利用空載地球物理探勘和鑽井資料
建立基於轉移機率的隨機水文地質模型

He, X., J. Koch, T. O. Sonnenborg, F. Jorgensen, C. Schamper, and J. Christian Rofsgaard, 2014. Transition probability-based stochastic geological modeling using airborne geophysical data and borehole data, *Water Resources Research*, **50**, 3147-3169.

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報告日期：2022/01/06

摘要

建立水文地質模型時異質性（Heterogeneity）是一個非常重要的考慮因素。基於地質統計之隨機地質場模擬能用來展現異質性。然而，地質統計方法和觀測資料皆包含了各種類型的不確定性。本研究使用地質統計建模工具 TProGS 來模擬丹麥境內某源頭集水區域冰川沉積物的結構異質性，並將觀測資料的不確定性納入模擬過程。研究中使用兩種類型的觀測資料：鑽井和空載地球物理探勘（AEM）。鑽井資料在水平方向上的密度通常較為稀疏而無法表現出該方向上之異質性；而高解析度之 AEM 資料能使地質統計特性在水平方向上呈現的更為準確。

本研究應用直方圖機率匹配（ histogram probability matching ）方法以得到 AEM 資料轉換地質材料的經驗公式，同時考慮資料之不確定性，使用轉換後的資料能得到轉移機率（Transition probability）並用來建立馬可夫鏈模型。本研究提供了有關使用綜合資料的優勢和挑戰，模擬結果顯示空間結構上的顯著差異取決於用於模型的資料，當使用鑽井資料時，空間統計將符合現實，而使用 AEM 數據時，則傾向於遵循特定條件。當鑽井資料不足時，地球物理探勘資料的使用能為模型帶來很大的改進。

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE
10.1002/2013WR014593

Special Section:
Patterns in Soil-Vegetation-Atmosphere Systems: Monitoring, Modelling and Data Assimilation

Transition probability-based stochastic geological modeling using airborne geophysical data and borehole data

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Key Points:
- The relation between resistivity data and geological units is largely uncertain
- AEM data show advantage for transition probability in the horizontal direction
- The selection of conditioning method is critical for geostatistical simulations

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Citation:
He, X., J. Koch, T. O. Sonnenborg, F. Jørgensen, C. Schamper, and J. Christian Refsgaard (2014), Transition probability-based stochastic geological modeling using airborne geophysical data and borehole data, *Water Resour. Res.*, *50*, 3147–3169, doi:10.1002/2013WR014593.

Received 16 AUG 2013
Accepted 19 MAR 2014
Accepted article online 25 MAR 2014
Published online 10 APR 2014

Abstract Geological heterogeneity is a very important factor to consider when developing geological models for hydrological purposes. Using statistically based stochastic geological simulations, the spatial heterogeneity in such models can be accounted for. However, various types of uncertainties are associated with both the geostatistical method and the observation data. In the present study, TProGS is used as the geostatistical modeling tool to simulate structural heterogeneity for glacial deposits in a head water catchment in Denmark. The focus is on how the observation data uncertainty can be incorporated in the stochastic simulation process. The study uses two types of observation data: borehole data and airborne geophysical data. It is commonly acknowledged that the density of the borehole data is usually too sparse to characterize the horizontal heterogeneity. The use of geophysical data gives an unprecedented opportunity to obtain high-resolution information and thus to identify geostatistical properties more accurately especially in the horizontal direction. However, since such data are not a direct measurement of the lithology, larger uncertainty of point estimates can be expected as compared to the use of borehole data. We have proposed a histogram probability matching method in order to link the information on resistivity to hydrofacies, while considering the data uncertainty at the same time. Transition probabilities and Markov Chain models are established using the transformed geophysical data. It is shown that such transformation is in fact practical; however, the cutoff value for dividing the resistivity data into facies is difficult to determine. The simulated geological realizations indicate significant differences of spatial structure depending on the type of conditioning data selected. It is to our knowledge the first time that grid-to-grid airborne geophysical data including the data uncertainty are used in conditional geostatistical simulations in TProGS. Therefore, it provides valuable insights regarding the advantages and challenges of using such comprehensive data.