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Important Findings Expected From Europe's Largest Seismic Array

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An international, interdisciplinary project, which 2 years ago deployed the largest dense seismic antenna ever in Europe, expects in the next 2 years to present important findings on the lithosphere and asthenosphere of a portion of the Trans-European Suture Zone (TESZ). Final processing is currently under way of the data from the array of 120 seismographs along a 900-km-long by 100-km-wide strip from Göttingen, Germany, in the south, through Denmark, to Stockholm, Sweden in the north, across the northwestern part of the TESZ (Figure 1).

Project Tor is a teleseismic tomography experiment with interdisciplinary data exploitation. It extends across the broad TESZ boundary between two markedly different lithospheric domains. These are (1) Proterozoic Europe, with Precambrian crust in Sweden and eastern Europe, and (2) Phanerozoic central Europe, with most of the crust influenced by the Caledonian and Variscan orogenies and only small areas of relic Precambrian crust. The project is designed to investigate the deep lithosphere traces of the broad-scale geology of the TESZ area, including the Tor nquist Zone, from which Project Tor has its name. It is part of EUROPROBE, a major Earth science program of the European Science Foundation, which is run by a regional committee of the International Lithosphere Program.

The TESZ area around the NW-SE trending Tornquist Zone has been tectonically active since Silurian time (~ 440 Ma), starting with continental collision. Since Permo-Carboniferous time, the region has undergone complicated motions leaving a Precambrian block, the Ringkobing-Fyn-High in the middle of Denmark, almost undisturbed, and this block has, since Permian time, been surrounded by 2 basins, north and south of it, where initial extension and later transpression occurred.

The Tornquist Zone itself experienced tectonic inversion in Cretaceous-Tertiary time. In Sweden, Denmark, and Germany, the exact location and form of the lithospheric transition is unclear. Several lineaments besides the Tornquist Zone are candidates as far south as the Elbe Line in northern Germany. In Poland, where the Tornquist Zone is a well-defined, 50-100-km-wide belt, recent geological studies have also raised doubts about the exact location of the significant lithospheric boundary, the TESZ.

Project Tor is integrating surface and subsurface geology with deep-seated structures and is testing different methods of modeling lithospheric structure. Previous deep geophysical studies [*Ansorge et al.*, 1992; *Spakman et al.*, 1993; *Zielhuis and Nolet*, 1994; *Pedersen et al.*, 1994; *Babushka et al.*, 1998] have demonstrated a significant lithospheric contrast across the central European part of TESZ. The Tor seismic antenna was chosen along profiles of earlier

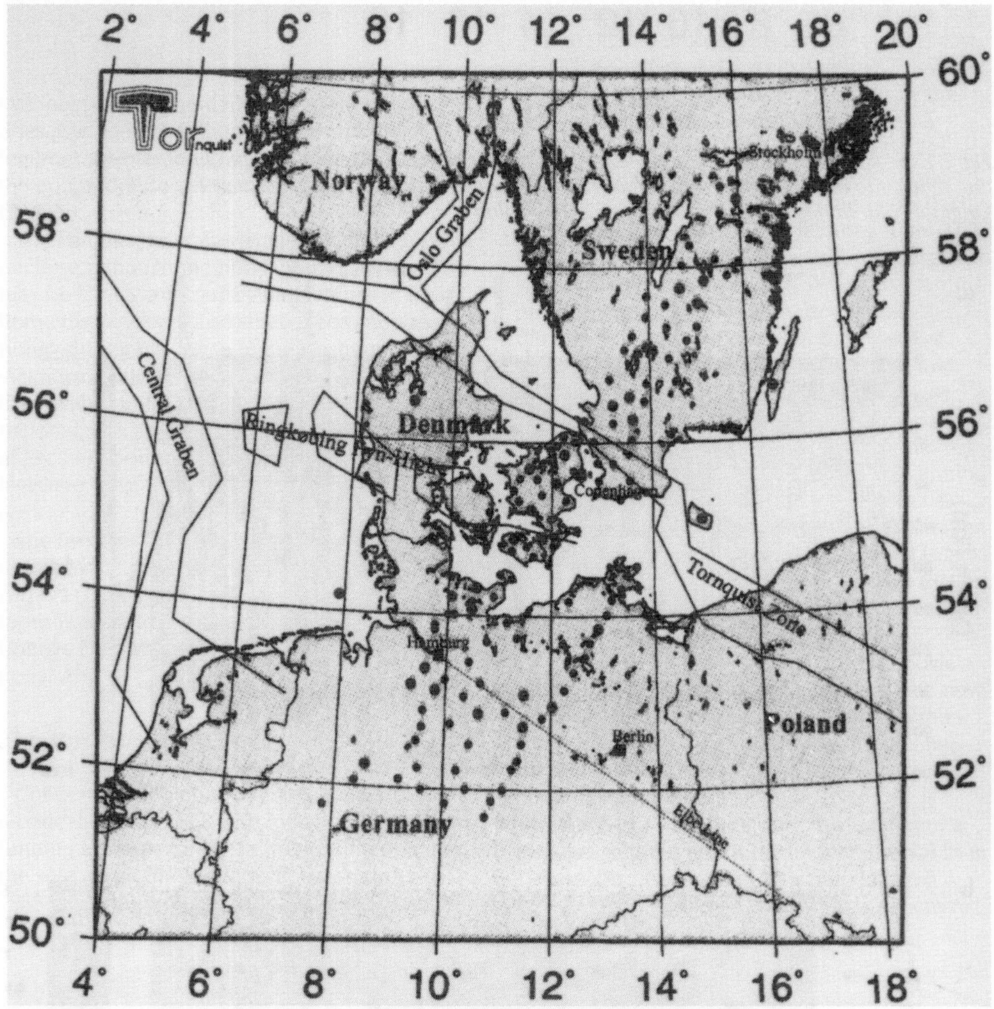


Fig. 1. Tor location map with some geological features, including the Tornquist Zone. Blue dots denote short period and red dots broadband stations. The line of stations in the southeast Tor region coincides with a DEKORP reflection profile in the North German Basin (DEKORP Research Group, The deep structure of the northeast German Basin: Implications for Caledonian sutures and intracratonic development, unpublished manuscript, 1998). The active and passive observations on this profile supplement each other. Original color image appears at the back of this volume.

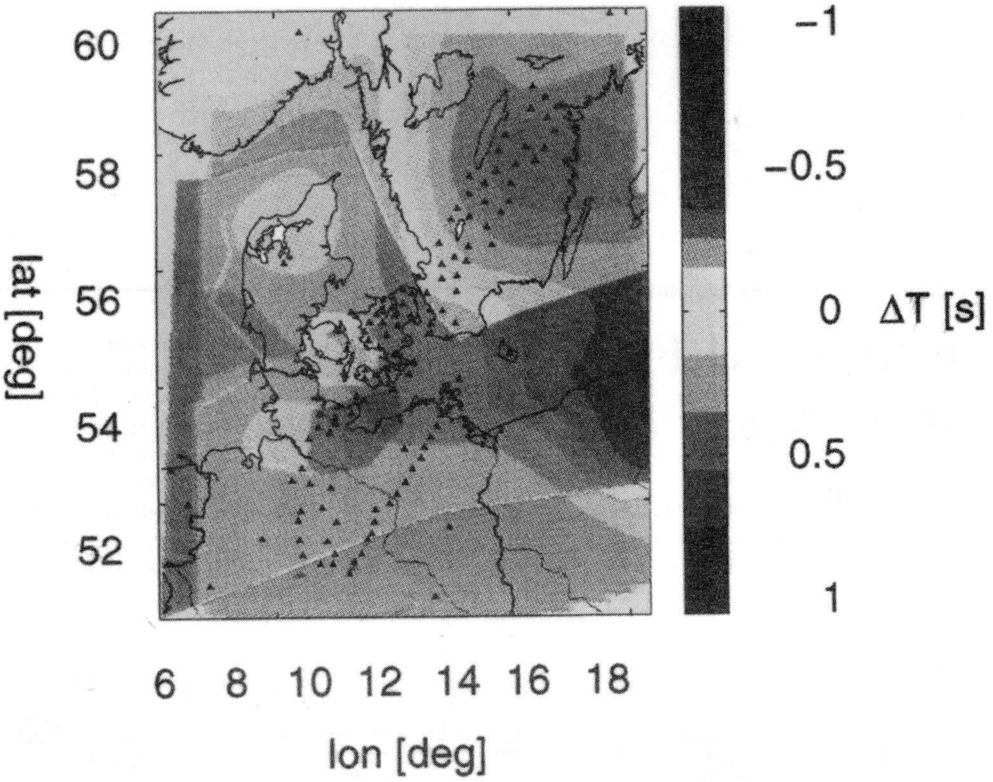
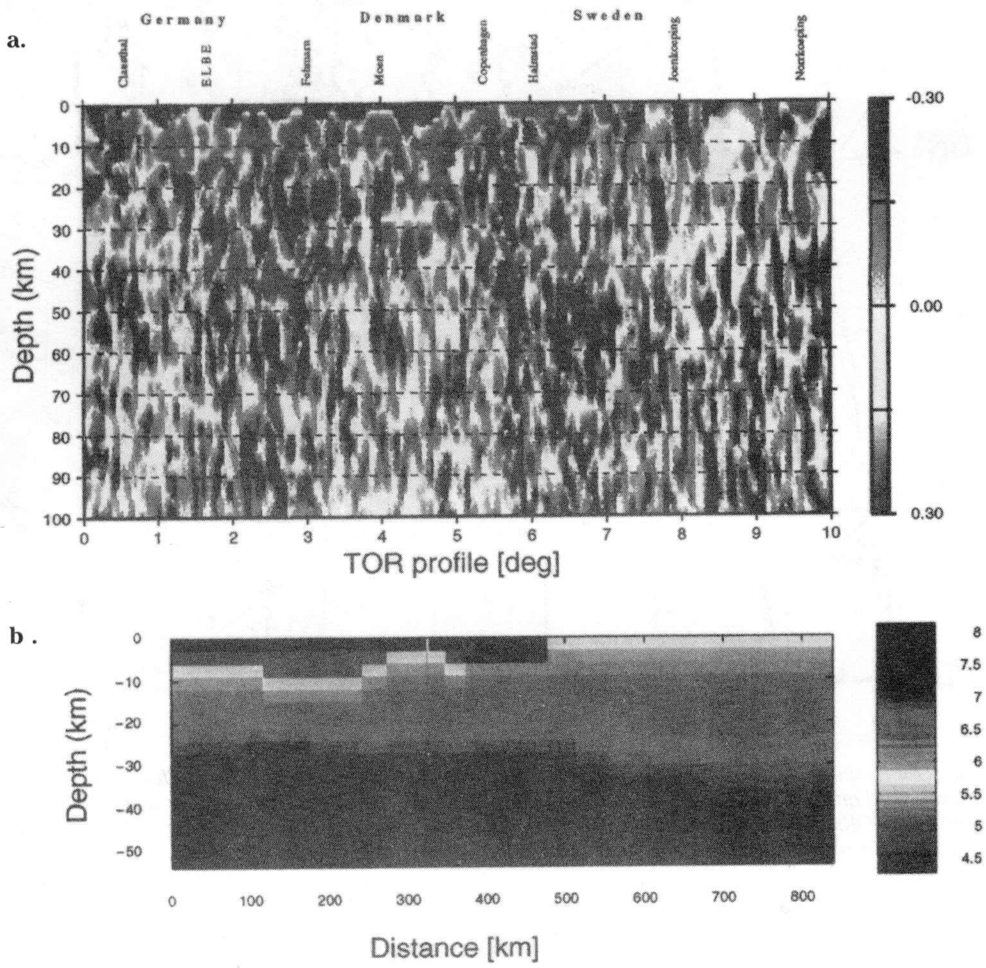


Fig. 2. Expected delay times of a teleseismic wave front in the Tor region owing to known crustal structure relative to arrival times in a laterally homogeneous crust/upper mantle (courtesy of R. Arlitt). Original color image appears at the back of this volume.



active seismic studies [*EUGENO-S Working Group*, 1988; *BABEL Working Group*, 1991], which provided detailed knowledge of sedimentary and crustal structure. Consequently, crustal structure is already well constrained, and current research efforts are concentrated on lower lithospheric and asthenospheric lateral contrasts to depths of around 300 km, and especially on improved lateral resolution.

Two belts of investigation have been chosen perpendicular to the northwest-southeast-trending zone. The western belt, Tor-1, across Sweden, Denmark, and Germany, is the one currently under study. In the future, a similar belt across Poland will be investigated. This Tor-2 array will be deployed along one of the best known crustal sections derived by Polish scientists of the Tor project. Signals from 276 selected events have been extracted from the immense digital data bank. Signal-to-noise ratios are larger on the Baltic Shield in Sweden than farther southwest; absolute amplitudes of the signals show the opposite tendency. The transition is sharp in some areas and more gradual in others. Using a recently developed technique [*Waldhauser et al.*, 1998], we have estimated the effect of crustal structure on *P*-wave arrival time at each station (Figure 2) on the basis of three-dimensional structure [*Steck and Prothero*, 1991] deduced from previous geophysical studies in the area. This effect will be used as a correction factor when inverting for deeper structure.

We have also imaged crustal structure using the receiver function method (Figure 3a). Two red zones of high P-SV converted energy can be recognized in the figure. In the south, converted energy from the bedrock-sediment interface is concentrated at depths of around 10 km. This differs from the north, where bedrock is exposed at the surface of the Baltic Shield. At depths of 30-40 km, another concentration of converted energy corresponds to the Moho, deepening to the NE. Both features are consistent with the crustal structure (Figure 3b), derived from existing explosion profiles (see, e.g., EUGENO-S Working Group [1988] and *BABEL Working Group* [1991]). The data of the passive and active experiments correlate well.

Final data of the Tor project will be publicly available in about a year.

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Fig. 3. a) P-SV converted energy migrated from time into depth along the Tor profile. The color scale denotes the energy of P to SV converted waves relative to P wave (courtesy of J. Gossler). b) P-wave crustal model cross section (courtesy of R. Arlitt). Base of the sediment and the Moho can be followed in both displays. Original color image appears at the back of this volume.

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A Potomac Perspective on the Growing Global Greenhouse

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Large-scale climatic patterns, rather than a growing "heat island" effect, are the overriding influence on weather in the Potomac River area, and temperature data in the area can therefore be validly compared to global trends. At least temporarily, however, the area, which includes Washington, D.C., has lost its coupling with global temperature trends.

Short-term regional anomalies in the Potomac River area's weather, especially high summer temperatures, may promote legislative action in the U.S. Congress on long-term global climate research. However, the current benign weather conditions in the political center of the United States tend to divert attention away from global climate research, diminishing the likelihood of significant expansion of research funding and greenhouse gas legislation.

The global greenhouse is a major focus of research today, particularly global warming as influenced by anthropogenic causes. Analysis of the weather records of five sites in the Potomac River area suggests the area has not experienced the recent succession of record hot years evident globally. Nor has the area experienced a decreasing daily temperature range compared to normal as expected in a growing global greenhouse [*Arrhenius*, 1896]. More subtle indicators of an increased greenhouse effect, however, are present. The daily temperature range does tend to be less than normal and daily high temperature records (DHTRs) tend to exceed the number of daily low temperature records (DLTRs).

The Potomac area was singled out for study because, although members of U.S. Congress may be largely affected by happenings in their home districts, they also share a common experience during residence in the Washington, D.C., vicinity, making what happens there, including the weather, important to science budgets and national policy. In addition, many congressional aides, so important in suggesting and drafting legislation, live permanently in the metropolitan area.

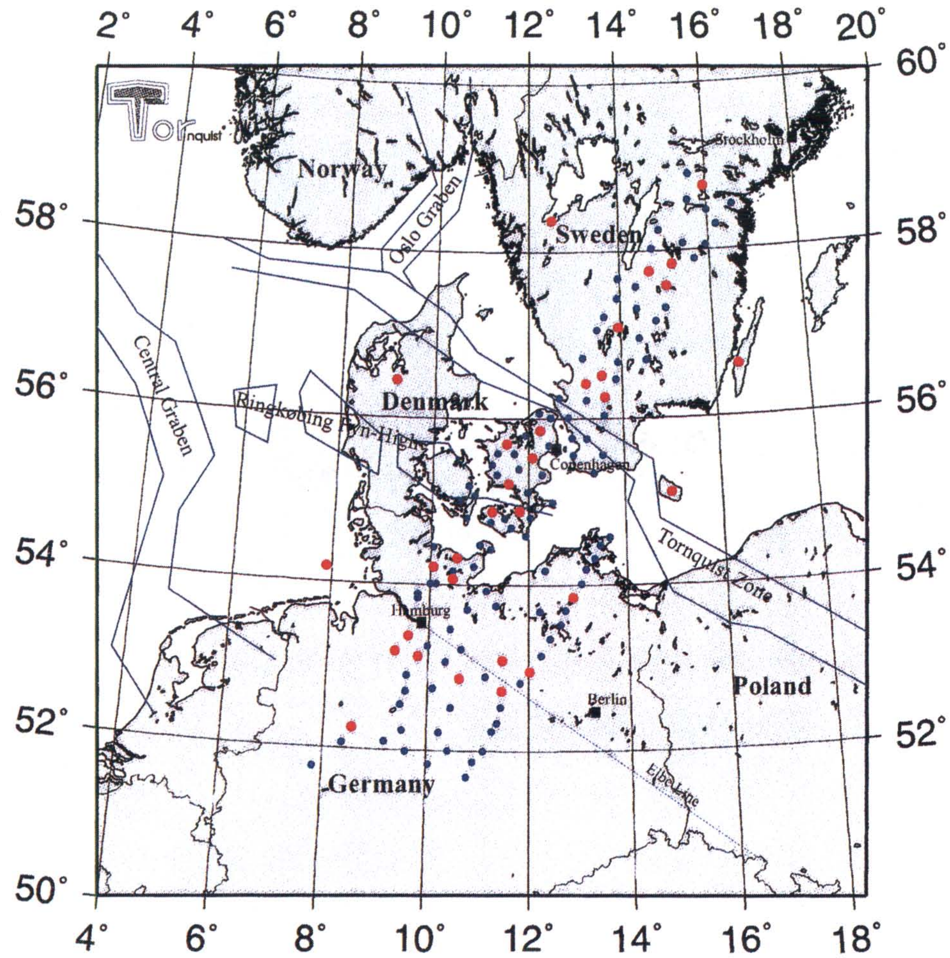
The five sites from which weather data were obtained are the Ronald Reagan National Airport (DCA); Baltimore, Maryland (BAL); Baltimore-Washington International Airport (BWI); College Park, Maryland (CP); and Dulles International Airport (IAD).

The Hot Summer of 1988

Concerns over global climate change reached a critical level in 1988 with initiation of major funding for research on the topic. Although not the sole cause, the fortuitously hot summer of 1988 in Washington, D.C., has been informally suggested to have assisted in gaining congressional appropriation of these funds. The summer had a record-tying 22 consecutive days of 90°F or higher and a record-setting 7 days of 100°F or higher at DCA. But paradoxically the year overall was the coolest in more than a decade. The next year, 1989, was even cooler, although both years were among the 4 hottest years ever seen globally at the time [*Doe*, 1993].

Although global warming, deduced to be 0.5°C this century, receives the overwhelming emphasis, it was only one of several effects that Arrhenius [1896] noted from increased carbon dioxide in the atmosphere. Another was that nights should warm more than days, and thus the daily temperature range should decrease compared to normal. In other words, the daily difference between high and low temperatures should be less. Indeed, although global warming has been disputed, Karl et al. [1986] noted a decrease in the average daily temperature range for North America even though evidence is lacking for a temperature increase there over the last 100 years. The study of the trend in daily temperature range was extended to three large countries (the United States, the former Soviet Union, and China) by Karl et al. [1991] and now globally by Easterling et al. [1997], where the temperature range is found to be decreasing, even in the absence of increases in average annual temperature.

"Normal" for this study were the temperature averages and ranges for the 30-year interval from 1961 to 1990, except for IAD where full-year records began only in 1963. Temperatures were



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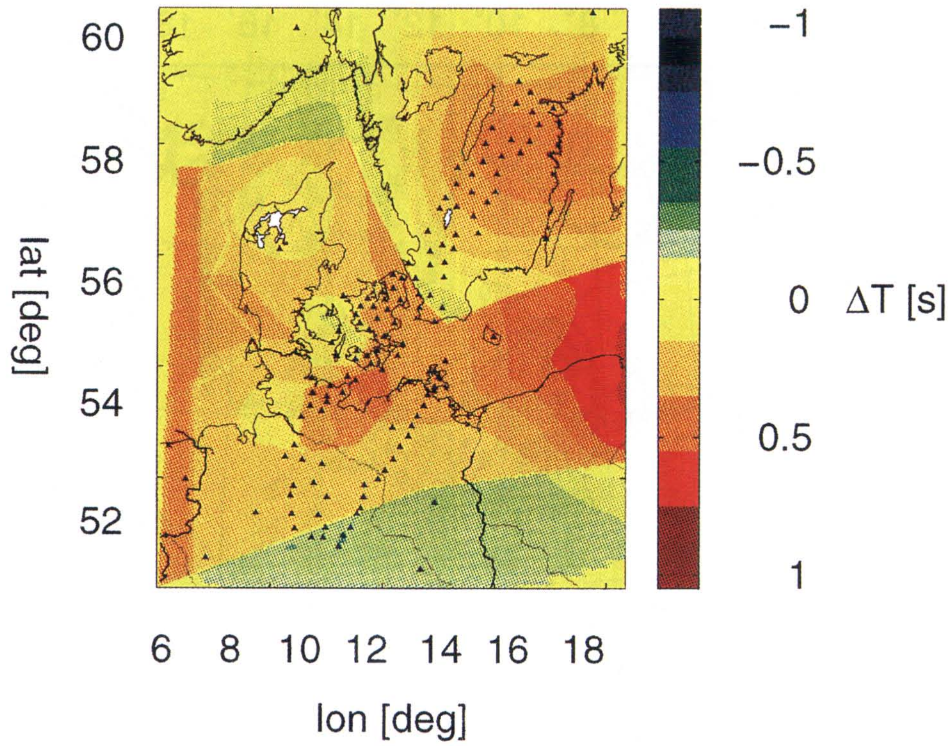

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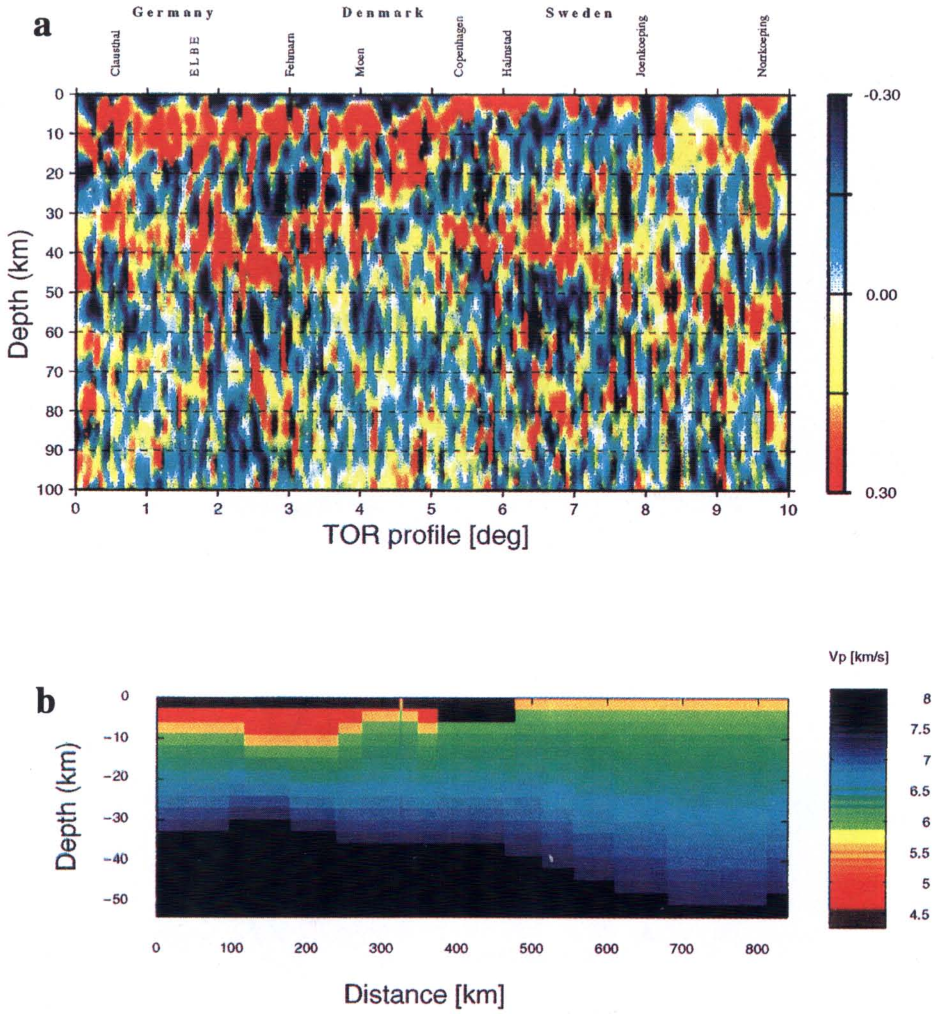

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