Geotectonic evolution of the Hellenic Rhodope Massif as inferred from magnetic fabric studies in the Vrondou and Symvolon plutons

Irene Zananiri[1], Sarantis Dimitriadis[2], Despina Kondopoulou[3], Adamantios Kilias[4]

[1] Institute of Geology and Mineral Exploration, Mesogeion 70, 115 26, Athens, Greece; E-mail: izanan@geo.auth.gr
[2] Department of Mineralogy and Petrology, School of Geology, Aristotle University of Thessaloniki, P.O. Box 352-1, 54124 Thessaloniki, Greece; E-mail: sarantis@geo.auth.gr
[3] Department of Geophysics, School of Geology, Aristotle University of Thessaloniki, P.O. Box 352-1, 54124 Thessaloniki, Greece; E-mail: despi@geo.auth.gr
[4] Department of Geology, School of Geology, Aristotle University of Thessaloniki, P.O. Box 352-1, 54124 Thessaloniki, Greece; E-mail: kilias@geo.auth.gr

Key words: Hellenic Rhodope Massif, geodynamics, anisotropy of magnetic susceptibility, palaeomagnetism

Introduction

A lot of work has been done concerning the Tertiary tectonic evolution of the Rhodope (Kronberg, 1969; Kronberg et al., 1970; Burg et al., 1990; Koukouvelas, Doutsos, 1990; Dinter, Royden 1993; Dinter 1991, 1994; Dimitriadis, 1995; Burg et al., 1995; Dimitriadis et al., 1998; Kilias, Mountrakis 1998; Mposkos 1998; Soldatos et al., 1998; Kilias et al., 2002). This is characterized by the presence of a several km thick mid crustal subhorizontal shear zone with a top to the SW sense of shear, which affected successively the Rhodopian units from top to bottom during Eocene to Oligocene — Miocene times.

The anisotropy of magnetic susceptibility (AMS) with its scalar and directional aspects has become a standard technique, which in conjunction with field tectonic and microscopic texture analyses is a powerful tool for unravelling the emplacement, cooling and deformational history of granitic plutons (e.g. Bouchez et al., 1990; Trindade et al., 1999). AMS can detect feeble anisotropies imperceptible in the field, imprinted in the rock either at super-solidus temperatures during the emplacement of partly crystallized magmatic bodies, or shortly after their complete crystallization at sub-solidus yet relatively high temperatures, or even long after their emplacement, crystallization and cooling. A combined AMS and microtextural analysis of the state and spatial distribution of deformation covering Vrondou and Symvolon plutons (fig. 1) could help understand the emplacement sequence and the reasons for the observed differences in the deformational behaviour between them. This is the aim of the present study, preliminary results of which have already been presented in Zananiri et al., 2002.

Sampling and measurements

Drilled cores and oriented hand samples were collected at 40 sites from each pluton. Sampling was restricted only in areas exposing fresh rock; due to its deep weathering most of the central part of the Vrondou pluton was for this reason left out. Both

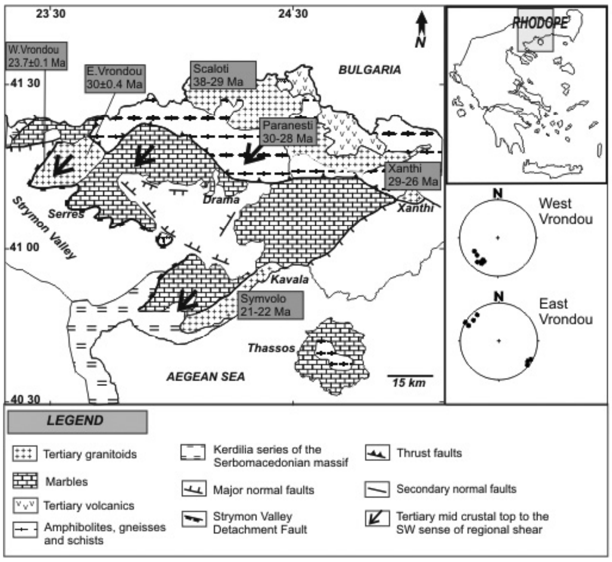

Fig. 1. Tertiary granitoid intrusions (with their isotopic ages) and the main lithological and tectonic features of the Greek Rhodope. (After Kilias, Mountrakis, 1998). The two stereoplots represent stretching lineations measured in the present study in western and eastern Vrondou.

AMS and palaeomagnetic measurements were performed on the collected samples. Thermomagnetic analyses, isothermal remanent magnetization (IRM) measurements and the Lowrie-Fuller and Cisowski tests were carried out to investigate the magnetic mineralogy. Microscopic examination of oriented thin sections helped characterizing the microstructures. All these data were combined with field structural data.

Magnetic results

The magnetic carriers vary slightly with lithology but consist mainly of magnetite in Symvolon and magnetite accompanied by small amounts of heamatite in Vrondou (fig. 2). In some thermomagnetic analyses, before reaching 580°C, the magnetic susceptibility shows a slight increase related to the Hopkinson effect. Magnetite as the prevailing magnetic phase is also verified by thermal and AF-demagnetization experiments. Finally, combining the results of the thermomagnetic curves and the Lowrie-Fuller tests we can assume that we have a mixture of coarse- and fine-grained magnetites.

In both plutons the bulk susceptibility magnitude as well as the magnetic anisotropy, sometimes reaching 60%, are high, thus pointing to a dominant ferromagnetic control of the magnetic properties. Two groups of magnetic lineations were identified: a prevailing NE-SW-trending linear fabric, visible main-

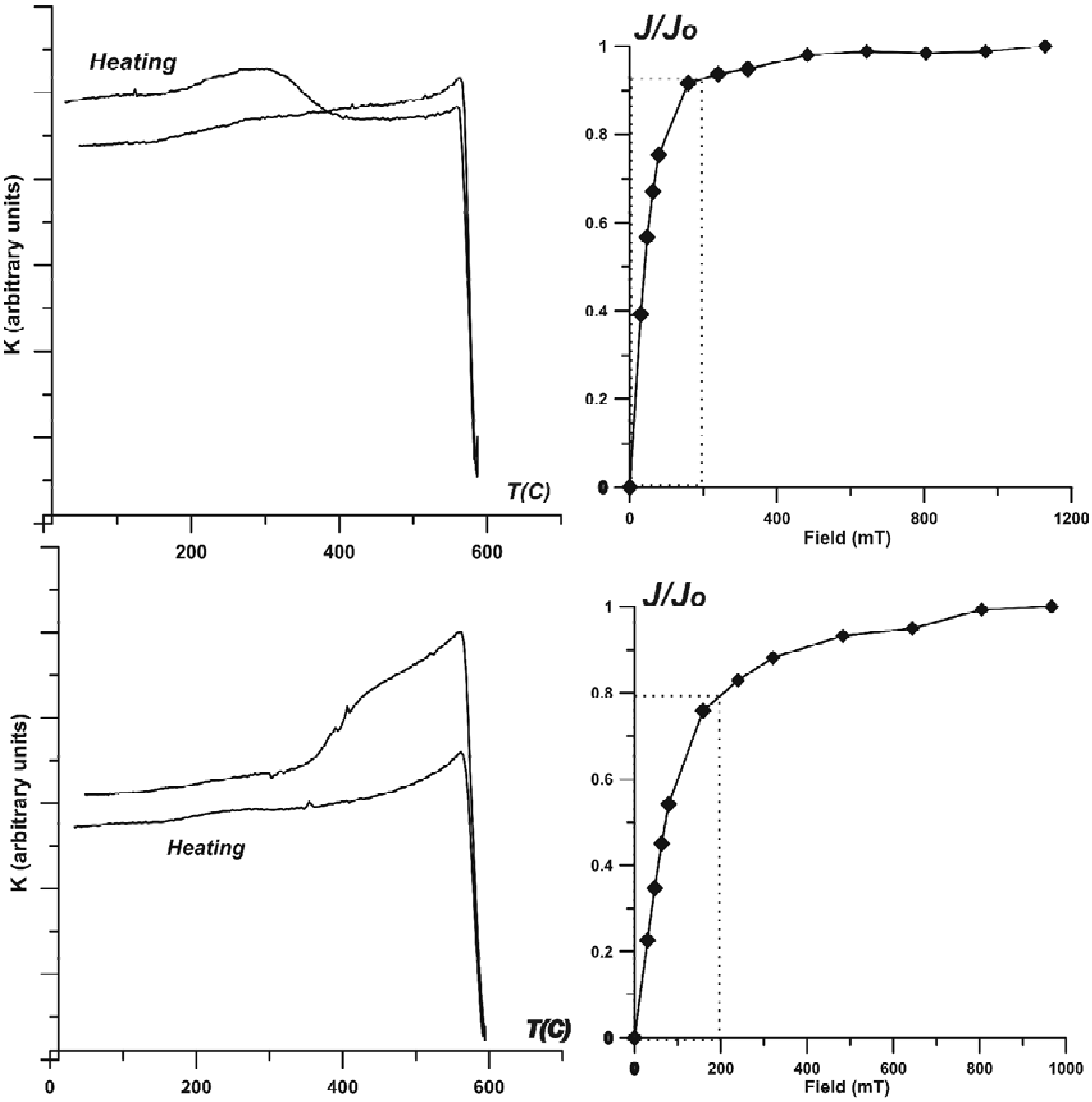

Fig. 2. Representative thermomagnetic and IRM acquisition curves for Symvolon (top) and Vrondou (bottom) plutons

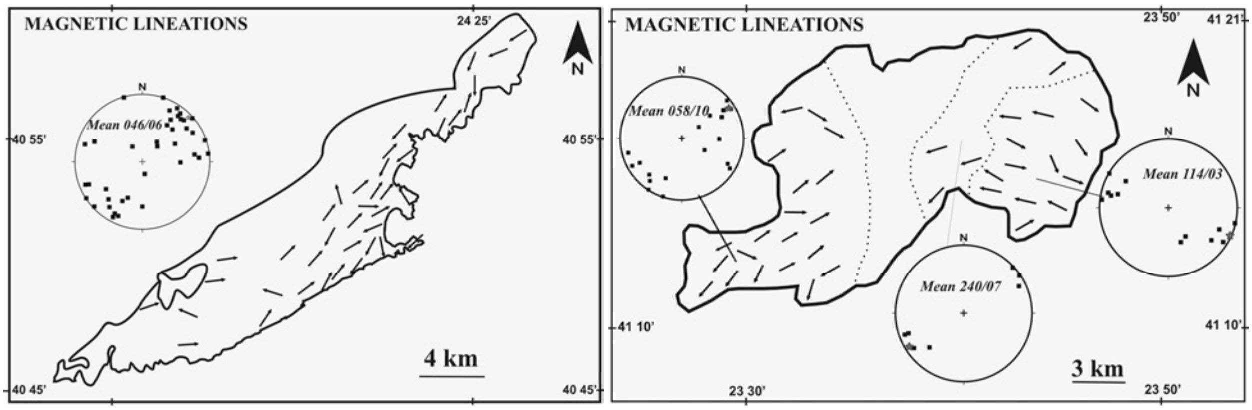

Fig. 3. Magnetic lineations (K_1 axe), Schmidt plots (lower hemisphere) and average orientations in Symvolon (left) and the western and eastern parts of Vrondou (right) plutons. The dashed lines distinguish between the parts of the pluton where the stereoplots are valid.

ly in the Early Miocene plutons, and a second NW-SE-trending fabric, clearly imprinted in the Mid-Oligocene eastern part of the Vrondou pluton (fig. 3). Macro- and microtextural study revealed the presence of magmatic textures, mainly in eastern Vrondou, and sub-solidus plastic deformation textures, in Symvolon and western Vrondou. Paleomagnetic results displayed a complex pattern with both clockwise and counterclockwise rotations.

Conclusions

The emplacement model we present is inspired from one already proposed by Kolokotroni and Dixon (1991) and Kolokotroni (1992). Following these authors we envisage a subhorizontal extensional ramp space at mid crustal levels formed by the regional top to the SW shear movement in the Rhodope, active during the Mid Oligocene to Early Miocene period. A box-like extensional ramp space was incrementally widening and was simultaneously being filled with batches of magma generated at deeper levels. Free space for the influx of magma within the extensional ramp was provided by the southwestward movement of its frontal edge in relation to its back edge, and this may have been accommodated by strike-slip movements on two subvertical shear zones bounding the ramp space from NW and SE and acting as paths for the ascending magma, which was therefore entering from the NW or SE the gradually developing ramp space and was filling it by steaming along a NW-SE direction. Early magmatic intrusions were attached to the back edge of the ramp space, while new space was developing in its frontal edge. A similar subvertical shear zone may have acted as a path for the ascending magma in the case of the Symvolon pluton. This same shear zone, after the exhumation of the pluton, could have developed into the normal Kavala — Xanthi — Komotini fault. The older eastern part of the Vrondou pluton is much less deformed than the Early Miocene western Vrondou and Symvolon plutons. Magmatic textures are well preserved in the older intrusion whereas they are scarcely present in the younger ones. They indicate a NW-SE direction of magmatic flow in both cases. Sub-solidus plastic deformation affected mostly the younger intrusions and only locally the older eastern one. In all cases mineral lineations trending NE-SW were developed. An increase in the shear rate by the Early Miocene or a localization of shear mainly in the west, in combination with the more silica saturated rock types present there, are probably the reasons for the different deformational behaviour of the two parts of the Vrondou pluton.

References

Bouchez, J.-L., G. Gleizes, T. Djouadi, P. Rochette. 1990. Microstructure and magnetic susceptibility applied to emplacement kinematics of granites: the example of the Foix pluton (French Pyrenees). — *Tectonophysics, 184*, 157—171.

Burg, J. P., Z. Ivanov, L. E. Ricou, D. Dimov, L. Klain. 1990. Implications of shear-sense criteria for the tectonic evolution of the central Rhodope massif, southern Bulgaria. — *Geology*, *18*, 451—454.

Burg, J. P., I. Godfriaux, L. E. Ricou. 1995. Extension of the Mesozoic Rhodope thrust units in the Vertiskos-Kerdilion Massifs (Northern Greece). — *C. R. Acad. Sci. Paris*, 320 Iia, 889—896.

Dinter, D. 1991. Neogene detachment faulting and the Rhodope metamorphic core complexes, northern Greece. — In: *EOS Trans. AGU*, 72(44), Fall Meet. Suppl., 460.

Dinter, D. A. 1994. *Tectonic evolution of the Rhodope metamorphic core complex, northeastern Greece*. PhD thesis, Mass. Inst. of Technol., Cambridge, 320 p.

Soldatos, T., G. Poli, G. Christofides, G. Eleftheriadis, A. Koroneos, S. Tommasini. 1998. Petrology and evolution of transitional alkaline-subalkaline granitoids from Vrondou (NE Greece): evidence for fractional crystallization and magma mixing. — *Acta Vulcanologica, 10* (2), 319—330.

Dinter, D. A., L. H. Royden. 1993. Late Cenozoic extension in northeastern Greece: Strymon Valley detachment and Rhodope metamorphic core complex. — *Geology*, *21*, 45—48.

Dimitriadis, S. 1995. A likely petrological evidence for large scale southwestward displacement of the Serbomacedonian over the Pangaion Unit in Late Tertiary. — *Geological Society of Greece, Special Publications*, No 4, 21—23.

Dimitriadis, S., D. Kondopoulou, A. Atzemoglou. 1998. Dextral rotations and tectonomagmatic evolution of the southern Rhodope and adjacent regions (Greece). — *Tectonophysics, 299*, 159—173.

Kilias, A. A., D. M. Mountrakis. 1998. Tertiary extension of the Rhodope massif associated with granite emplacement (Northern Greece). — *Acta Vulcanologica*, *10* (2), 331—337.

Kilias, A., M. Tranos, M. Orozco, F. Alonso-Chaves, J. Soto. 2002. Extensional collapse of the Hellenides: a review. — *Rev. Soc. Geol. Espana*, *15* (3-4), 129—139.

Kolokotroni, C. 1992. *The emplacement and petrogenesis of the Vrodou granitoid pluton, Rhodope massif, NE Greece*. PhD thesis, University of Edinburgh, 425 p.

Kolokotroni, C. N., J. E. Dixon. 1991. The origin and emplacement of the Vrondou granite, Serres, NE Greece. — *Bulletin of the Geological Society of Greece*, *25*, 469—483.

Koukouvelas, J., T. Doutsos. 1990. Tectonic stages along a traverse cross cutting the Rhodope zone (Greece). — *Geol. Rundsch*., *79*, 3, 753—776.

Kronberg, P. 1969. Petrografie und Tectonik im Rhodopen-Kristallin des Tsal-Dag, Simvolon und Ost-Pangaon (Griechisch-Makedonien). — *N. J. Geol. Pal. Abh.*, *7*, 140—156.

Kronberg, P., W. Meyer, A. Pilger. 1970. Geologie der Rila-Rhodope-Masse zwischen Strimon und Nestos (Nordgriechenland). — *Beih. geol. Jb*., *88*, 133—180.

Mposkos, E. 1998. Cretaceous and Tertiary tectonometamorphic events in Rhodope zone (Greece). Petrological and geochronological evidences. — *Bulletin of the Geological Society of Greece*, *vol. XXXII/3*, 59—67.

Trindade, R., I. Raposo, M. Ernesto, R. Siqueira. 1999. Magnetic susceptibility and partial anhysteretic remanence anisotropies in the magnetite-bearing granite pluton of Tourao, NE Brazil. — *Tectonophysics, 314*, 443—468.

Zananiri, I., S. Dimitriadis, D. Kondopoulou, A. Atzemoglou. 2002. A preliminary AMS study in some Tertiary granitoids from Northern Greece: integration of tectonic and paleomagnetic data. — *Physics and Chemistry of the Earth, 27*, 25-31, 1289—1297.