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Supplement of

The anisotropic properties of granites – effects of tectonic emplacement mode on potential crystalline host rocks for nuclear waste deposits in Germany

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THE ANISOTROPIC PROPERTIES OF GRANITES

Effects of tectonic emplacement mode on potential crystalline host rocks for nuclear waste deposits in Germany

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For permanent nuclear waste disposals sites, crystalline rocks, and especially granite is considered as an appropriate host rock. Three principal types of granitic plutons occur in the extra-alpine crystalline basement of Germany, which were consolidated during the late Paleozoic Variscan orogeny of Central Europe.

i) **Pre-Variscan** voluminous granodiorites that are hardly affected by subsequent continent – continent collision.
ii) Voluminous granites in various tectonic settings intruded during the **late-orogenic** stage of the Variscides.
iii) **Post-orogenic** granites related to vast Permian intracontinental extension.

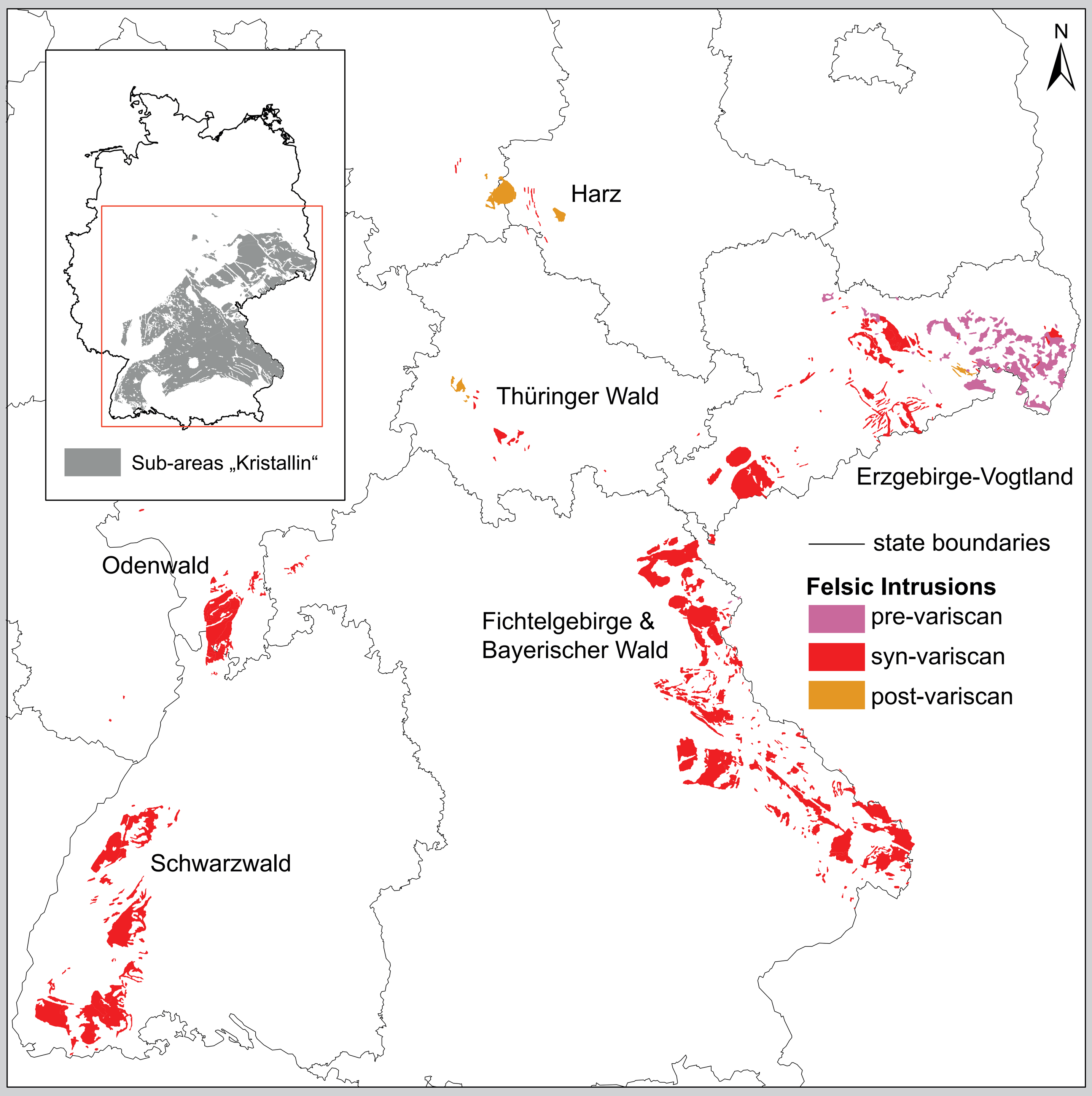


Fig. 1: Overview map of the felsic plutonites of Germany which are not covered.

Although it can be expected that different tectonic environments cause significant differences of the material properties, for Germany, however, there is no systematic study regarding the fabric of such plutonites. In order to find the most suitable "granite" we will investigate the primary anisotropy of granites evolved during the emplacement and crystallization of the melt. For this we sample rocks of all three principal types and various syn-intrusive tectonic settings, i.e., compression, extension, strike-slip, transtension and transpression.

By means of combined measurements of the **"Anisotropy of the Magnetic Susceptibility" (AMS)** and the **"Shape Preferred Orientation" (SPO)** we characterize the syn-intrusive flow pattern, i.e., the magmatic foliation and lineation. The **Crystallographic Preferred Orientation (CPO)** will be analyzed by the combination of neutron time-of-flight (ToF) experiments and electron backscatter diffraction (EBSD) measurements at the Frank Laboratory of Neutron Physics at JINR, Dubna, Russia and the TU Bergakademie Freiberg, respectively. This allows to obtain a wide range of texture information, from volume (~60 cm³) to spatially resolved at sub-grain scale. Special attention lies on the systematic mapping of annealed microcracks evolved during late magmatic fluid escape and/or post-crystallization hydrothermal activity. These datasets will be organized in a geoscientific information system (GIS) allowing for a complete traceability of the different investigation steps. In a second step we compare the primary anisotropy with the post-magmatic fracture pattern of the particular granites. Those fractures constitute probable fluid pathways and, thus, the first order risk for a potential permanent nuclear waste disposal. Conclusions on the (re-)activation conditions of cracks derived from these datasets provide the basis for the future detailed exploration.

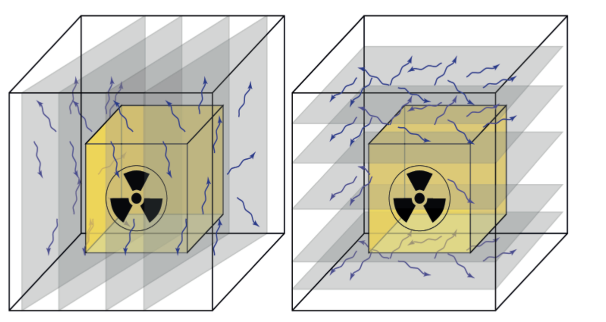


Fig. 2: Potential fluid pathways within granitic host rocks resulting from extensional fracturing are highly dependent on the anisotropic fabric of the granitic material. It is determined by various geological processes such as magmatic flow, static crystallisation, plastic deformation, post-intrusive hydrothermal processes, etc.

Primary Anisotropy

Fig. 3: Strongly aligned magmatic flow fabric of a granite, Land's End, Cornwalll, England.

Fig. 4: Seemingly isotropic fabric of the Niederbobritzsch granite. Despite the optical appearance granites are primarily anisotropic (Bouchez 1997).

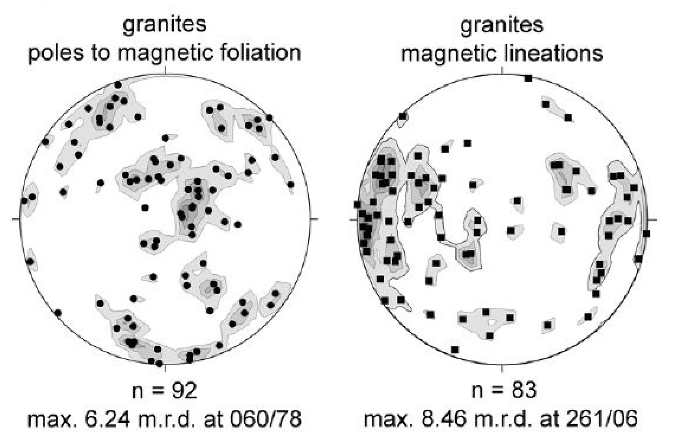


Fig. 5 Stereograms of magnetic foliations and magnetic lineations resulting from AMS measurements (Grimmer et al. 2016).

Crystallographic preferred orientation of quartz in geographical reference

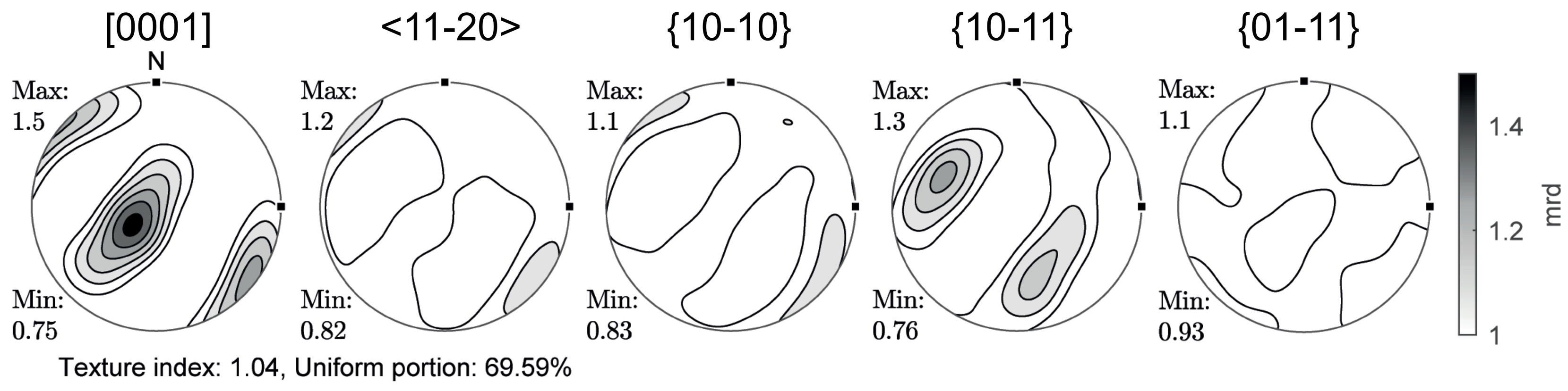


Fig. 6 (above): Quartz volume texture of the Niederbobritzsch granite resulting from neutron diffraction experiments at SKAT (JINR, Dubna, Russia).

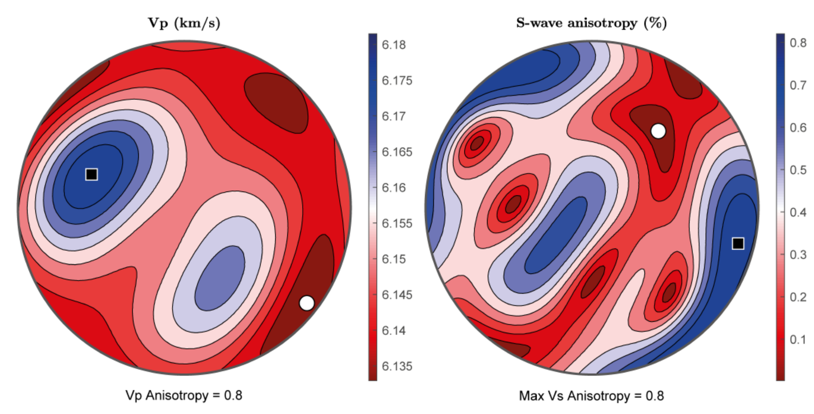


Fig. 7 (left): Calculation of anisotropic seismic properties from texture data (see Mainprice et al. 2011). Displayed are P- and S-wave velocities of quartz crystal orientations of the Niederbobritzsch granite.

Late- to Postmagmatic Anisotropy

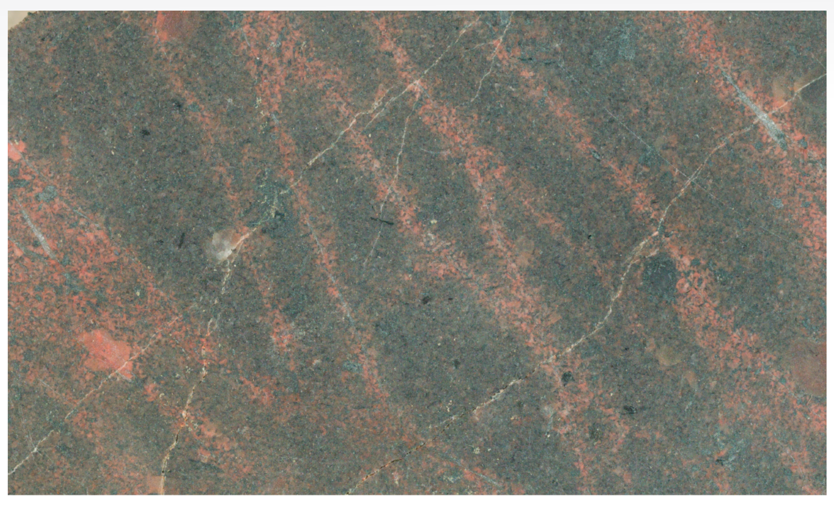


Fig. 8 (left): Niederbobritzsch granite, fractures with alteration zones (annealed) and open, younger fractures.

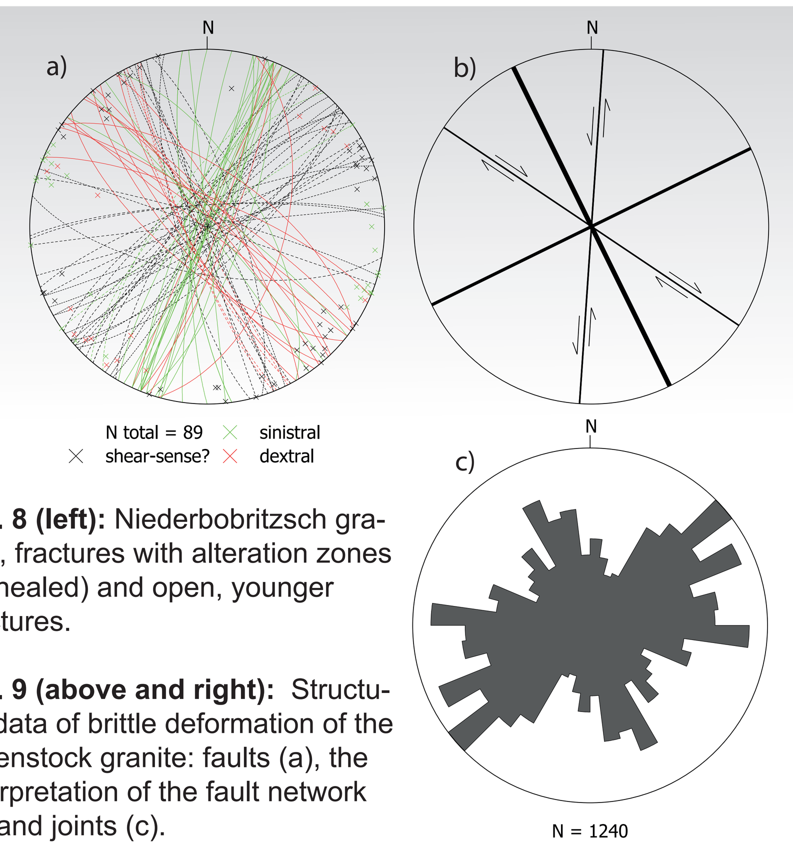
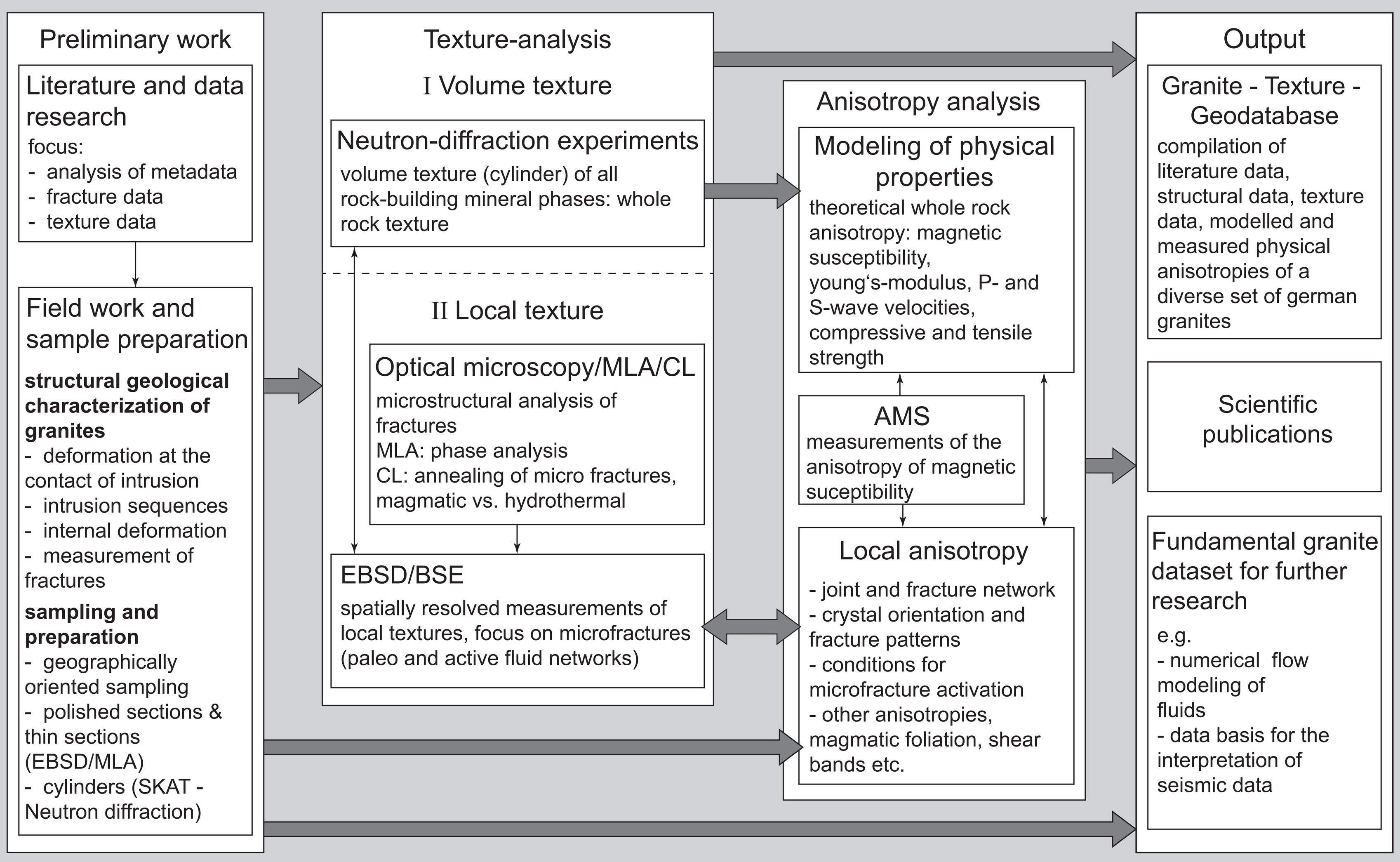


Fig. 9 (above and right): Structural data of brittle deformation of the Eibenstock granite: faults (a), the interpretation of the fault network (b) and joints (c).

Workflow



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