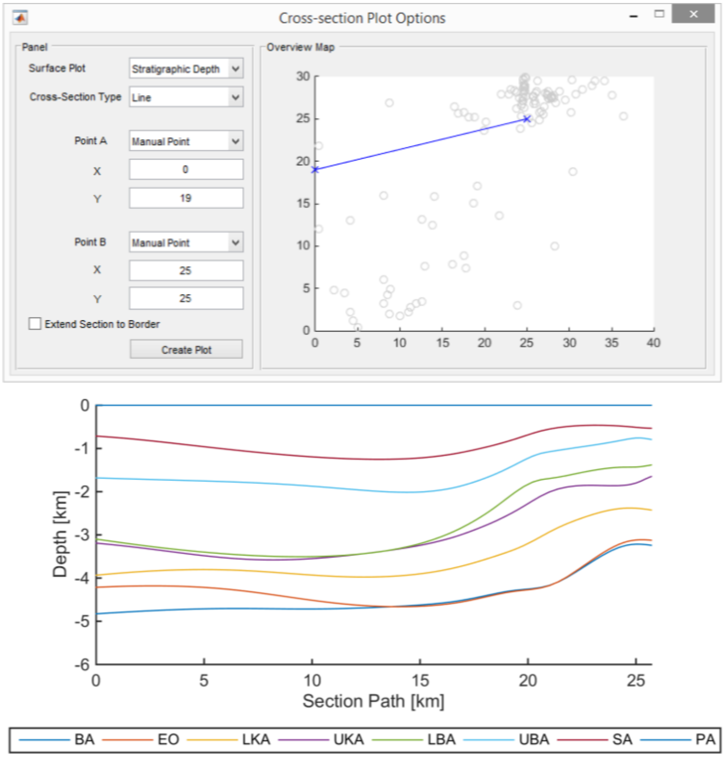


Figure 10. *Cross-section plot option with preview of the section location and generated section plot.*

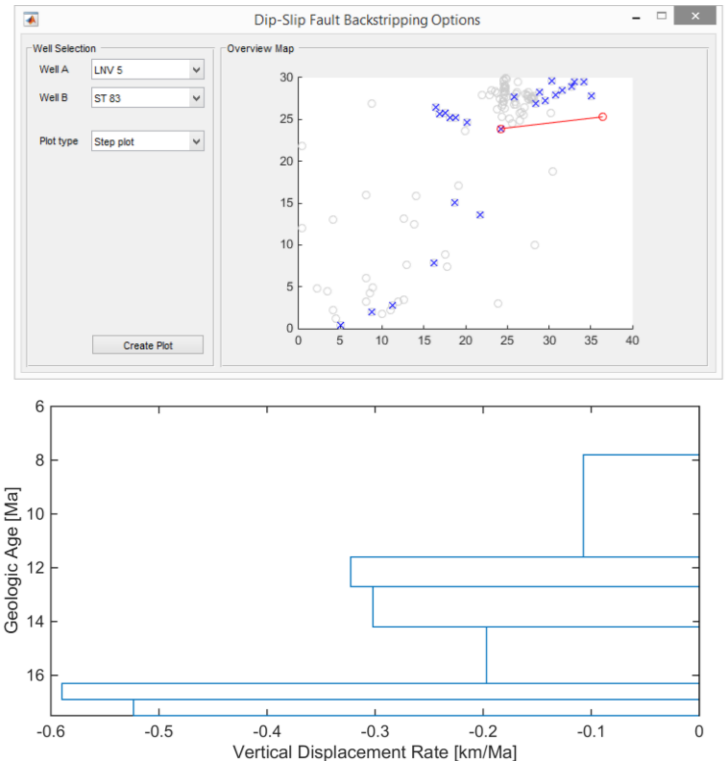


Figure 11. *Dip-slip fault backstripping between the wells LNV 5 and ST 83 for the Laksary fault.*

Discussion & Conclusions

- We compared the results of BasinVis 1.0 with previous stratigraphy, structure, and subsidence studies conducted in the central Vienna Basin (e.g. Hinsch et al., 2005; Hölzel et al., 2008b; Jiříček and Seifert, 1990; Kováč et al., 2004; Lankreijer et al., 1995; Wessely et al., 1993). Our final results match those of preceding works and in several cases provide even better model representations (e.g. Lee and Wagreich, 2016a,b, EAGE oral presentation We SRS1 11).

- One limitation of our standard surface interpolation techniques is the increased uncertainty of mapping results near or at fault structures. The provided interpolation methods currently do not completely integrate the displacement and timing of faults.

- BasinVis 1.0, a MATLAB-based program, provides geologists with a streamlined tool to analyze and visualize sedimentary fill and subsidence evolution of a sedimentary basin. The resulting visualizations are highly useful to understand overall geologic trends and characteristics of each geologic stage. As part of the workflow it grants novice users access to high-level data analysis and interpolation functions.

- The provided functionalities of BasinVis 1.0 are not limited to sedimentary basin analysis. Many research areas in the geosciences rely on the analysis and interpolation of spatial data.

Thank you for your attention!

BasinVis

http://geologist-lee.com/basinvis.html

Lee, E.Y., Novotny, J., Wagreich, M., 2016.
BasinVis 1.0, a MATLAB®-based program for sedimentary basin subsidence analysis and visualization.
Computers & Geosciences 91, 119-127.
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