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Some problems in the interpretation of the seismotomographic model

I.V. Bugaienko, L.M. Zaiets, 2025

S. Subbotin Institute of Geophysics of National Academy of Sciences of Ukraine, Kyiv, Ukraine

The paper considers some problems that arise in the analysis of the velocity structure of the mantle. The seismic tomography method developed by V.S. Geyko was used. The analysis of the counter-slope high-velocity layers between the East European and African plates and between the Turanian and Arabian plates was carried out. The greatest attention was paid to the nature of the high-velocity transition zone of the upper mantle between them: when, where and under what conditions it was created. The problematic issues that arose in the interpretation of the velocity structure of the mantle of the Deccan Traps (Indian Plate) were considered, since it contradicts the theory of their origin.

Key words: seismic tomography, mantle, problems of interpretation.

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Introduction. Seismic tomography is one of the most important methods for studying the Earth's internal structure, in particular the mantle. But various discrepancies may arise when deciphering the same data, which the authors have repeatedly encountered. That is, different scientists can interpret the same results differently.

Method. The authors take as a basis the seismic tomography method developed by V.S. Geyko [Geyko, 2004]. This method and technique for building a three-dimensional model of the mantle on the example of Zagros is presented in the work [Tsvetkova et al., 2023].

Data. Fig. 1 shows a horizontal section of the three-dimensional model of the mantle at a depth of 75 km in the region, which includes the ancient East European and Turanian plates in the north, the African, Arabian and Indian plates in the south, as well as the younger Alpine-Himalayan mobile belt sandwiched between them in the center. The upper mantle of the ancient plates is high-velocity, and the mobile belt is low-velocity. In the transition zone of the upper mantle, a velocity inversion occurs (Fig. 2). It should be noted that in other tomographic models, velocity inversion usually does not occur, and the top and bottom of the transition zone are highlighted as depths at which a velocity jump occurs, for example, in the work [van der Meer et al., 2018].

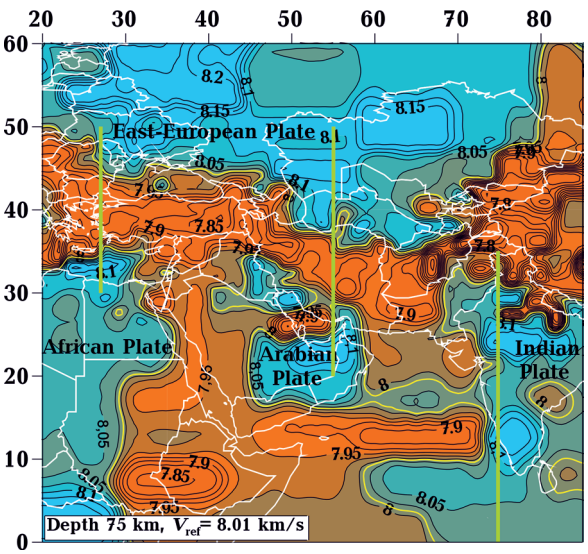

Fig. 1. Horizontal section of 75 km of a three-dimensional *P*-velocity model of the mantle of the studied region. Yellow contour line — reference velocity at a given depth. Green lines — spatial location of vertical sections presented below (Figs. 2, 3).

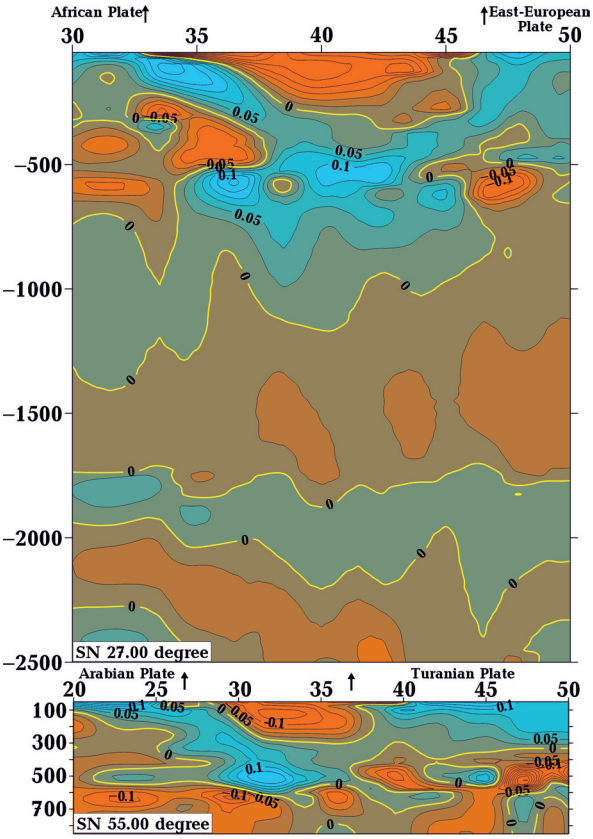

Fig. 2. Vertical longitudinal sections of 27° and 55°E of the three-dimensional *P*-velocity model of the mantle of the studied region (to depths of 2500 and 850 km, respectively).

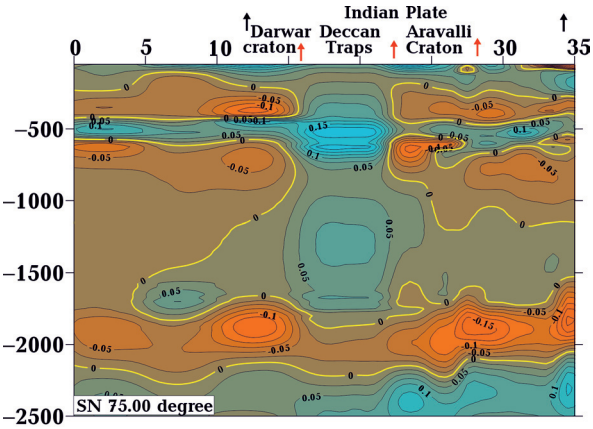

Fig. 3. Vertical longitudinal section 75°E of the three-dimensional *P*-velocity model of the mantle of the studied region to a depth of 2500 km (from [Zaiets et al., 2021]).

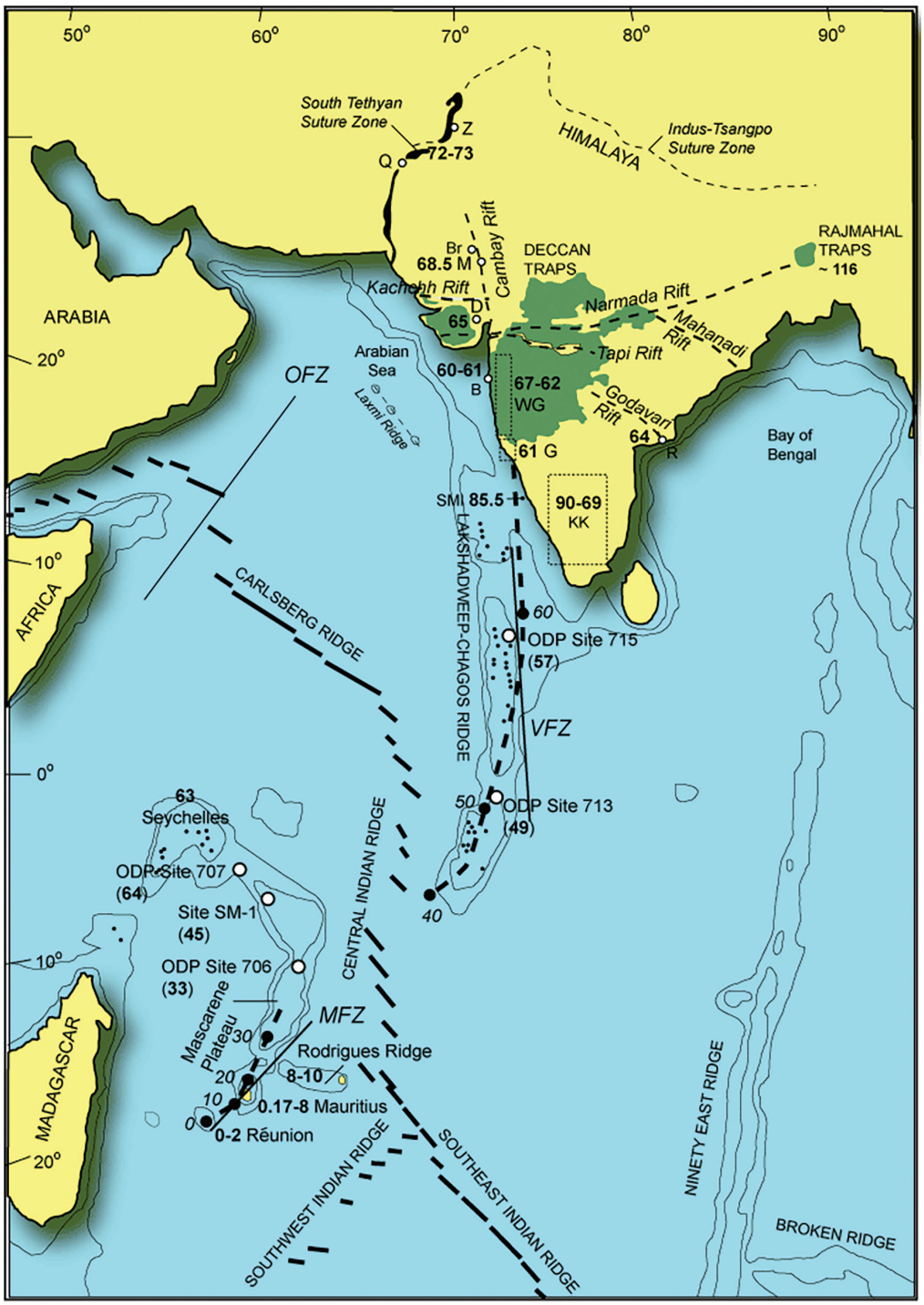

Fig. 4. Prominent structural-tectonic features of southern Asia and the Indian Ocean basin (based on [Mahoney et al., 2002]).

The most interesting and ambiguously resolved even among the authors is the question of the nature of the high-velocity transition zone of the young Alpine-Himalayan mobile belt. Fig. 2 shows two vertical sections, on which there are counter-slope high-velocity layers spreading towards each other. Perhaps these inclined layers created the high-velocity transition zone of the upper mantle (the section at 27°E shows the modern subduction of the African plate under the Aegean microplate)? Some seismotomographic works

show that slabs spread from the surface into the transition zone of the upper mantle. For example, in the work [van der Meer et al., 2018], the subduction mentioned above extends to a depth of 1400 km (starting from 120 Ma and up to now).

Another variant of the development may be that this high-speed transition zone was created even before the Alpine epoch of mountain formation. And the selected inclined high-speed layers only flow into it. But here the question arises to what depth and how far they spread in it, because it is not possible to distinguish this on the model sections. The authors also believe that the idea that these layers reached the transition zone and stopped without violating its borders is false. But this version still has several questions that do not have a clear answer. Perhaps this high-speed zone was created by the intraoceanic subduction of Neotethys. But many works, in particular [van der Meer et al., 2018], claim that the high-speed Neotethys slab is separated at the depths of 1100—2200 km. In addition, the aforementioned work indicates that this slab is separated under the Arabian plate. Many questions arise. For example, according to paleoreconstructions, for example [Torsvik et al., 2012], Neotethys 300 Ma was in the southern hemisphere and subducted there. It turns out that not only the so-called lithosphere can move, but also the mantle with it (in the above-mentioned case up to 2200 km). According to paleomagnetic data, the territory of modern Ukraine in the Devonian was located in the southern hemisphere in the region of 10—20°S [Bakhmutov, Poliachenko, 2014]. Let us assume that at that time the velocity character of the mantle under the territory of modern Ukraine was formed. Then this means that after 300 Ma not only the lithosphere, but also the mantle (at least up to 1000 km) was moving in the north direction. Fig. 2 (cross section 27°E) in the north shows the velocity mantle structure of the Podolia mantle.

Another interesting example of ambiguity is the velocity mantle structure beneath the Deccan Traps (Fig. 3), one of the largest volcanic formations on Earth. The magmatic province is considered to be the product of a mantle plume and covers a significant part of western peninsular India. The Deccan igneous province is marked by a voluminous basaltic flow, closely related to the drift of the Indian Plate over the Réunion plume (Reunion Island in the Indian Ocean), during which the microcontinent of the Seychelles separated from the western continental margin of India. This drift is demonstrated in Fig. 4. The active volcano on Reunion Island is associated with a mantle hotspot. According to some scientists, it was this mantle hotspot that served as a source of magmatic material for the Deccan Plateau traps about 65 million years ago. The trace of this mantle hotspot on the surface of the earth is also marked by the following structures: the Chagos-Laccadisse Rift, the Mascarene Plateau, and the island of Mauritius (formed 18 and 28 million years ago).

According to seismic tomography data, a high-speed heterogeneity of 50—1900 km is distinguished under the Deccan Traps. How did such an intrusion into the mantle from a depth of 1900 km arise? It turns out that in this case, not only the lithosphere, but also the mantle (at least to a depth of 1900 km) drifts in the northward direction.

Conclusions. In this work, the authors considered only a few cases of ambiguity in the interpretation of seismic tomography data, demonstrating that the experience of the researcher and his ability to integrate with other methods are of great importance.

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Деякі проблеми інтерпретації сейсмотомографічної моделі

І.В. Бугаєнко, Л.М. Заєць, 2025

Інститут геофізики ім. С.І. Субботіна НАН України, Київ, Україна

Розглянуто деякі проблеми, які виникають при аналізі швидкісної структури мантії. Використано метод сейсмічної томографії, розроблений В.С. Гейком. Проведено аналіз зустрічних похилих високошвидкісних шарів між Східноєвропейською й Африканською плитами та між Туранською й Аравійською плитами. Найбільше уваги було приділено природі високошвидкісної перехідної зони верхньої мантії між ними: коли, де і за яких умов вона була створена. Розглянуто проблемні питання, що виникли при інтерпретації швидкісної структури мантії Деканських трапів (Індійська плита), оскільки вона суперечить теорії їх походження.

Ключові слова: сейсмічна томографія, мантія, проблеми інтерпретації.