| Ber. Inst. Erdwiss. K.-F.-Univ. Graz | ISSN 1608-8166 | Band 9 | Graz 2004 |
|---|---|---|---|

# AUTOMATED IMAGE ANALYSIS OF MICROSTRUCTURES: EXAMPLES FROM THE DETACHMENT MYLONITES OF THE SERIFOS METAMORPHIC CORE COMPLEX (GREECE)

Christian RAMBOUSEK, Bernhard GRASEMANN, Konstantin PETRAKAKIS, Christoph IGLSEDER & Andras ZAMONLYI

Department of Geological Sciences, University of Vienna, Austria (christianrambousek@hotmail.com)

The Attic-Cycladic belt is part of the Alpine orogene in the eastern Mediterranean. It is located SE of the Greek mainland and trends parallel to the Hellenic volcanic arc. Since the Miocene the whole area of the southern Aegean region is characterized by a NS orientated extensional regime which is the result of back-arc extension and/or collapse of the inner part of the thickened Alpine crust. After a period of crustal thickening achieved in a cold thermal environment attested by high-pressure, low-temperature metamorphic complexes, internal thrusts were reactivated by extensional structures such as large-scale detachments, below which high-temperature metamorphic core complexes (MCC ) were exhumed (Jolivet & Faccenna 2000)

Some of the islands in the eastern Cyclades (Naxos, Paros, Ios) have been suggested to represent MCC indicating an asymmetric extension partly to the N and to the S (e.g. Lister et al. 1984).

The island of Serifos is situated about 100km SSE of Athens in the Aegean Sea (Salemink 1985) and belongs to the Attic-Cycladic massif. The geology of Serifos is largely characterized by a shallow hornblende-biotite granodiorite pluton that intruded into a, under blueschist conditions previously deformed, sequence mainly consisting of ortho- and paragneisses, calc-silicate marbles, amphibolites and schists. The pluton takes the form of a dome-shaped body occupying the central and southern parts of the island (Salemink 1985). Published geochronological data (Altherr et al 1982) of Hornblende from the granodiorite yield a K-Ar age of 9.5±0.3 Ma while biotite shows Rb-Sr ages ranging from 7.92±0.08 to 8.42±0.08 Ma.

Whereas the northern contact of the pluton is intrusive, in the SE, towards structurally higher levels, this core becomes foliated with increasing intensity and, under greenschist facies conditions, transformed into S dipping low temperature mylonitic to ultramylonitic rocks with abundant SSW-directed kinematic indicators (scc´ fabrics, sigma and delta clasts, flanking structures and mica fish). This zone forms the main greenschist facies to brittle/ductile detachment of the Serifos MCC. The lineation in these rocks has a remarkably consistent NNE-SSW direction whereas the foliation varies and follows the dome shaped structure caused by the exhumation and unloading of the MCC.

On peninsulas in the S and SE part of Serifos (E of Livadi) statically recristallized mylonitic marbles and amphibolite grade metabasic and metapelitic rocks with typical Ca-Fe-Mg skarns, a rock association which is typical for the northern intrusive margin of the pluton, occur in a hanging wall position of the main detachment zone. These characteristic lithologies also occur as mega boudins (several tens of meters long) in the main detachment zone. We therefore conclude that the detachment displaced and shear the northern margin of the pluton in the order of several kilometres.

Quantitative kinematic indicators and micro structures with monoclinic symmetry have been investigated in order to characterize the flow within the main detachment zone. It is well known that in mylonitic zones, an increase in intensity of deformation is expressed by a decrease in grain size, accompanied by recrystallisation (Berthé et al. 1979) as it can be observed in the ultramylonitic granodiorites of the SE detachment zone. There the

undeformed core gets, with increasing intensity, foliated towards the S and turns into a ultramylonite with quartz-, feldspar- and biotite-porphyroblasts in a very fine grained matrix.
Rigid objects in rocks undergoing penetrative ductile non-coaxial flow will tend to rotate with respect to the kinematic frame of the bulk flow, and disturb the developing foliation pattern an a small adjacent domain. Gosh & Ramberg (1976) have shown that, even in non-coaxial flows, rigid objects of specific axial ratio will follow asymptotic movement patterns and can become stationary at high strain (Passchier 1987). This work focuses on the investigation of the rotational behaviour of porphyroblasts in aspect to their shape. With the image analysis program Scion Image (www.scioncorp.com) thin sections of the ultramylonitic Hbl-Bt granodiorite of the southern detachment were analyzed and quartz, feldspar and biotite were separately plotted in aspect to their orientation ($\theta$) and the normalized length-width ratio ($B^*$) of their ideal strain ellipsoid (Fig.1).
Governing equations of the movement of rigid objects in homogeneous flow are least complex for axially symmetric ellipsoidal objects. The axial ratio of such objects can be expressed by a component B* of the Bretherton shape (Bretherton 1962).

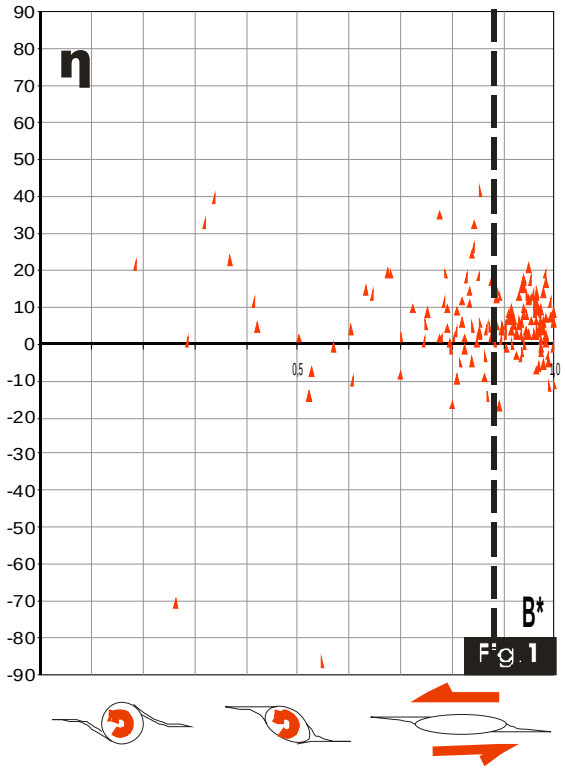


Fig.1. At high B* values, to the right of the cut-off point where basal glide is the main deformation mechanism, the quartz porphyroblasts tend to reach a stable sink position up to a η-value of 20°.

At low B* values, objects rotate permanently and generate δ-type and complex tails. At high B* values, to the right of the ´cut-off point´, objects have their long axis at a stable sink position and generate σ-type tails only. η increases with decreasing B* (Passchier 1987).
As Jeffery 1922 estimated, for simple shear, all rigid inclusions rotate in the same sense. But during combined pure and simple shear elongate rigid inclusions can stabilize with long axes parallel to the shear plane, and there is a range of orientations for which rigid inclusions rotate in an opposite sense as the sense of shear (Ghosh & Ramberg, 1976).

The presented data show that the deformation of the southern detachment zone of the Serifos metamorphic core complex was very close to simple shear though the p/t- conditions are emphasizing a low temperature/low pressure deformation. Quartz c-axis patterns taken from samples of this detachment support this thesis.

## References

ALTHERR, R., KREUZER, H., WENDT, I., LENZ, H., WAGNER, G. A., KELLER, J., HARRE, W. & HOHNSDORF, A. 1982. A late Oligocene / early Miocene high temperature belt in the Attic-Cycaldic crystalline complex (SE Pelagonian, Greece). Geologisches Jahrbuch E23, 97-164.

BEAM, E. C., FISHER, D. M. 1999. An estimate of kinematic vorticity from rotated elongate Porphyroblasts. Lournal of Structural Geology 21, 1553-1559.

BERTHÉ, D., CHOUKROUNE, P., JEGOUZO, P. 1979. Orthogneiss, mylonite and non coaxial Deformazion of granites: The example of the South Armorican Shear Zone. Journal of Structural Geology 1, 31-42.

BRETHERTON, F. P. 1962. The motion of rigid particles in shear flow at low Reynolds number. Journal o f Fluid. Mech. 14, 284-301.

BONS, P., JESSELL, M. W.1996. Image Analysis of Microstructures in Natural and Experimental Samples. Structural Geology and Personal Computers, 135-166.

GHOSH, S., RAMBERG, H. 1976. Reorientation of inclusions by combination of pure and simple Shear. Tectonophysics 34, 1-70.

GHOSH, S. K., SEN, G., SENGUPTA, S. 2003. Rotation of long tectonic clasts in transpressional Shear zones. Journal of Structural Geology 25, 1083-1096.

HEJL, E., RIEDL, H., WEINGARTNER, H. 2002. Post-plutonic unroofing and metamorphogenesis of the Attic-Cycladic complex (Aegea, Greece). Tectonophysics 349, 37-56.

JEFFERY, G. B. 1922. The motion of ellipsoidal particles immersed in a viscous fluid. Proc. R. Soc. Lond. A102, 161-179.

JOLIVET, L., FACCENNA, C. 2000. Mediterranean extension an the Africa-Eurasia collision. Tectonics 19, 1095-1106.

LISTER, G. S., BANGA, G. & FEENSTRA, A. 1984. Metamorphic core complex of Cordilleran type in the Cyclades, Aegean Sea, Greece. Geology 12, 221-225.

PASSCHIER, C. W. 1987. Stable positions of rigid objects in non-coaxial flow – a study in vorticity analysis. Journal of Structural Geology 9, 679-690

RING, U., LAYER, P. W., REISCHMANN, T. Miocene high-pressure metamorphism in the Cyclades and Crete, Aegean Sea, Greece. Evidence for large-magnitude displacement on the Cretan detachment

SALEMINK, J. 1985. Skarn and ore formation at Serifos, Greece, as a consequence of granodiorite intrusion. Unpublished PhD Thesis, University of Utrecht.

VISSERS, R. L. M. 1989. Asymmetric quartz c-axis fabrics and flow vorticity: a study unsing Rotated garnets. Journal of Structural Geology 11, 231-244.