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Case study

BasinVis 1.0: A MATLAB®-based program for sedimentary basin subsidence analysis and visualization

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ABSTRACT

Stratigraphic and structural mapping is important to understand the internal structure of sedimentary basins. Subsidence analysis provides significant insights for basin evolution. We designed a new software package to process and visualize stratigraphic setting and subsidence evolution of sedimentary basins from well data. BasinVis 1.0 is implemented in MATLAB®, a multi-paradigm numerical computing environment, and employs two numerical methods: interpolation and subsidence analysis. Five different interpolation methods (linear, natural, cubic spline, Kriging, and thin-plate spline) are provided in this program for surface modeling. The subsidence analysis consists of decompaction and backstripping techniques. BasinVis 1.0 incorporates five main processing steps; (1) setup (study area and stratigraphic units), (2) loading well data, (3) stratigraphic setting visualization, (4) subsidence parameter input, and (5) subsidence analysis and visualization. For in-depth analysis, our software provides cross-section and dip-slip fault backstripping tools. The graphical user interface guides users through the workflow and provides tools to analyze and export the results. Interpolation and subsidence results are cached to minimize redundant computations and improve the interactivity of the program. All 2D and 3D visualizations are created by using MATLAB plotting functions, which enables users to fine-tune the results using the full range of available plot options in MATLAB. We demonstrate all functions in a case study of Miocene sediment in the central Vienna Basin.

1. Introduction

We present BasinVis 1.0, a MATLAB-based program that allows geologists to analyze and visualize sedimentary basin in a comprehensive workflow. Our software tool is particularly aimed at 2D/3D stratigraphic and subsidence visualization of sedimentary basins with well data or stratigraphic profile (e.g. synthetic wells interpolated from time–depth conversion of stratigraphic boundaries within seismic reflection data). BasinVis 1.0 provides a set of five different interpolation techniques to visualize 3D maps: linear, natural, cubic spline, Kriging, and thin-plate spline interpolation. The program visualizes the stratigraphic setting of each input stratigraphic unit over the study area based on three dimensional depth data. The stratigraphic data can be analyzed using subsidence analysis technique, used widely in basin studies since Van Hinte (1978), resulting in graphs and 3D-models for basement subsidence, tectonic subsidence, and their respective rates. The cross-section and dip-slip fault backstripping functions of this program provide insights into the internal basin structure and vertical fault displacement. The outputs aid geologists in understanding the internal setting of a basin and provide insights into its stratigraphic and tectonic evolution.

Dedicated maps with various geoscientific information (e.g. stratigraphic subsurface, isopach, and structure) have become essential to understand the depositional and structural setting of a sedimentary basin, especially regarding hydrocarbon and ground water exploration (Allen and Allen, 2013). Furthermore, reconstruction by 2D and 3D modeling is required for the careful and precise study of basin evolution and provides significant insights for basin formation. However, processing and modeling the typically sparsely scattered geologic data with 3D techniques often requires a complex workflow of proprietary software packages. BasinVis 1.0 aims to simplify this analysis by providing an extensive set of tools within a single software package.

Several publications introduced programming and algorithms for sedimentary basin subsidence analysis (e.g. Friedinger (1988), Hölzel et al. (2008a), Jin (1994), Springer (1993) and Stam et al. (1987)). Different from the previous studies, this study choses MATLAB® as a numerical computing environment for

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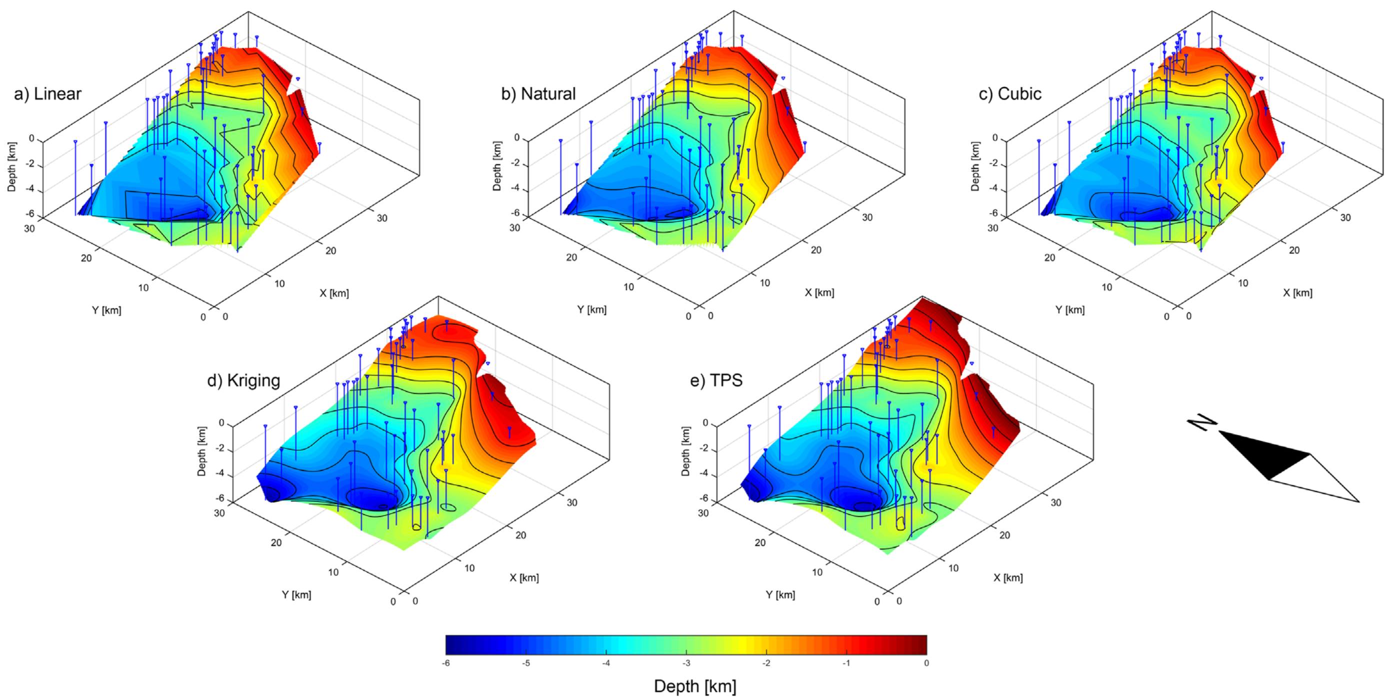
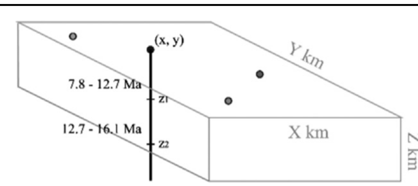


Fig. 1. Interpolation methods; a) linear, b) natural, c) cubic spline, d) Kriging, and e) thin-plate spline. The example shows the depth model of the pre-Neogene basement in our case study area.

Table 1
Required input data in BasinVis 1.0.

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	$Ø_0$	Initial porosity of porosity–depth relation (%)	From Sclater and Christie (1980)	$Ø_0$	*c*	ρ_s
Coefficient	*c*	Coefficient of porosity–depth relation ($\times 10^{-5}$)	Shale	63	0.51	2.72
Densities	ρ_s	Average density of sediment grain (g/cm^3)	Sand	49	0.27	2.65
	ρ_m	Average density of mantle (3.3 g/cm^3)	Shaly sand	56	0.39	2.68
	ρ_w	Average density of water (1.0 g/cm^3)	Chalk	70	0.71	2.71
Water-depth	W_d	Paleowaterdepth				
Sea-level	Δ_{SL}	Paleosealevel				

programming and provides 2D/3D visualization functions. MATLAB® is a software package developed by MathWorks Inc. to perform mathematical calculations, to analyze and visualize data, and to facilitate the writing of new software programs (Trauth and Sillmann, 2013). MATLAB is a powerful tool for software development and the language is relatively easy to learn. It contains a large collection of functions from different scientific and technical fields such as image and signal processing and statistics that access state-of-the-art libraries for matrix and sparse matrix computation (Schwanghart and Kuhn, 2010). During the last few years it has been extensively and widely used in academic, research, and industrial fields. In the Earth sciences, various MATLAB-based programs have been developed to process, analyze, and visualize data (e.g. Chen et al. (2013), Lanari et al. (2014), Monnet et al. (2003), Ricard and Chanu (2013), Witten (2002, 2004)). While aimed mainly at sedimentary basin analysis, BasinVis 1.0 has been designed as a modular open-source tool. This allows users with programming experience to edit and customize all provided functionalities to fit their own research area.

The following sections will introduce the functions of BasinVis 1.0 and demonstrate their application via a case study.

2. Numerical methods

2.1. Interpolation methods

This section introduces the provided interpolation methods, and details about the properties of their reconstructed surfaces. Because data are often distributed sparsely over a study area, we provide a set of five interpolation methods for irregular data points. We sample the interpolants on a tight grid covering the study area (gridded interpolation) to integrate it with MATLAB 3D surface plotting functions. Three methods – linear, natural, and cubic spline interpolation – can be classified as local approaches that optimize the resulting surface based on local neighborhoods