Community Comment (CC1):

General comments:

Very good and novel research in the area of deep hydrogeology with a variety of applications in the geo-energy sector. However, some detail is missing. Please, consider the following minor comments to improve the manuscript before publication.

Response:

We sincerely thank the community member for the encouraging and constructive feedback. We appreciate the recognition of the novelty and significance of our research in deep hydrogeology and its relevance to geo-energy applications.

We agree that the manuscript can benefit from additional detail, and we have carefully addressed all the minor comments and suggestions to enhance the clarity and completeness of the work. We believe the revised version better reflects the scope and contributions of our study.

As per the journal's submission guidelines, we are first submitting our detailed responses to the reviewer's comments. Following this, we will submit the revised manuscript reflecting all the suggested changes.

Specific comments:

Comment 1:

Lines 69-72. "Consideration of hydraulic properties is crucial in groundwater evaluations. Permeability is the most popular aquifer measure and is mainly used to assess the water-holding capacity of rocks all over the world". Insert these papers where there is discussion on the role of geophysical and hydrogeological methods to detect the hydraulic properties of fractured rocks to inform flow models in granites, metamorphic and sandstone lithologies.

- Medici, G., Ling, F., Shang, J. 2023. Review of discrete fracture network characterization for geothermal energy extraction. Frontiers in Earth Science 11, 1328397.

- McKeown, C., Haszeldine, R.S., Couples, G.D. 1999. Mathematical modelling of groundwater flow at Sellafield, UK. Engineering Geology 52(3-4), 231-250.

Response 1:

The following revision was made to improve clarity and integrate the suggested references:

"Consideration of hydraulic properties is crucial in groundwater evaluations. Permeability is one of the most widely used aquifer parameters for assessing the water-holding and transmitting capacity of rocks across the globe. In fractured rock environments, such as granites, metamorphic, and sandstone formations, fluid flow is primarily governed by the geometry and connectivity of fractures rather than the rock matrix itself. Therefore, accurately characterizing hydraulic properties in these settings requires integrated approaches. Recent studies emphasize the role of combining geophysical and hydrogeological methods to detect and model these hydraulic properties effectively (McKeown et al., 1999; Medici et al., 2023). These approaches are essential for improving the reliability of flow models and for guiding groundwater management and geo-energy extraction strategies in complex geological settings."

Comment 2:

Lines 146-152. Lots of multiple objectives (5). Please, clarify the general aim of your hydrogeological research.

Response 2:

ORIGINAL:

“The primary goals of this study were as follows: (1) to rapidly predict two- and three dimensional k models using geophysical methods; (2) to reliably assess the hydrogeological properties of rock formations for deep groundwater assessments in challenging geological settings; (3) to minimize costly boreholes and maximize the use of scarce drilling resources to collect hydrogeological data over large areas; (4) to decrease uncertainties in hydrogeological models; and (5) to promote the use of non-invasive geophysical techniques for hard rock groundwater investigations instead of costly drilling that can damage the rock.”

REVISED:

"The primary aim of this study is to develop and implement a geophysical-based approach for accurately predicting the spatial distribution of permeability (k) in deep, hard rock environments. By integrating CSAMT data with strategically selected borehole measurements, this research enhances the two and three dimensional assessment of hydrogeological properties across various rock types in geologically complex settings, reduces reliance on extensive and costly drilling, and promotes the use of non-invasive geophysical techniques for deep groundwater exploration."

Comment 3:

Lines 173-181. The geometrical relation between the different lithologies is unclear.

Response 3:

ORIGINAL:

"Intruding rocks from the Indosinian, Caledonian, and Yanshanian eras are among the many geological formations and periods represented in the study region. Other layers from the Paleogene period are also present. The most common types of rock that have been discovered are sandstone, granite, and hornstone. The complex Kaiping concave fault and fold systems were the dominant geological features in the project region, which were developed as a result of magmatic processes and various structures (Qin, 2017). Emergence of joint fissured features symbolizes the various tectono-geological periods, with the local tectonic line corresponding with the faults strike, especially in the northeast orientation (Yang et al., 2021)".

REVISED:

"The study area exhibits a complex and diverse geological history, characterized by well-defined geometrical relationships among various lithologies. These formations and structural features are the result of multiple tectono-magmatic events spanning several geological periods. Intrusive rocks from the Indosinian (Late Triassic), Caledonian (Silurian–Devonian), and Yanshanian (Jurassic–Cretaceous) orogenies are well-represented, indicating a long sequence of crustal deformation and magmatic activity. These intrusions are primarily composed of granitic bodies, which suggest deep-seated magmatic processes associated with continental collision and subduction zones. In addition to these intrusive phases, sedimentary strata from the Paleogene period are also present, reflecting a later stage of basin development with fluvial and lacustrine depositional environments. Among the most prevalent rock types encountered in the region are sandstone, granite, and hornstone. Sandstone reflects high-energy sedimentary deposition. Granite indicates deep magmatic intrusions likely associated with Yanshanian tectonics. Hornstone (hornfels) results from contact metamorphism caused by magma intruding sedimentary rocks. The structural framework of the region is dominated by the Kaiping concave fault and fold system, a geologically significant and highly deformed zone that reflects multiple deformation episodes (Qin, 2017). These structures were primarily shaped by magmatic intrusions, crustal movements, and regional stress regimes. The presence of extensive jointed and fissured zones throughout the rock mass further supports a history of dynamic tectonic activity. These joints often serve as secondary permeability pathways and are critical in controlling groundwater flow in the fractured rock environment. Importantly, the orientation of these structural features, including faults and joints, is often aligned with northeast-trending tectonic lines, which are consistent with broader regional stress directions (Yang et al., 2021). This relationship among lithologies and structural features plays a critical role in controlling groundwater flow and permeability distribution."

Comment 4:

Lines 173-181. The detail is not enough on presence of faults. Which type of faults?

Response 4

More details on the presence of faults:

"The structural analysis of the study area reveals a combination of fault types influenced by multiple tectonic phases. The presence of fold systems indicates compressional tectonics, primarily associated with reverse and thrust faults, likely developed during orogenic events such as the Caledonian and Indosinian periods. Additionally, the dominant northeast-oriented fault strikes, which align with broader regional tectonic trends, suggest a strong component of strike-slip movement. These strike-slip faults are typically linked to late-stage tectonic adjustments, particularly during the Yanshanian orogenic phase, and often coexist with complex fault-fold geometries, further complicating the subsurface structure."

Comment 5:

Lines 173-181. Nature of the joints? I am talking about the tectonic genesis.

Response 5:

Explained as:

"The joint fissure systems observed within the sandstone, granite, and hornstone units are predominantly of tectonic origin, representing brittle deformation features formed in response to regional stress regimes associated with multiple orogenic and magmatic events. These joints reflect the structural imprint of successive tectonic episodes, particularly the Caledonian, Indosinian, and Yanshanian orogenies. Systematic joint orientations, especially those aligned with the dominant northeast-trending fault systems, indicate their genetic link to regional tectonic stress fields. The geometry, spacing, and persistence of these joints vary with lithology and are closely tied to the complex tectonic evolution and structural framework governed by the Kaiping fold-and-fault system."

Comment 6:

Line 538. I prefer "Discussion". You have a unique discussion on a scientific paper where you face different topics. This point also depends on the guidelines.

Response 6:

Thank you for your valuable suggestion. We agree that "Discussion" is a more appropriate and conventional title for this section, as it aligns with standard scientific writing practices for presenting and interpreting key findings. Accordingly, we have changed the section title from "Discussions" to "Discussion" in compliance with the journal's formatting guidelines. Furthermore, the entire Discussion section has been thoroughly revised and enhanced based on the suggestions provided by both the reviewers and the community, with the aim of improving clarity, depth, and overall scientific value.

Comment 7:

Lines 600-837. Insert the relevant literature suggested above on the hydraulic properties of deep aquifers in a variety of sites worldwide.

Response 7:

The relevant literature suggested above has been incorporated into the revised *References* section of the manuscript.

Comment 8:

Figure 1. Letters are too small in both the figures. Please, make the figure larger.

Response 8:

Fig. 1 has been improved. Please see the revised figures at the end of the response/comments section in the attached file.

Comment 9:

Figure 1. Pay lot of attention of figure 1b. This is a conceptual model and you can get citations from the figure. Make the figure larger and increase the font of the words.

Response 9

Fig. 1b has been improved accordingly. Please see the revised figures at the end of the response/comments section in the attached file.

Comment 10:

Figure 2. There is room to make the figure larger.

Response 10:

Fig 2 has been enlarged. Please see the revised figures at the end of the response/comments section in the attached file.

Comment 11:

Figure 4. Check the depth of the boreholes.

Response 11:

The depth of boreholes in the updated Fig. 5-7 has been corrected. Please see the revised figures at the end of the response/comments section in the attached file.

Comment 12:

Figure 9. The words are too small. The figure is difficult to read. Please, improve it.

Response 12:

The updated Fig.12 has been improved. Please see the revised figures at the end of the response/comments section in the attached file.

Revised Figures

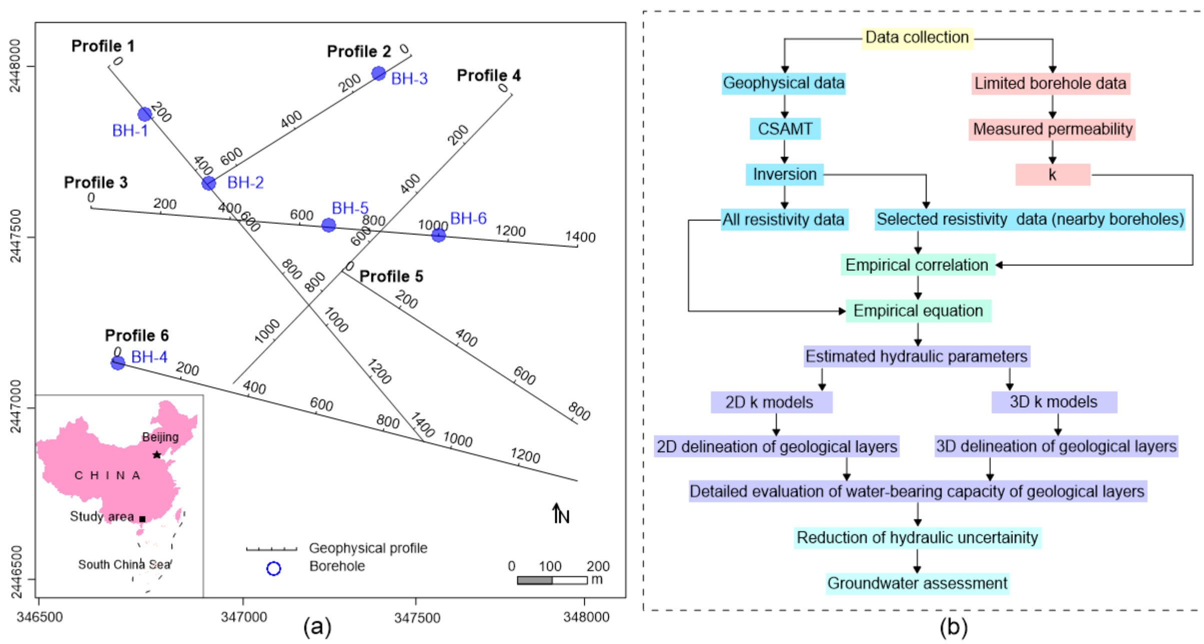

Fig. 1. (a) The location of the project site, with six boreholes BH1–BH6 (blue circles) and six CSAMT profiles 1-6 (black lines), (b) Flow diagram outlining the planned method for getting 2D and 3D k models for better, more thorough assessments of groundwater resources over large regions

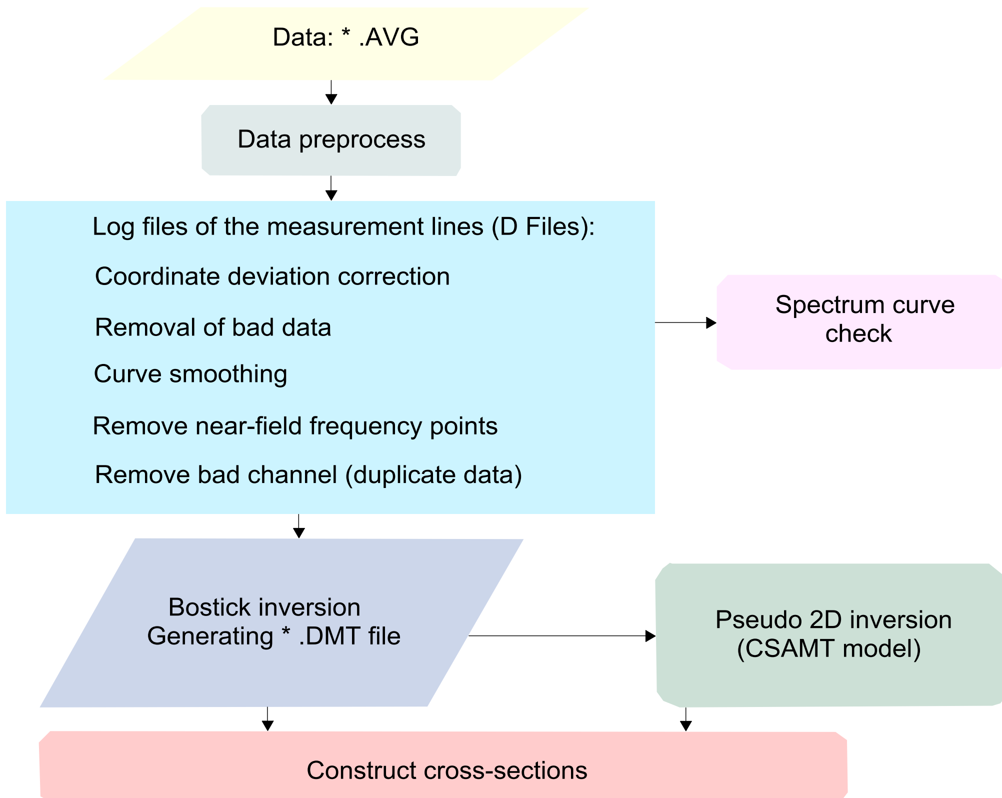

Fig. 2. Displaying the procedure of 2D inversion of CSAMT data by the use of Bostick inversion

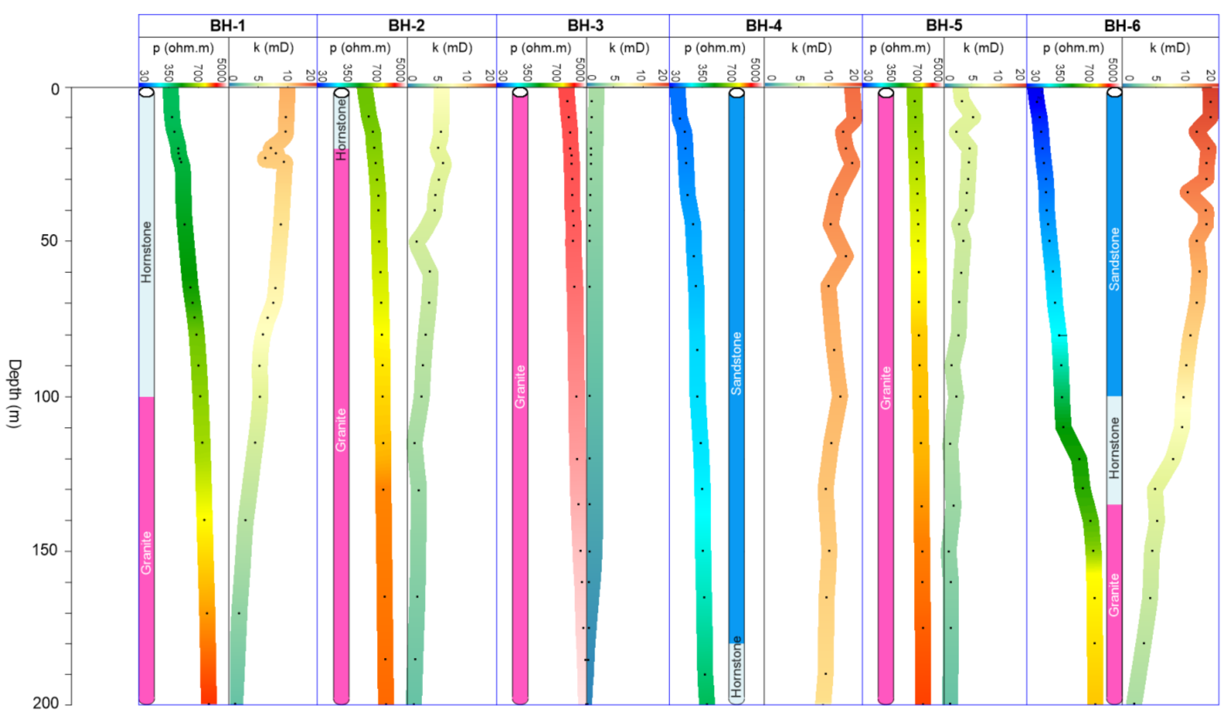

Fig 3. The evaluation of hornstone (HS), sandstone (SS), and granite (G) carried out by presenting 116 resistivity-k data points at depths ranging from 5 to 200 m using 6 drilled tests (BH1–BH6) and associated resistivity (ρ) from CSAMT soundings. The small black dots show the data points

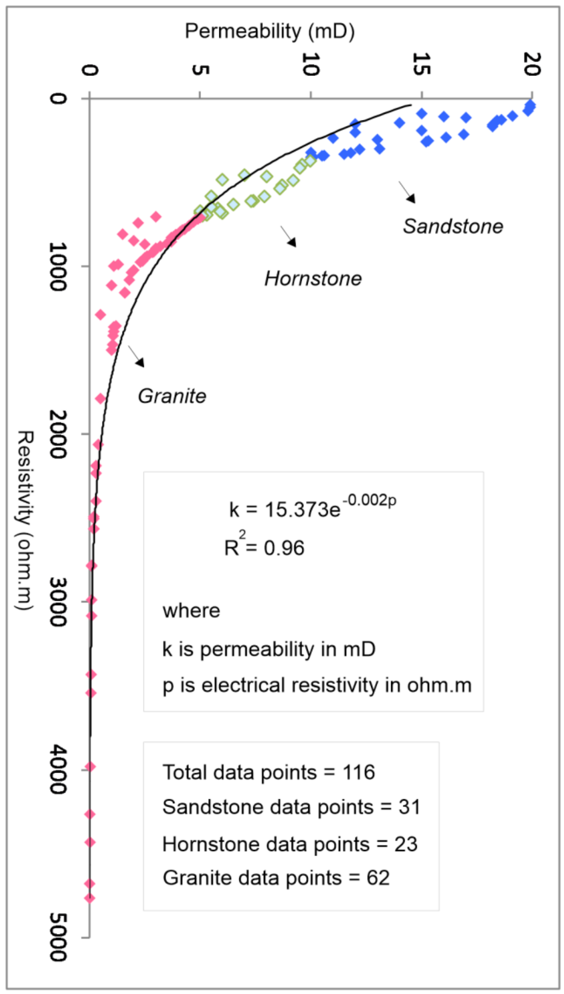

Fig 4. Using a total of 116 data points, the geophysical-borehole correlation for the predicted k

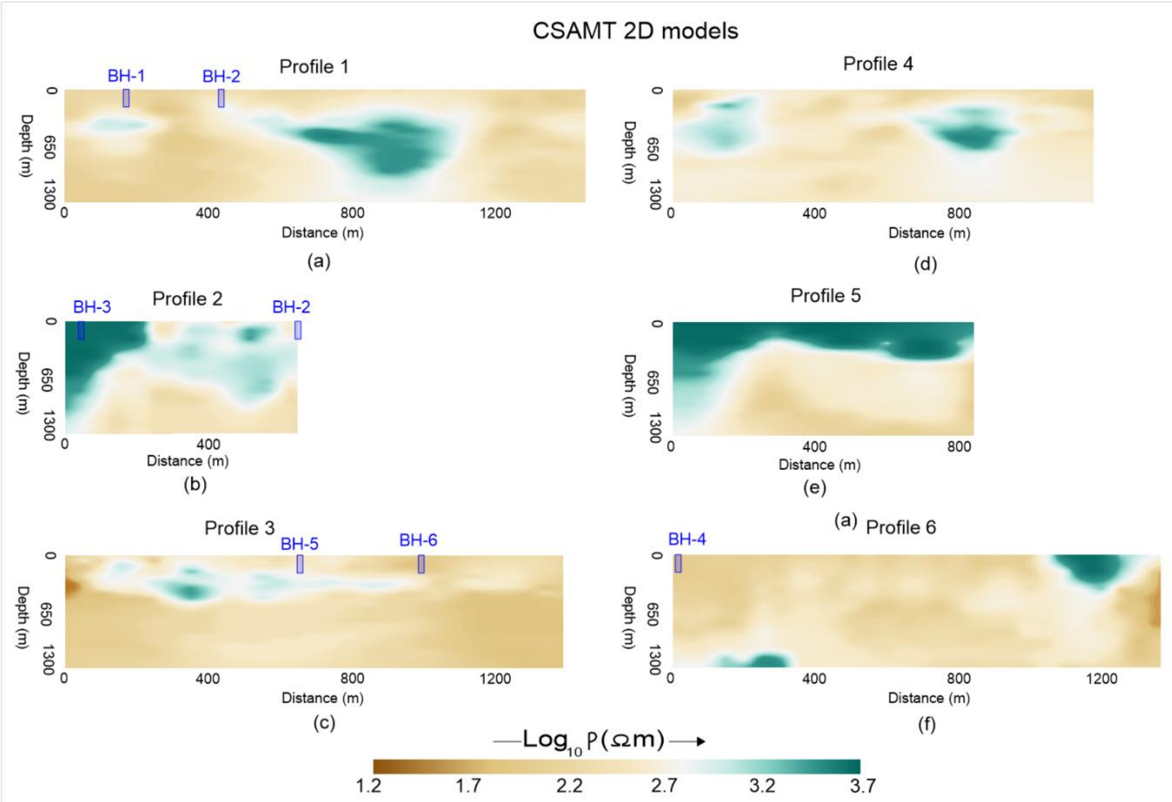

Fig. 5 2D CSAMT models along six geophysical profiles 1-6. Where resistivity increases from brown to green on a color bar.

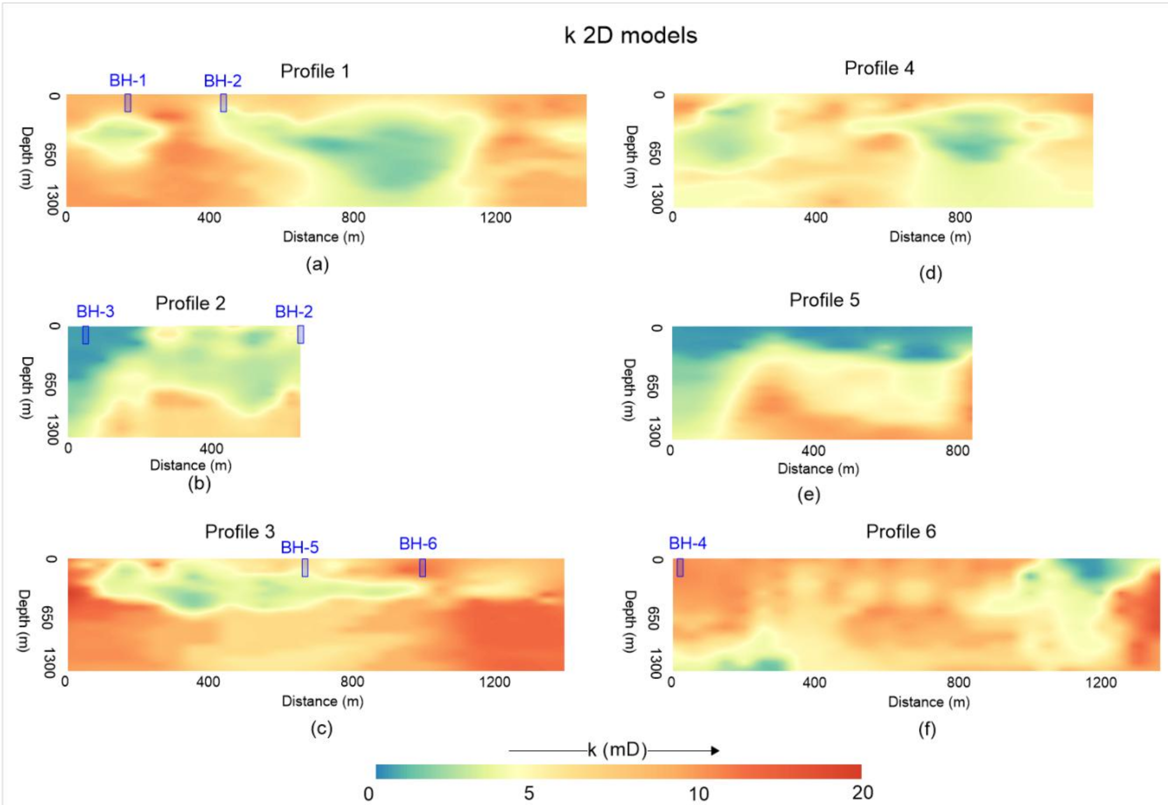

Fig. 6 The predicted 2D k models obtained from CSAMT data along six geophysical profiles 1-6. Where k increases from light green to red on a color scale

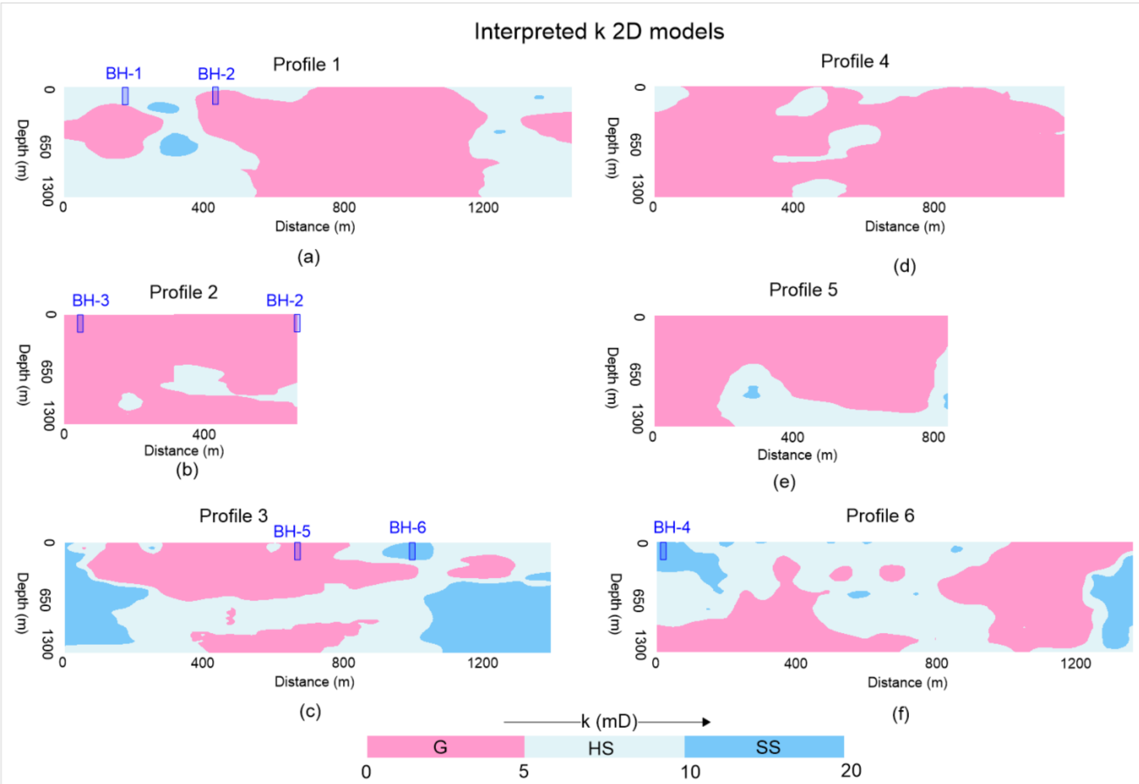

Fig.7 The interpreted (hydrogeological) 2D models along six geophysical profiles 1–6 obtained via geophysical-borehole correlation, facilitates groundwater assessment through high potential aquifer (HPA), medium potential aquifer (MPA), and low potential aquifer (LPA) associated with sandstone (SS), hornstone (HS), and granite (G), respectively

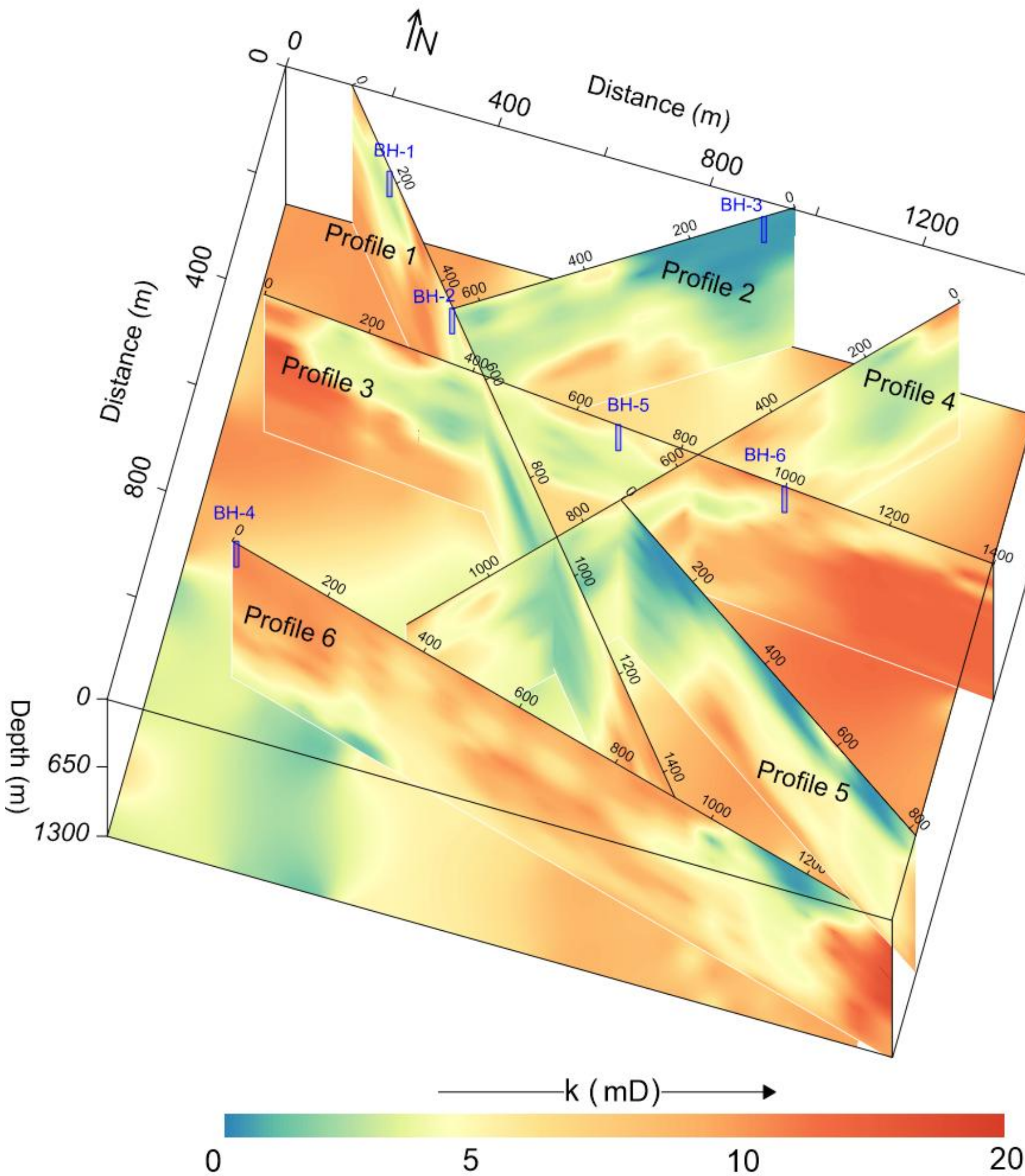

Fig. 8 The integrated 2D k models derived from the incorporation of geophysical and drilling data, with k represented on a color bar spanning from green to red

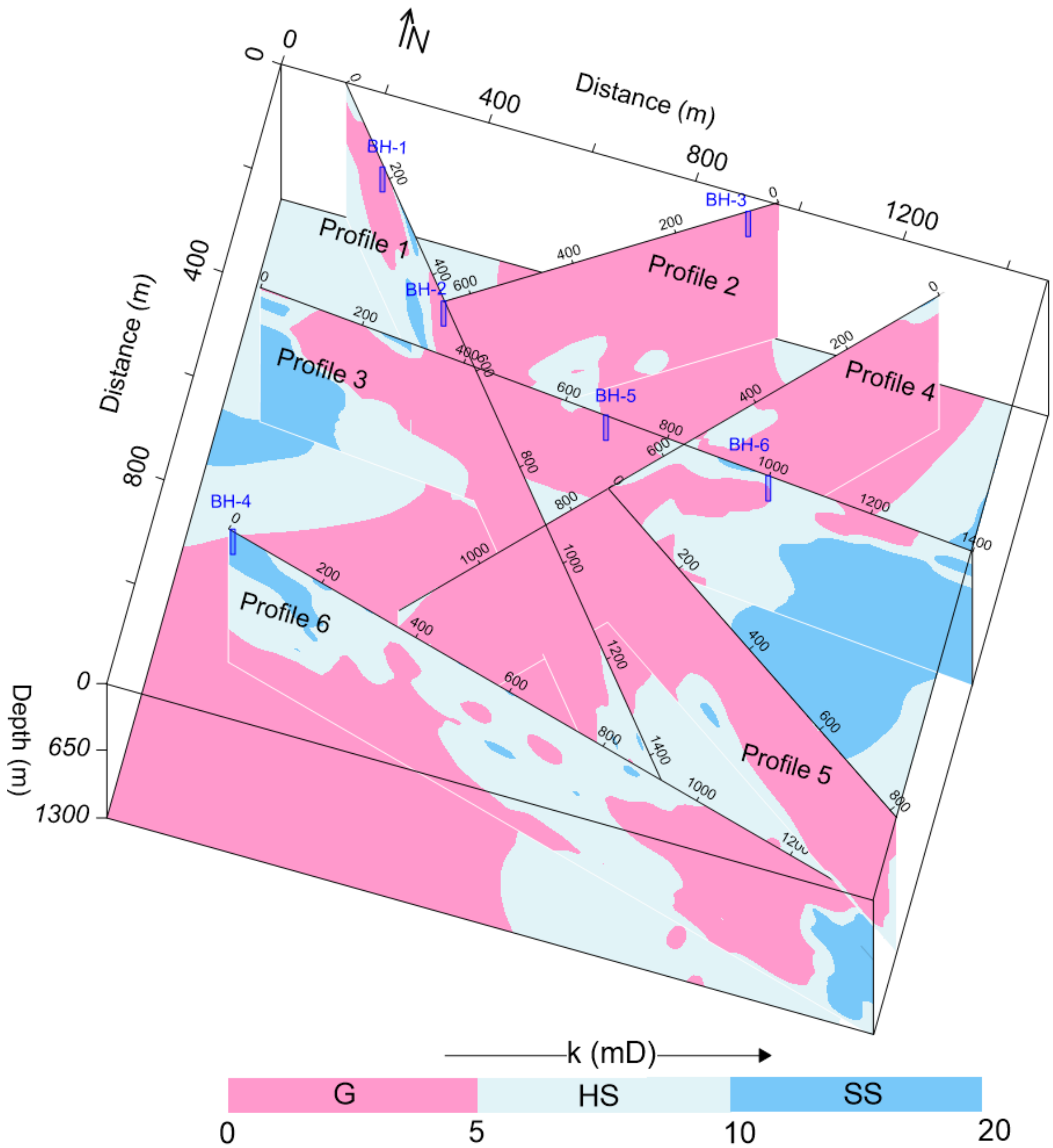

Fig. 9 Analysis of the integrated 2D k models (derived from designated k ranges) for three groundwater potential aquifers: low potential aquifer (LPA), medium potential aquifer (MPA), and high potential aquifer (HPA), associated with three geological formations: granite (G), hornstone (HS), and sandstone (SS), respectively

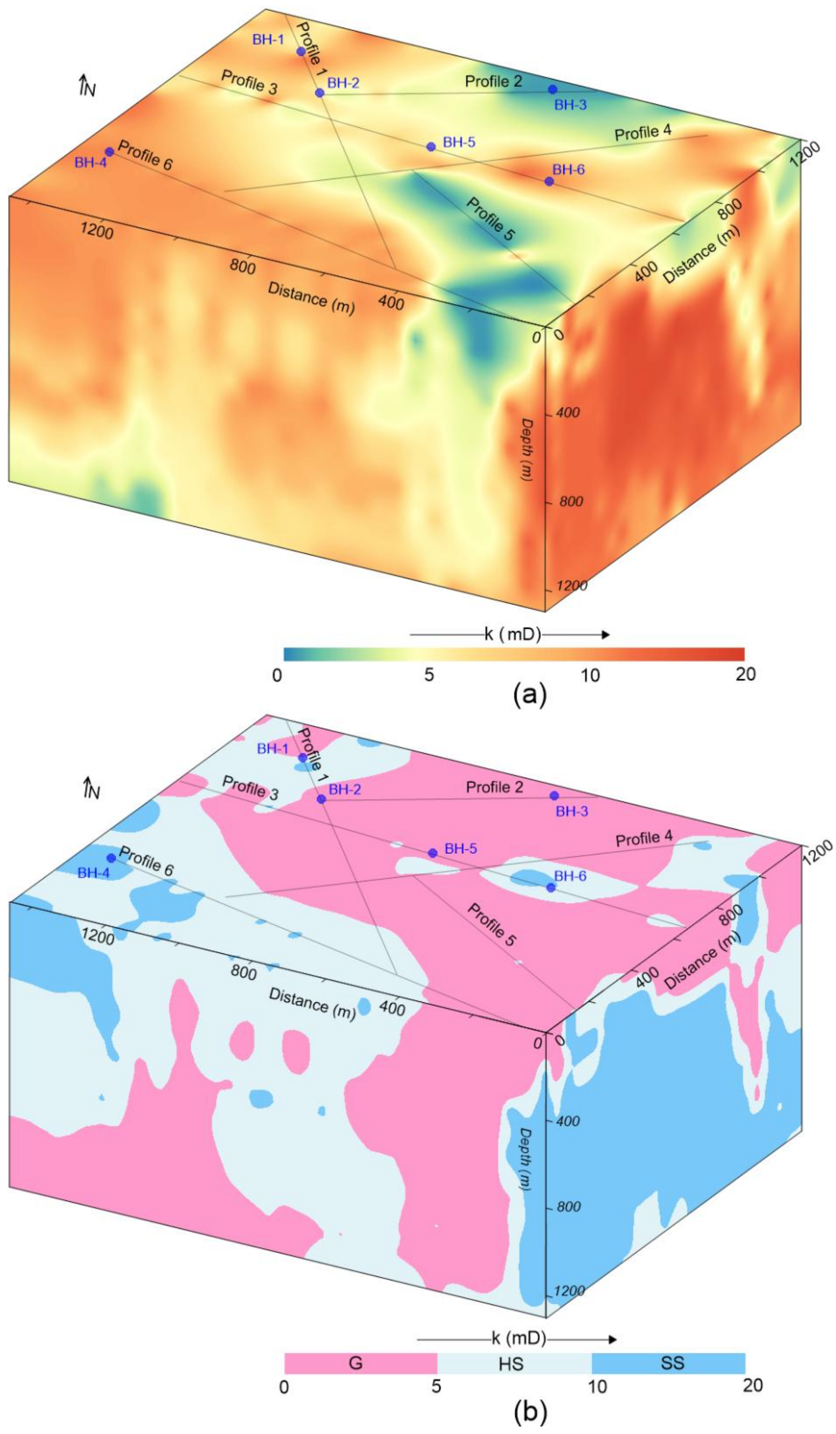

Fig. 10 The 3D k models, generated from the correlation of CSAMT and borehole data (with k represented on a color scale ranging from green to red), correspond to three groundwater potential aquifers: low potential aquifer (LPA), medium potential aquifer (MPA), and high

potential aquifer (HPA), associated with three geological strata: granite (G), hornstone (HS), and sandstone (SS), respectively, for (a) the external view of the 3D k model, and (b) the analysis of the 3D k model from an external perspective

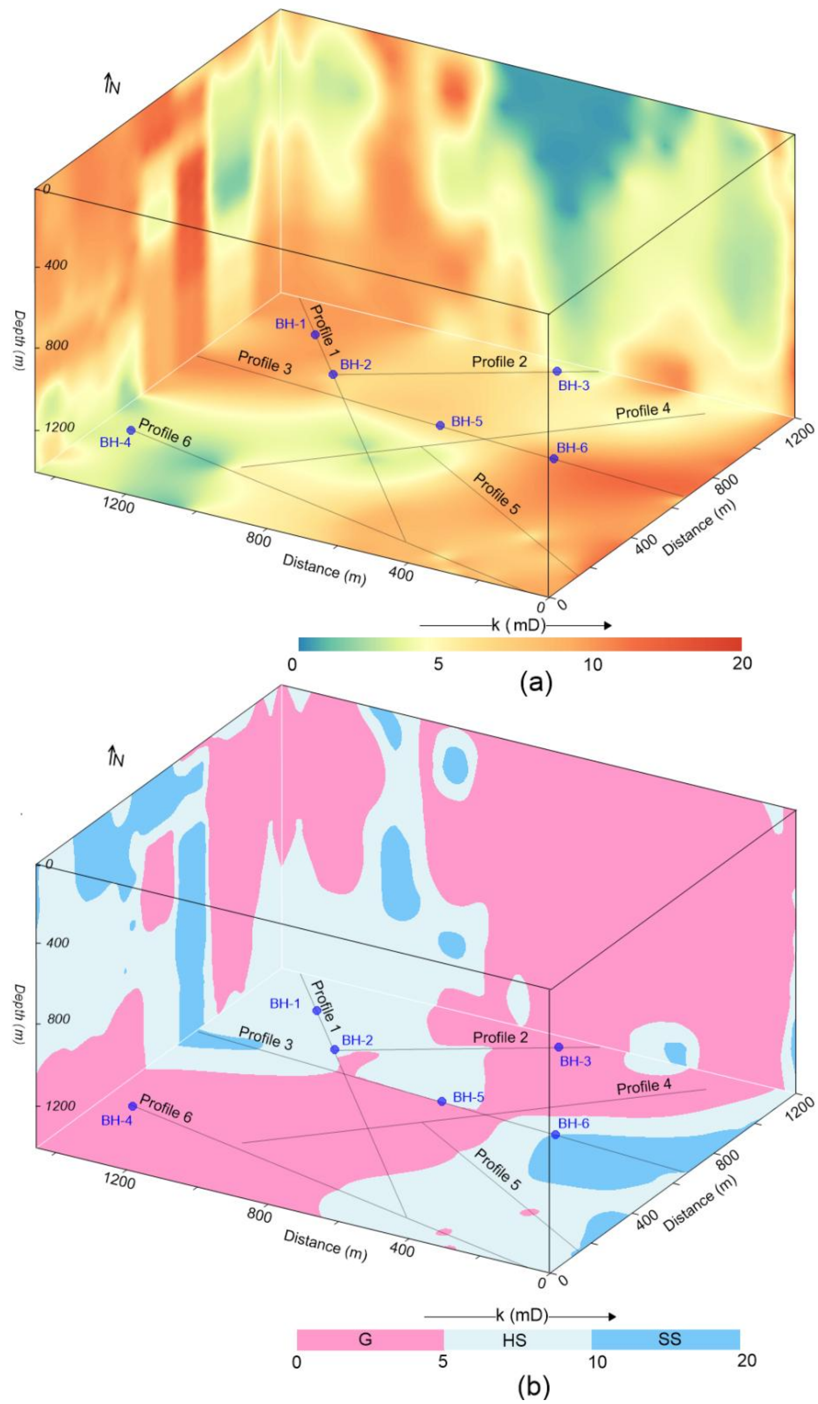

Fig. 11 The 3D k models, obtained from the correlation of CSAMT and borehole data (with k represented on a color scale ranging from green to red), illustrate three groundwater potential aquifers: low potential aquifer (LPA), medium potential aquifer (MPA), and high potential aquifer (HPA), associated with three geological strata: granite (G), hornstone (HS), and sandstone (SS), respectively, for (a) the internal view of the 3D k model, and (b) the analysis of the 3D (internal perspective) k model

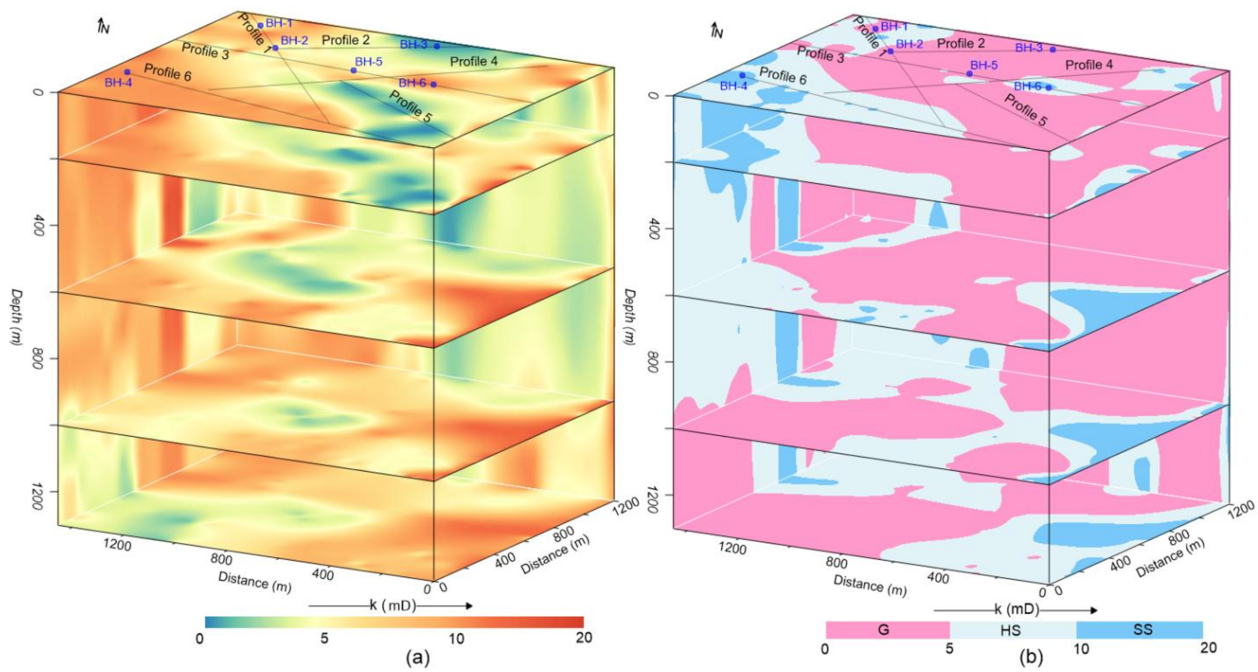

Fig. 12 (a) Geophysical-based k imaging at various depths (0, 200, 600, 1000, and 1300 m) with inner 3D view is represented by K on a color bar that goes from green to red, (b) Assessment of geophysical-derived k (using specified k ranges) at different depths for various types of aquifers: low potential aquifer (LPA) granite (G), medium potential aquifer (MPA) hornstone (HS), and high potential aquifer (HPA) sandstone (SS)