



Introduction

In the nature, the stress field shows some colours only in special materials (Fig. 1). In other cases, we have to colour it ourselves according to the specific purpose of imaging.

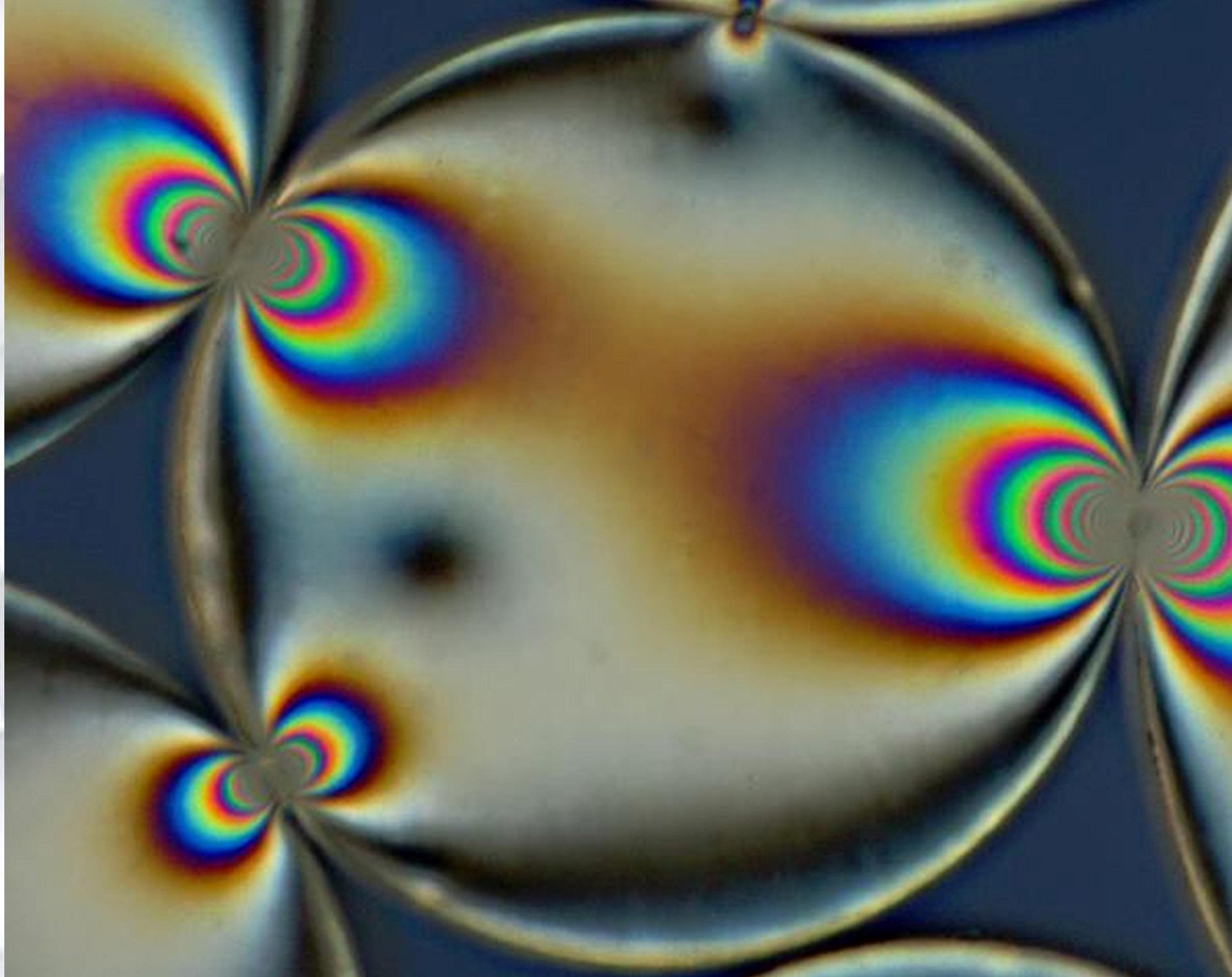


Fig. 1 Colour fringes in a photoelastic experiment

The advantage of colour in graphics is the high density of information it can carry – if we are able to code the information into the colour. A symmetric tensor of rank 2 in 3D space (like the stress or strain tensor) has got 6 independent components, of which only 3 can be shown by RGB colour. Thus, we have to discard the information about the tensor orientation and concentrate on the tensor invariants. Various kinds of invariants can be defined for stress and strain (the eigenvalues, the shape descriptors etc.). The mutually independent invariants always form a triplet. If properly chosen and colour-coded, they can show very interesting features of the stress or strain field. We have to state right at the beginning that the triplet of eigenvalues (principal stresses or strains) is not a good choice for a meaningful colouring. The data processing flow leading to stress/strain colouring contains several stages (Fig. 2)

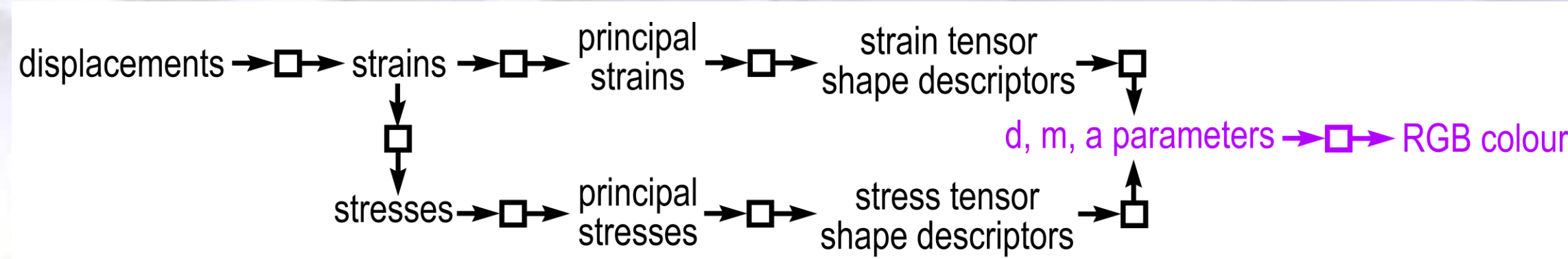


Fig. 2 Data processing flow leading to stress/strain colouring

The squares symbolize the applicable operators/functions transforming the input to output. The functions transforming the principal stresses or strains to the tensor shape descriptors depend strongly on the purpose of imaging. In failure analysis, the chief descriptor (later transformed to the parameter d) is the output of the chosen failure criterion. Another one is the mean stress determining the overall character of the stress state (later transformed to the parameter m). The last one (later transformed to the parameter a) indicates the relative magnitude of the intermediate principal stress.

In the last stage (in Fig. 2 in purple) a colour function transforms its three arguments into an RGB colour. It can be visualized by a colour cube palette shown in Fig. 6 in the Example 2. Here is the formula of the white background colour function used in Fig. 6:

$$c(d, m, a) = \frac{1}{4} \begin{pmatrix} 3 + a - d + m + ad + dm - a|m|(1+d) \\ 3 + a - d - m + ad - dm - a|m|(1+d) \\ 3 - a - d - ad \end{pmatrix}^T$$

Reference: Bednárík, M., Kohút, I. 2012. Three-dimensional colour functions for stress state visualisation. Computers and Geosciences, 48, 117–125, doi: 10.1016/j.cageo.2012.05.010

Example 1 – Colouring of the stress field in Brazilian test

The Brazilian test is an amazing paradox of continuum mechanics: it determines the tensile strength of the material by uniaxial compression of a cylinder from its sides (Fig. 3a). Nowadays it is considered as unreliable and obsolete. Nevertheless, the stress field it generates is highly interesting and worth to be coloured (Fig. 3b).

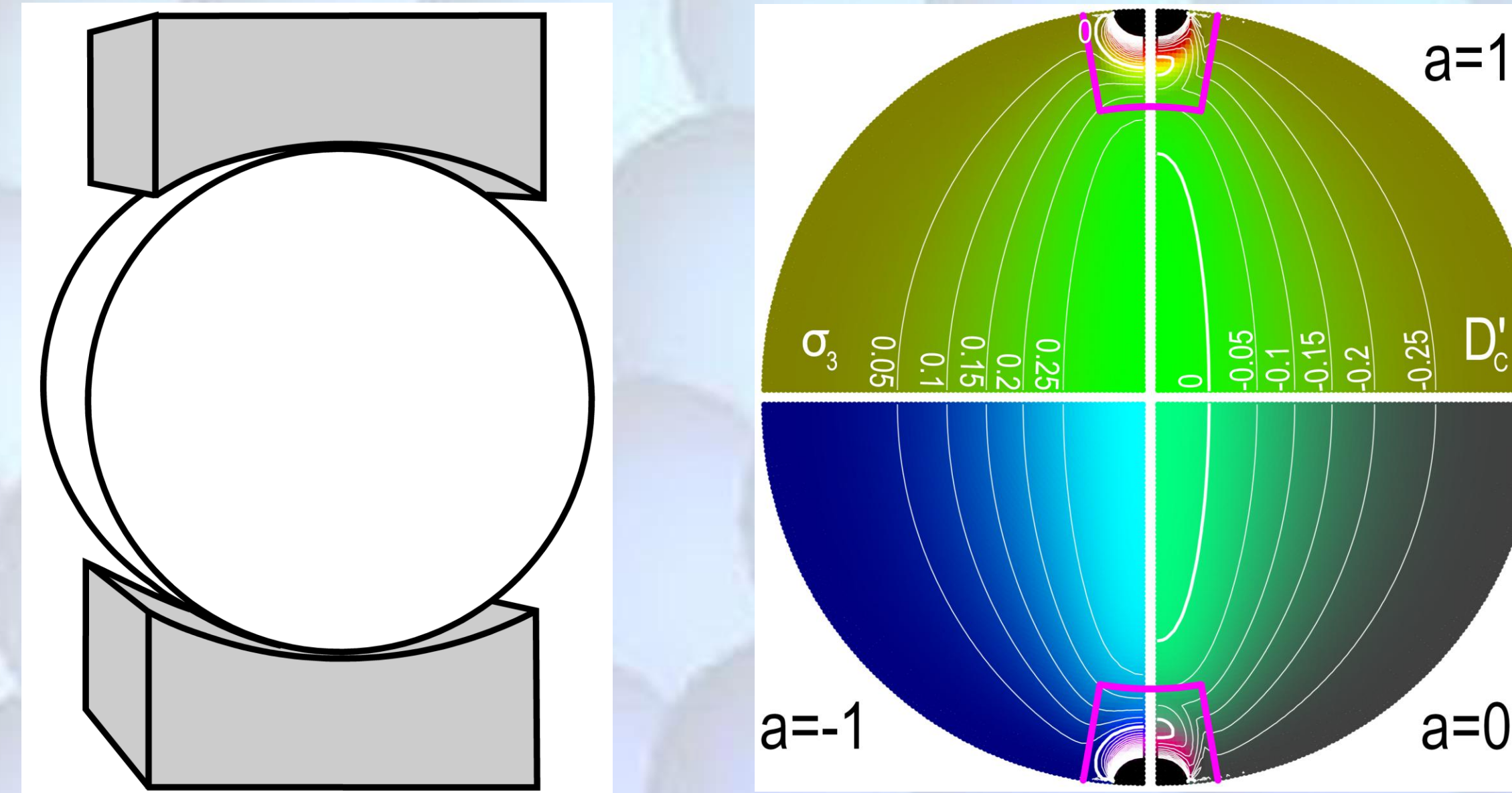


Fig. 3a Geometry of the Brazilian test

Fig. 3b Stress field of the Brazilian test coloured by a 2D colour function with the parameter a free to set. The area of load application is shown in detail in Fig. 4.

The Brazilian test is a planar problem of elasticity. It can be described by a system of PDE in polar coordinates within the cross-section of the cylinder. The front and rear base of the cylinder are in the state of plane stress, the medium section of a sufficiently long cylinder is in the state of plane strain. Because of a more colourful stress field, we chose the latter case.

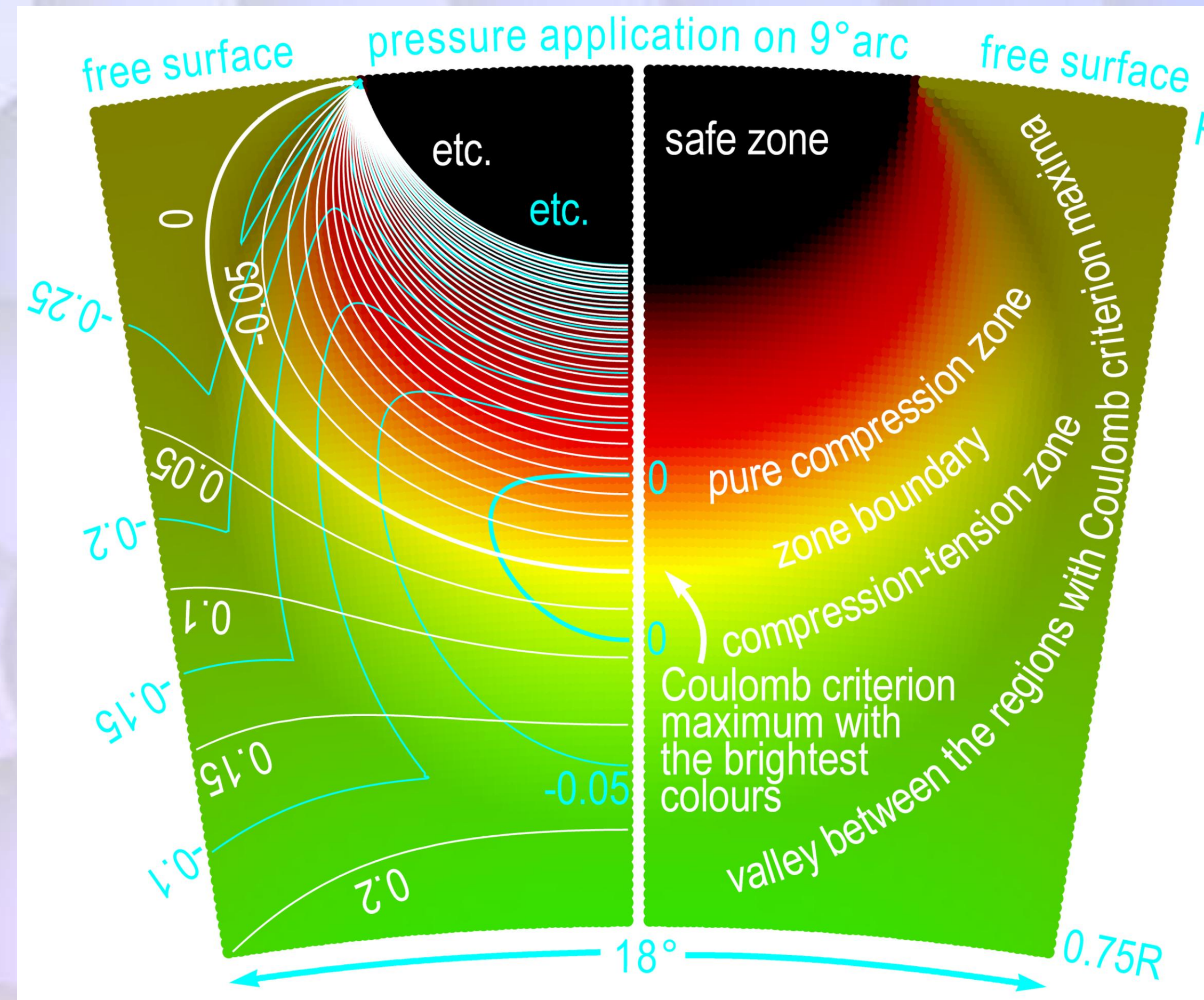


Fig. 4 Commented detail of the load application area in the Brazilian test cross-section. Even a 2D colour function of d, m with $a=1$ shows in a single colour map the features otherwise to be shown in two separate contour plots.

Black background colour function has been used for the Brazilian test colouring:

$$c^{Blk}(d, m, a) = \frac{1}{4} \begin{pmatrix} 1 + a + d + m + ad + dm - a|m|(1+d) \\ 1 + a + d - m + ad - dm - a|m|(1+d) \\ 1 - a + d - ad \end{pmatrix}^T$$

Example 2 – Colouring of the strain rate field around Tatra Mountains (Slovakia)

The GNSS stations are being increasingly used for the monitoring of tectonic processes. In the region of High Tatras in the north of Slovakia, a network of 11 stations recorded the horizontal surface velocities in the order of 1mm/year (Fig. 5).

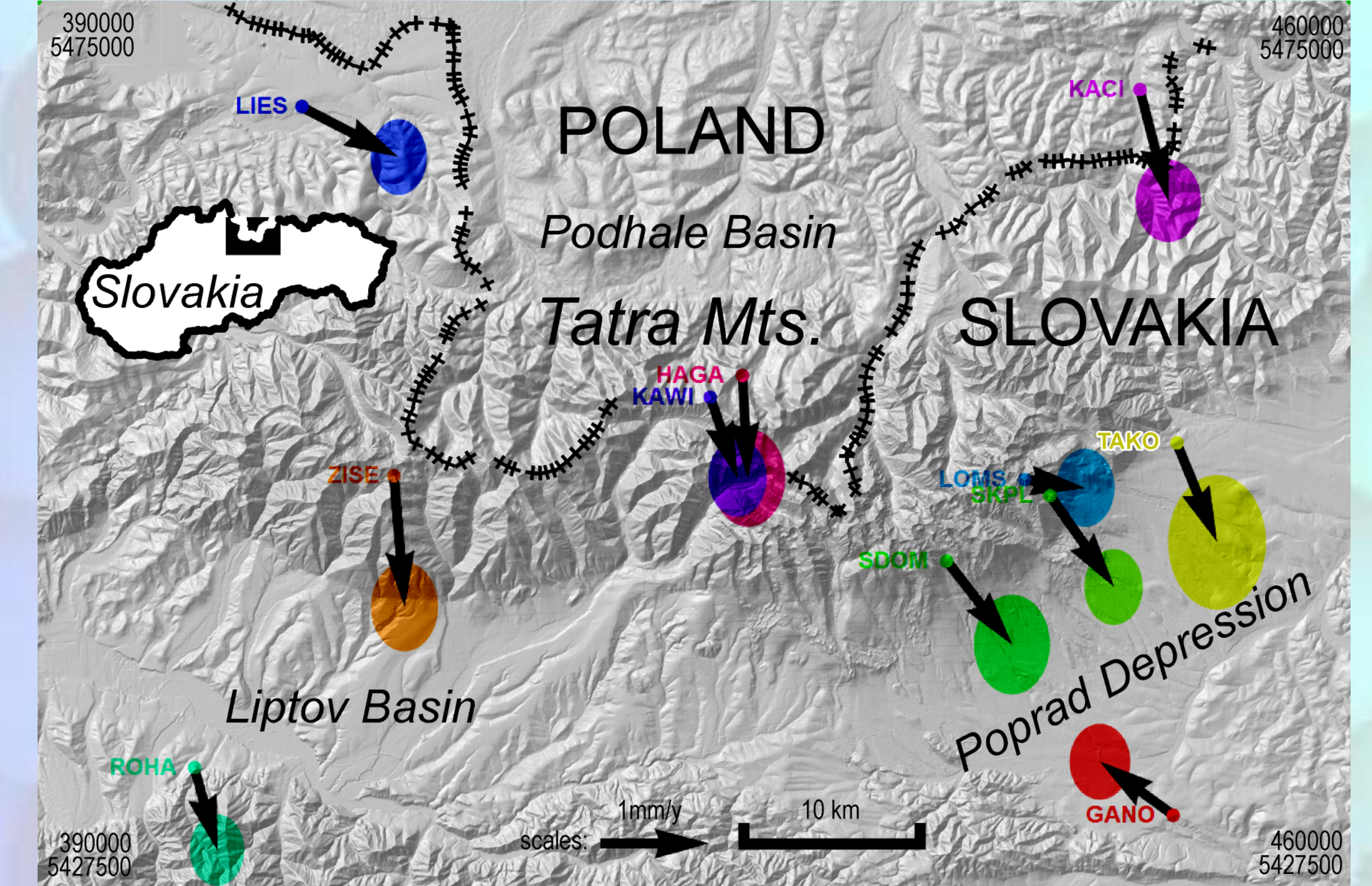


Fig. 5 Horizontal surface velocities and their uncertainties at the GNSS stations of Tatra Mountains region

Given the low density and unequal distribution of the stations and small velocities with small variations, it is very hard to tell from Fig. 5, what is happening with Tatra Mountains. Advanced interpolation methods are needed to construct a continuous surface velocity field. For a better assessment of tectonic processes, the velocity field shall be differentiated into a strain rate field and visualized in colour (Fig. 6).

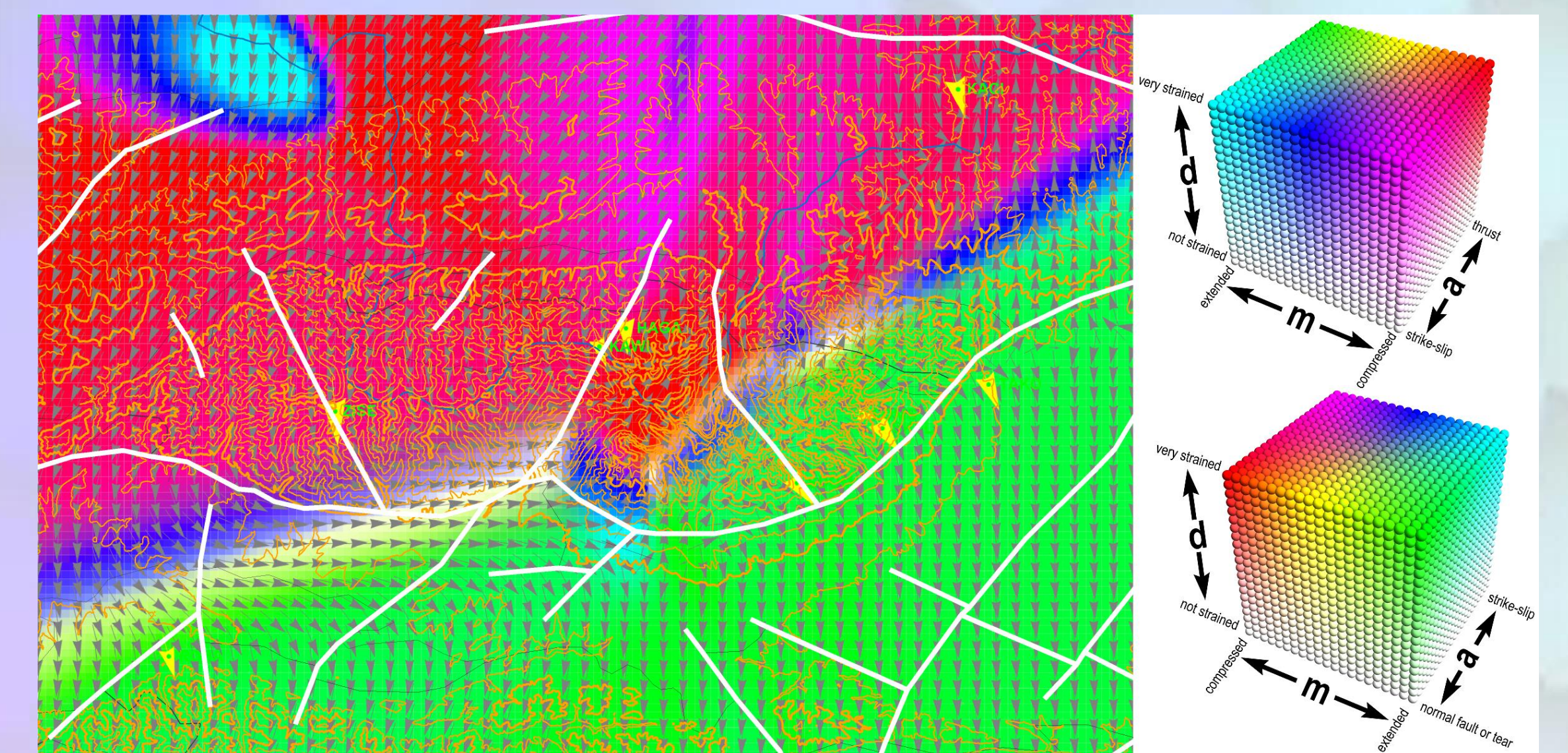


Fig. 6 Strain rate colour map of Tatra Mountains region. Red means compression, green extension. The GAN station has been discarded.

From the GNSS data, we extracted a relatively weak evidence supporting the continuation of the asymmetric uplift of the southern slopes of Tatra along the Sub-Tatra fault.

Reference: Bednárík, M., Papčo, J., Pohánka, V., Bežák, V., Kohút, I., Brimich, L. 2016. Surface strain rate colour map of the Tatra Mountains region (Slovakia) based on GNSS data. Geologica Carpathica, 67, 509 – 524, doi: 10.1515/geoca-2016-0032.

Would you like to express your opinion or suggest some IMS tensor data for colouring? Feel free to write your message onto the margins or send me an email to Martin.Bednarik@savba.sk