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Seismic Velocity Uncertainties and their Effect on Geothermal Predictions: A Case Study

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Abstract

Geothermal exploration relies in large parts on subsurface models derived from seismic reflection profiling. Based on a case study of the Larderello area we discuss the influence of seismic velocity uncertainties in geothermal prospecting and highlight the role of unrecognized seismic anisotropy. For the field study we investigated the anisotropy of typical rock samples under simulated in-situ HP/HT conditions. It turns out that the target horizons may be found up to 300 m shallower and 200 m horizontally displaced compared to the isotropic case due to anisotropic bias. Correspondingly, the uncertainty of temperature extrapolation may increase from 10 to 20%.

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Keywords: Geothermal prospecting; seismic velocity; seismic anisotropy; uncertainty estimate

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1. Introduction

Geothermal exploration relies in large parts on geophysical subsurface models derived from seismic reflection profiling (Fig.1). These models are the framework of hydrogeothermal modeling, which further requires estimating thermal and hydraulic parameters to be attributed to the seismic strata. All petrophysical and structural properties involved in this process can be determined only with limited accuracy and thus impose uncertainties onto the resulting model predictions of temperature-depth profiles.

In the present paper we analyze sources and effects of uncertainties of the seismic velocity field, which translate directly into location uncertainties of the geothermal targets and the related estimated temperature-depth function.

We demonstrate these effects using data of the European Union Horizon 2020 project DESCRAMBLE investigating a geothermal reservoir in the Larderello area (Fig.1). The target is the seismic K-horizon, a structure of regional extent [1][2], where supercritical conditions are supposed to be possible (~450°C temperature) [3]. Depth and structural appearance of the K-horizon are laterally variable, and the location accuracy of seismic imaging obviously depends on the accuracy of the underlying seismic velocity model. Therefore, drilling security and economical reasons require careful uncertainty analysis of the seismic velocity field and the propagation of velocity uncertainties into structural and temperature uncertainties.

In this article we first discuss causes of uncertainties of the seismic velocity field and focus, second, on the influence of unrecognized seismic anisotropy. Third, we show the propagation of these uncertainties into the estimated location and temperature of the target horizon for the example location.

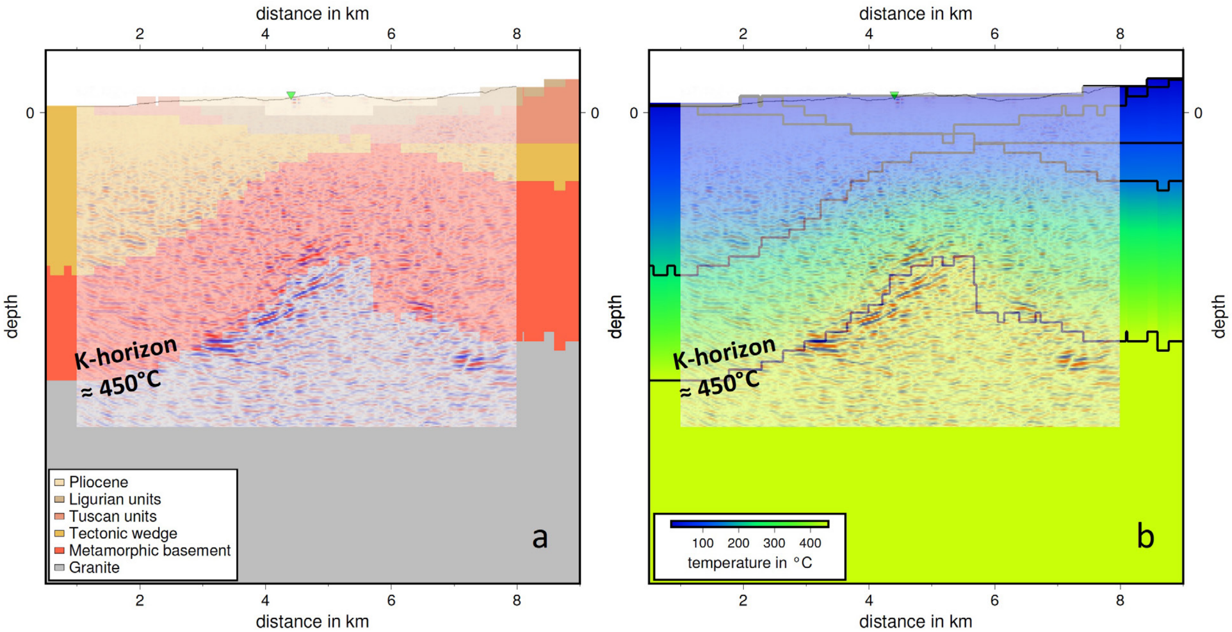

Fig. 1. (a) Cutout of 3D geological model based on geological mapping, 2D & 3D seismic (overlain) and boreholes [4]; (b) Modeled temperature distribution based on (a) [5][6]. The geothermal example target is the "K-horizon" identified with the 450°C isotherm.

2. Seismic velocity uncertainties

The determination of seismic velocity fields is generally based on analyzing the travel times of P-waves reflected from a set of key horizons. The information on velocity is basically in the move-out of reflection hyperbolae, meaning in the increase of travel time with increasing source-receiver distance. Independently of the details of the applied analysis method two groups of sources of velocity uncertainties can be identified: