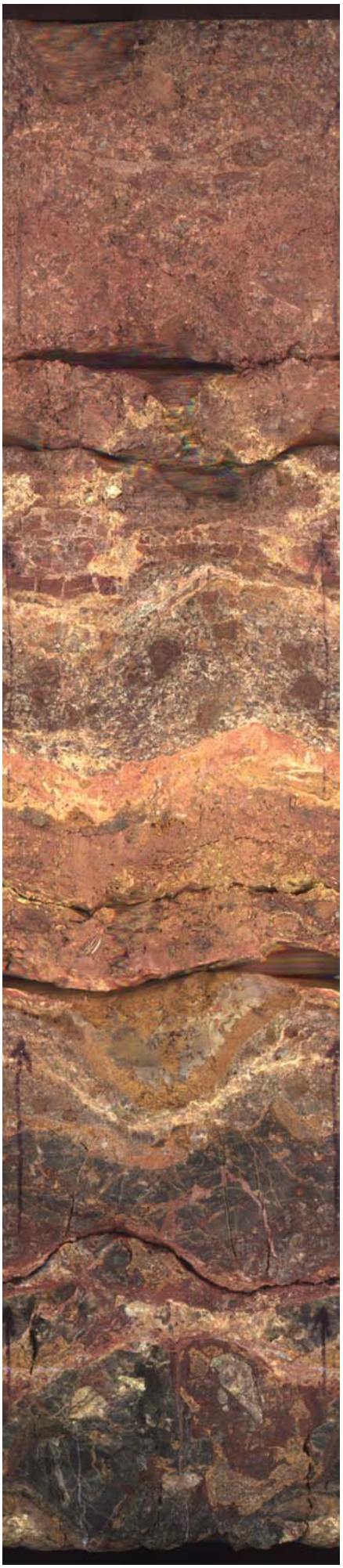

PHD THESES

STRUCTURAL EVOLUTION OF THE MÓRÁGY GRANITE ON THE GROUNDS OF THE BOREHOLE EVALUATION BY THE IMAGEO CORESCANNER

GYULA MAROS

SUPERVISOR
DR. ZOLTÁN NÉMEDI VARGA
PROFESSOR EMERITUS

SÁMUEL MIKOVINY PHD SCHOOL
MISKOLC UNIVERSITY
HEAD OF THE PHD SCHOOL
DR. H.C. MULT. DR. FERENC KOVÁCS
MEMBER OF THE MTA

GEOLOGICAL INSTITUTE OF HUNGARY
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1. HISTORY

The research of the Mórágy Granite started in 1862 when Karl Peters published his observations about the stratigraphy of the Liassic strata and also mentioned the magmatic formations. A more detailed work of these magmatic rocks was issued by Samu Roth in 1875 connected to the mapping done by Böckh–Hoffman. Elemér Vadász was the next to map in the 1910s, but his map was published only in 1935. The following decades produced primarily works of petrological-geochemical theme, then Béla Jantsky started to study the area in the 1950s and remained a dominant figure of the research for a long time. Szádeczky-Kardoss reasoned for a palingene origin, which idea was taken over by Jantsky in his subsequent works. Tibor Szederkényi studied the granite bodies and the connected metamorphic rocks thoroughly all over the South Transdanubia in the 1970s and 1980s, while György Buda was dealing with the mineralogical and age determination problems of the granite. He also achieved significant results in comparing the granite with other Variscan plutons. He was the first to publish the modern magma-mingling theory of the complex. The so-called National Project started in the 1990s aiming at the final disposal of low and intermediate radioactive waste. This research has been supervised by Zoltán Balla since then. The research includes extremely complex methods: surface and deep-borehole geophysical, geological, tectonical, hydrogeological, geochemical, and analytical methods on various objects: deep-boreholes, maps, artificial outcrops, and tunnels. Remarkable new methods and instruments have been born, too. This PhD thesis has also arisen within the frames of this research.

2. RESEARCH OBJECTS, AIMS

I set myself a triple aim when started my PhD thesis.

- I introduce the ImaGeo corescanner and the joined hardware and software system, in the development of which I took on a capital part.
- I introduce its new and effective abilities in core logging with the help of deep-boreholes drilled in the research area.
- I try to outline a consistent structural evolution history of the research area on the basis of the obtained data.

3. RESEARCH METHODS, ANALYSES

As for the *research methods*, they mix with the results, since the major part of the research methods is implied in the data collection and evaluation done by the ImaGeo corescanner and the joined system. This system is self-developed.

The ImaGeo corescanner is part of the ImaGeo field data-collecting and evaluating system (*Fig. 1*). Other incorporated parts of the system are the LIPS (Laser Induced Plasma Spectrometer) and the Photorobot. The former is an instrument to quickly analyse element composition in the field, the latter serves to take oriented, georeferred photo series in the field. The corescanner is built in a van and scans core samples with high resolution. Vectorial evaluation or image processing may be done on the images deriving from the corescanner or the Photorobot by the self-developed CoreDump, CoreTime, and PetCore software. The CoreDump software makes it possible to evaluate planar, linear, or point-like geological objects, it feeds the data into a flexibly extendable database that allows various queries and displays, e.g. stereograms, pole distribution diagrams, self-developed maximum wandering diagrams, rose diagrams, tadpole diagrams, and histograms. The CoreTime software makes a database of the time-relations among the objects and visualises the relations. The PetCore software is suitable for raster image processing on corescanned, outcrop, or thin section images.

The corescanned images and the evaluated vectorial geological objects on them can be oriented with the help of the CoreDump software on the basis of the oriented acoustic borehole televiewer measurements. Thus, the data of the scanned core samples can be evaluated oriented in space.

19 deep boreholes have been analysed with this method, which involved the scanning of 5228 m core samples. In this thesis about 50,000 oriented data have been evaluated. 125 fracture zones have also been evaluated and characterized by means of their state of deformation development.

4. RESULTS

1. I developed the ImaGeo hardware and software system, which is a mobile group of instruments (Corescanner, LIPS, Photorobot) to help the structural and general field geological research, especially the borehole and tunnel documentation. Thus, I made oriented, high resolution borehole documentation possible. I developed softwares (CoreDump, CoreTime, PetCore) for the field data processing, query, and visualization of borehole, outcrop, and tunnel documentation.

2. In my thesis, I determined numerous magmatic, ductile, transitional ductile-brittle, and brittle deformational phenomena. I studied their features and spatial distribution in 19 boreholes. I evaluated more than 50,000 oriented data.
   I distinguished several magma-mingling and leucocratic dyke formation events during the image processing on the basis of intersecting structures. A new feature is the presence of two foliation generations and their separation from the mylonitic zones. Newly described phenomena are the quasi ductile deformational planes and the reddening along fractures.

3. I established characteristic patterns in the spatial distribution of the oriented data: spherical and spherical section patterns, azimuth and dip angle fans, migration, undulation, deflection, and rotation. I explained the appearance of these patterns with geological and structural reasons.

4. I divided the magmatic evolution of the Mórágyi Granite into several phases. I concluded that the boundaries of the rock variations formed by magma-mingling show a two-poled, deformed spherical pattern in space. Consequently, the pluton suffered a synmagmatic deformation during its formation, and it flattened along its present-day ~NE–SW long axis. Leucocratic dykes of different composition cut through the pluton, partly inheriting the original rock boundaries, partly breaking through them. The asymmetric, NE open spherical pattern of the dykes probably formed in a stress field characterized by ~NW–SE dilatation. After the formation of the deformed spherical patterns a multi-poled cooling fracture system evolved.

5. During the examination of its ductile structural evolution I specified the foliation relations of the Mórágy Granite. I separated two foliation generations (a gently dipping and a steep one), as well as a mylonitization event. On the basis of the changes in dip angle, I assumed a long-wavelength (~10 m) folding event that does not change the dip direction. The ductile deformation further polarized the deformed spherical patterns, which reflects best in the distribution of the enclaves. The foliations show a fan-like and not a spherical distribution. I explain the phenomena of refraction and deflection as refracture structures formed during the foliation. From the distribution of the leucocratic dykes a ~55/25° fold axis can be calculated. Thus, I assume that the granite pluton shows a large scale and gentle folding.

6. I divided the research area into domains (Northwestern, Transitional, and South-eastern) on the basis of the structural evaluation of the magmatic and metamorphic phenomena, and I determined their major structural features. In the Northwestern domain mainly NW, in the Transitional domain mixed, and in the Southeastern domain SE dips are dominant.

7. I separated a transitional ductile-brittle deformation phase that is characterized mainly by dextral strike-slips in a stress field of WNW–ESE σ_1; the cataclases form a fracture pair perpendicular to each other.

8. I concluded that the brittle structural evolution resulted in a diverse, multi-phase, multi-rejuvenated structural picture. The fractures altogether, the open, and the closed fractures show spherical distribution. Statistically, the fracture planes bearing striae also show mostly the deformation of the renewal. Most of the dislocations are sinistral, inverse-sinistral, and inverse, but on the same surfaces and directions — in a smaller number — dextral and normal dislocations occurred, too.

9. The brittle deformation principally "uses" fractures parallel with the foliations (~NE–SW strike), or fractures dipping NE, or striking E–W. The closed fractures usually dip towards NE, especially those infilled by hematite and chlorite. According to their distribution, these fractures are preferably steep, however, limonite appears also on gently dipping planes in great number. The most homogeneous distribution is produced by the reddening along fractures, namely it shows spherical dip towards NE in the whole area.

10. The fracture zones show similar distribution to that of the fractures. I classified them on the basis of their characteristic features seen on the borehole televiewer images and in the field, as well as the deformation intensity, and I established a genetic sequence among the various types, from the bundle of fractures to the cataclased rubbly-clayey zones. I determined their azimuth and dip in the deep boreholes. I set up a 3D model of the fracture zones and correlated the zones. I constructed the fracture model of the area (*Fig. 2*) and analysed the run and distribution of the zones. The map distribution of the zones — similarly to the magmatic and ductile structural features, as well as the general fracture distribution — dominantly shows parallel strike to the Mecsekalja Zone. The fracture zones show the characteristics of strike-slip duplexes followed by bundled, sigmoidal lenses and are accompanied by transverse and E–W striking faults. The fracture zones can be interpreted as dislocation zones by means of striae.

11. I qualified the pattern of the fracture zones as stable during the deformation due to the number of renewals, I mean that few new fractures formed with the change of stress-fields, rather, the already existing ones were used for dislocation again.

I assign this stability to the cooling fractures formed along the synmagmatic deformed spherical structure. The following stress-fields could reactivate the suitable planes of the inherited fracture pattern with different dislocation vectors. Accordingly, I set up various kinematic models to explain the different dislocation types in the present-day fracture zone system. The stress-fields characterized by dextral strike-slips are probably older than the the ones characterized by sinistral strike-slips.

The results of this PhD can be applied in the research aimed at the final disposal of the low and intermediate radioactive waste, as well as in the constraction of hydrodynamic and fracture transport models.

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Gyula Maros

Geological Institute of Hungary

1143 Budapest, Stefánia út 14.

Tel/Fax: +36 1 2517678

maros@mafi.hu

www.mafi.hu

Figure 1. Logo of the ImaGeo system

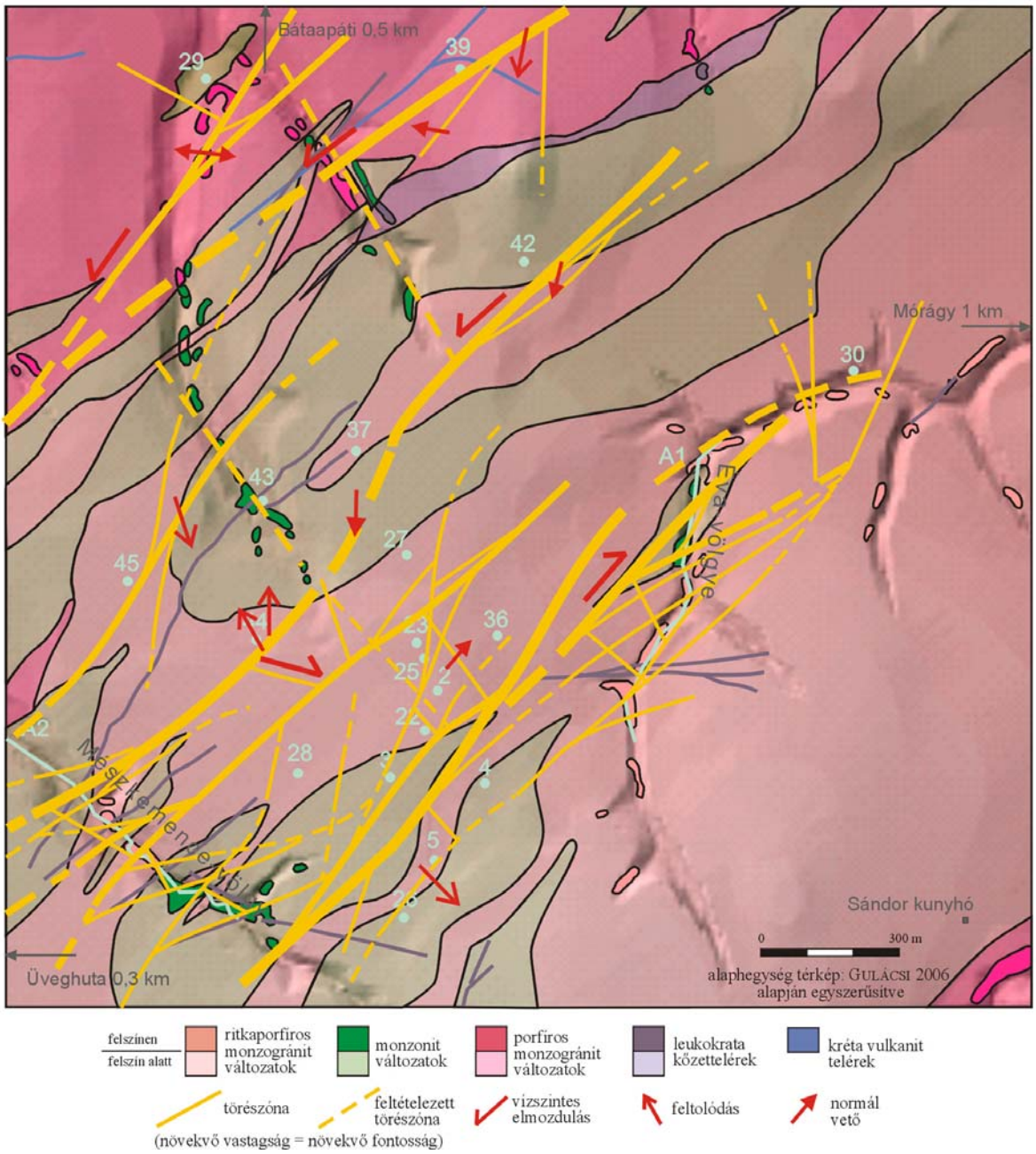

Figure 2. Structural map of the research area. The depth visualization was done by Gyula Maros on the basis of BALLA et al. (2003a)