3D reconaissance of a Quaternary terrace system for an enhanced hydro- and engineering-geological interpretation

3D-Modellierung eines quartären Terrassensystems für verbesserte hydro- und ingenieurgeologische Interpretation

Silvia Beer[1], Gerhard Lehrberger[2], Kurosch Thuro[3]

[1] Dipl.-Geol. Silvia Beer, Technische Universität München, silvia.beer@tum.de
[2] Dr. Gerhard Lehrberger, Technische Universität München, lehrberger@tum.de
[3] Prof. Dr. Kurosch Thuro, Technische Universität München, thuro@tum.de

Zusammenfassung

Blockdiagramme und geologische Karten sind von je her Grundformen der Darstellung geologischer Strukturen. Allerdings ist immer wieder festzustellen, dass das Verständnis für geologische Strukturen im Untergrund mit diesen Mitteln oft nicht zur Gänze zu vermitteln ist. Gerade in der urbanen Geologie spielen deshalb, auf Grund der vielseitigen hydro- und ingenieurgeologischen Planungsprozesse, dreidimensionale Untergrundmodelle eine immer größere Rolle. Am Beispiel geologischen Situation von Straubing, die in den oberen Schichten von Terrassensedimenten der Donau aufgebaut wird, soll gezeigt werden, wie eine derartige Visualisierung erfolgen kann. Es wurde mit den Programmen GSI3D (BGS) und ArcGIS bzw. ArcScene gearbeitet. In GSI3D wurden 280 Profilschnitte gezeichnet, welche zu einem 3D-Modell interpoliert wurden. ArcScene wurde für die räumliche Verschneidung und Analyse von geologischem Modell und Bauplanung- und Infrastrukturdaten verwendet.

Schlüsselworte: 3D-Modell, Stadtgeologie, GIS, GSI3D

Abstract

2D-maps and block diagrams are well-established methods to show geological structures in the subsurface. As these display formats are quite static and not easy to interpret for “non-geologists”, they are no longer state of the art for hydro- and engineering geological planning processes. With focus on the requirements of public demonstration we will explore the benefits of 3D models to display a quaternary terrace system in Bavaria (Danube River).

A 3D-subsurface model for the municipal area of the town of Straubing was created based on multiple self-collected and offical data such as drilling profiles, construction pit documentations as well as research publications (SCHELLMANN 2010). GSI3D (BGS) was used for the geological “modelling” including groundwater visualisation and ArcScene 10 (ESRI) for the intersection of geological information and engineering project data based on municipal requirements. For the geological model, we constructed 280 cross sections. They were used to interpolate a volume model of the terraces. The water table has been integrated as geospatial raster dataset. As currently the volume model export is not available in GSI3D, we have chosen point and raster data formats for the transfer into ArcScene 10. In this program, we analysed e.g. the groundwater situation and geological formations in bonstructionpits or geothermal drilling projects.

3D offers new perspectives for geological mapping and analysis. We present a possible solution for enhanced engineering geological planning as demonstrated for our project area, where quaternary terrace sediments dominate the engineering geology and subsurface properties are difficult to reveal. We use new dynamic 3D-techniques combined with the efficiency of geographic information systems, which are the basis of modern e-government.

Keywords: 3D mapping, urban geology, GIS, GSI3D

1 Introduction

In today’s live 3D visualization is nearly omnipresent. 3D movies and computer games are very popular. With this increasing trend and the advancements in computer technologies it is also possible to map three-dimensional geological structures with common desktop PCs (ROYSE 2012). As geologic 2D maps are often difficult to read for non-geologists this is an important development in public relations and engineering planning. Different software packages are available which offer 3D mapping and analysis tools. An overview is given on www.3d-geology.de. Probably the most popular program is GOCAD (Paradigm). A less expensive and less complex alternative is presented by the British Geological Survey named GSI3D. In addition to specialists’ software geographic information systems also offer a multiplicity of 3D analysis tools.

On the one hand side we want to focus on this technique, as our project area – the town of Straubing – is displayed in a 2D municipal geographic information system quite well. On the other side we will show a workflow for model in GSI3D. In our case study we utilise this program to test its potential and limitations in creating 3D subsurface models for a municipal GIS.

Finally, we want to underline the benefits that result of a 3D subsurface model for municipality and engineering consultancy.

2 Project area

The town of Straubing is located in the Danube valley 140 km NE of Munich (Fig. 1). The administrative area of the town measures around 67 km^2. The most important geological structure is a Quaternary fluvial terrace system of the Danube River. Several terrace systems can be distinguished (SCHELLMANN 2010). The Pleistocene terraces are mostly covered by loess deposits. The Holocene terraces which are covered by flood sediments are located next to the present-day river channel. The Danube River follows a tectonic depression along a NW-SE trending fault. Below the Quaternary terraces Tertiary and Mesozoic sediments and crystalline rocks of the Moldanubicum have been discovered (UNGER et al. 1995).

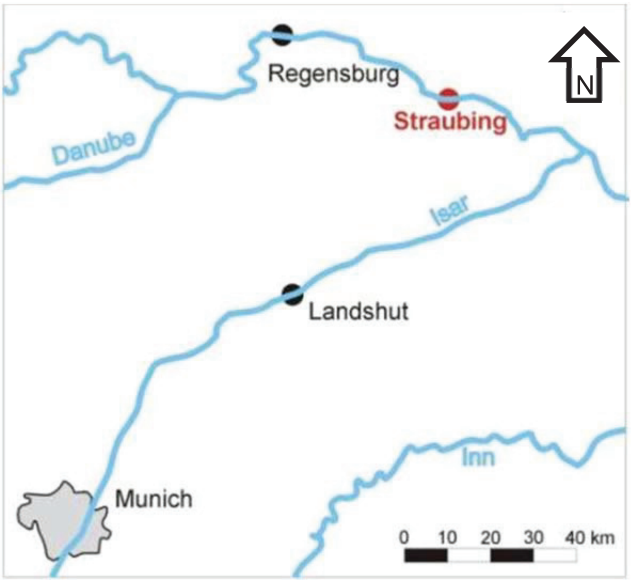

Abb. 1: Übersichtskarte des südöstlichen Bayern.

Fig. 1: Overview map of SE Bavaria.

3 Methodology

3.1 GSI3D

GSI3D is a 3D geological modelling software. The software was developed by the British Geological Survey (BGS) and the INSIGHT GmbH (www.gsi3d.org).

Based on a digital elevation model (1 m resolution), drilling profiles and construction pit documentations and research publications 280 cross sections were drawn (Fig. 2) and groundwater tables were included. The software uses a Delauny Triangulation between cross section nodes to interpolate a 3D volume model.

Abb. 2: Beispiel-Screenshot eines Profilschnitts einer Terrassenkante in GSI3D. Profil durch eine Terrassenkante mit pleistozänen Terrassen (blau, orange), sowie einer Auflage aus polygenetischer Talfüllung (grau) und Löss (beige). Links ist eine ins Profil projezierte Bohrung zu sehen.

Fig. 2: Screenshot of a cross section example of a terrace edge in GSI3D. The figure shows Pleistocene Terraces (blue, orange), as well as a coating of loess and polygenetic valley-filling. On the left side a projected drilling profile was included.

In order to transfer the model into a geoinformation system and for visualization purposes a variety of files were exported.

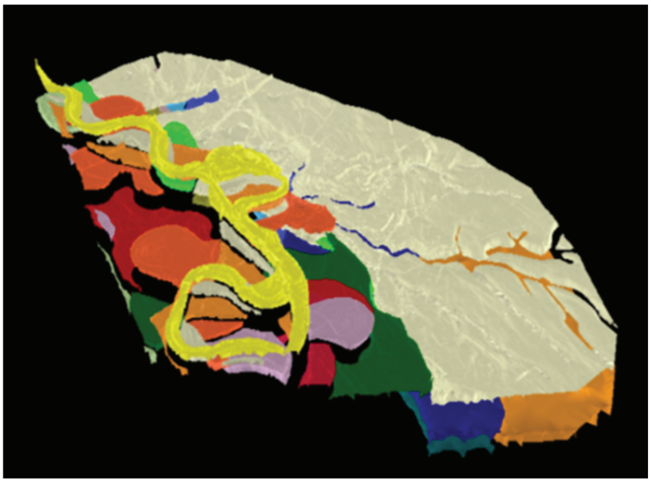

Abb. 3: 3D-Modell der separaten quartären Terrassen in Straubing (GSI3D).

Fig. 3: Exploded 3D model of the Quaternary terraces in Straubing (GSI3D).

At the moment, it is not possible to export 3D volumes. Therefore we created movies (Fig. 3), which can be used educational as well as 3D pdf-files. For further processing in GIS we exported ASCII-point data and raster files.

3.2 GIS

During our case study we used ArcGIS 10 (ESRI) – and especially ArcScene which offers various 3D drawing and analysis tools. In order to create a 3D data structure, we first built up a geodatabase, where all features including the 3D objects can be organized. We converted raster and point data into ArcGIS file formats. The next step was to calculate TINs (triangulated irregular network) from the raster datasets.

After polygon feature classes of all Quaternary terraces and separately all particular terrace edges were added the TINs were used to generate geospatial 3D volumes (Fig. 4) with the "Extrude between"- tool which expects two TINs – a top side (mostly DEM) und bottom side TIN of the terrace and a terrace feature class to define the calculated x/y-extension. For terrace edges the top side is formed by the bottom side of the next younger terrace.

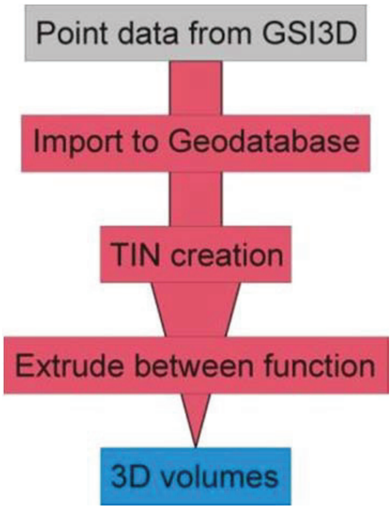

Abb. 4: Flussdiagramm zur Erzeugung von 3D Volumen in ArcGIS.

Fig. 4: Flowsheet of the 3D volume generation in ArcGIS.

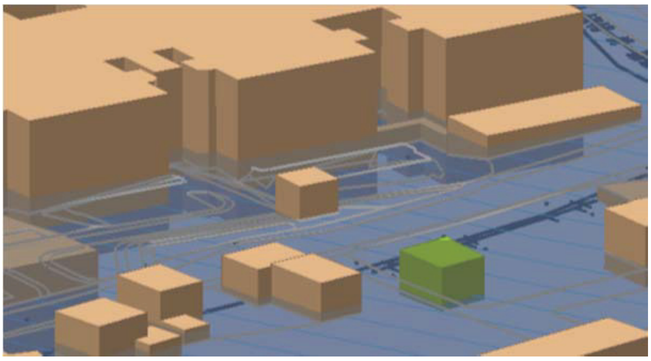

Abb. 5: Fiktive im unteren Teil von Grundwasser beeinflusste Baugrube (grün) mit Grundwasserspiegel (blau), Kellern (dunkelbraun), Kanalsystem (schwarz) und Flurstücksgrenzen (grau).

Fig. 5: Virtual construction pit (green) with groundwater table (blue), cellars (dark brown) and sewerage (black).

To analyse the subsurface situation we developed an application in ArcScene where we included the geological model, the groundwater tables, buildings (LoD1), cellar systems and the sewerage.

As an example we constructed a virtual construction pit (Fig. 5) in order to analyse the utilization of the model for construction planning. We also focused on the manageability of the whole model. The visualisation of this multiplicity of data as well as the analysis tools can help to identify potential hazards for projects at an early stage.

4 Discussion and Conclusion

Today 3D geological mapping is state of the art. We portrayed a workflow for a geological 3D model created with GSI3D which displays geologist's know-how and give reliable results. The transformation into a geospatial dataset was shown as well as the integration into a 3D GIS with the key aspects municipal hydrogeology and engineering aspects.

Even if GSI3D is not available in a municipality a 3D model can be extracted with GIS, which is actually a standard tool in urban administration. Point data are exported out of the original GSI3D project and new data e. g. drilling data can be integrated quite fast into GIS.

The benefit for municipalities as well as engineering of-fices is a broader awareness of the geological settings in a town, in our case with special focus on the groundwater situation. Utilization of GIS provides to be a fast import of municipal data which assures an early analysis of potential hazards e.g. in construction or groundwater protection.

Literature

Royse, K. (2012): 3D modelling and GIS technologies in understanding and predicting anomalous ground conditions in London. – Schriftenreihe der deutschen Gesellschaft für Geowissenschaften **80**: 287.

Schellmann, G. (2010): Zur Verbreitung, geologischen Lagerung und Altersstellung der Donauterrassen auf Blatt L7141 Straubing. – In: Bamberger physisch-geographische Studien 2002 – 2007/2: Studien zur quartären Talgeschichte von Donau und Lech, **24**: 89-178.

Unger, H. J., Risch, H. & Meyer, R. K. (1995): Die Thermalwasserbohrung Straubing Th 2. – Geologica Bava-rica, **99**: 415-431.