

DUCTILE SHEAR ZONE AND BRITTLE FAULTS IN THE SOUTHWESTERN SLOPE OF ZLATITSA-TETEVEN MOUNTAIN (CENTRAL BULGARIA)

Manol Antonov, Venelin Jelev

University of Mining and Geology "St. Ivan Rilski", Sofia 1700, Bulgaria, E-mail: msantonov@staff.mgu.bg; vjelev@staff.mgu.bg

ABSTRACT

The newly established Anton ductile shear zone is characterized by distinct SL fabric, constant orientation of mylonitic foliation and stretching lineation, and uniform top-to-north shear sense. It follows the southern contact of Vezhen pluton and is superimposed mainly on its granodiorite phase and the rocks of Dalgidel Group. The mylonitic foliation within the zone is cut by undeformed aplite veins of the pluton and most probably was formed towards the end of the Hercynian tectonic cycle. Late Alpine reverse faults and thrusts intersect the zone obliquely. These brittle faults are concentrated in two strips. The southern one includes the Anton reverse fault and the northern – the Vezhen thrust, Dzhemina reverse fault-thrust, Mechesh reverse fault, Kashana reverse fault-thrust and Svishtiplaz allochthone. The faults of the northern strip may be used to divide tectonic units of different age (Early and Late Alpine).

INTRODUCTION

The southwestern slope of Zlatitsa-Teteven Mountain between Zlatitsa pass and Anton village was not subject of detailed geological investigations until now, except its ridge part. That is why the descriptions of the established separate fragments of fold and fault structures (Poushkarov, 1927; Kamenov, 1936; Mandev, 1942; Trashliev, 1961; Tsankov, 1961; Kouykin and Milanov, 1970; Kouykin et al., 1971; Antonov, 1976) as well as some regional overviews (Bonchev, 1961; Bonchev and Karagyuleva, 1961; Yordanov et al., 1965; Vrablyanski, 1971; Cheshitev, 1971; Tsankov, 1995; Cheshitev, 1995 and others) suggest contradictory ideas about the structure of the region studied.

The region was mapped in scale 1:25 000 in view to reveal its prospective for endogenic gold-sulphide ore mineralizations. This work presents some results of this mapping concerning the location, geometry, trend, kinematics and temporal relationships of a newly established ductile shear zone and of some Alpine reverse faults and thrusts known from previous studies. The boundary between the high-grade and low-grade metamorphic rocks, cropping out in Zlatitsa pass and west of Anton Village and assumed to be a post-, syn- or pre-metamorphic thrust (Mandev, 1942; Tsankov, 1961; Kouykin and Milanov, 1970; Ivanov et al., 1987 and others), will be characterised in another paper.

Regional setting

Most of the previous investigators of the western part of Zlatitsa-Teteven Mountain assumed that it comprises parts of two large tectonic units, designated by different names. The northern unit was at first described as Etropole anticline (Kamenov, 1936), and later – as Central Balkan anticlinorium (Kouykin and Milanov, 1970), Shipka anticlinorium (Bonchev, 1971), Shipka Stara Planina (Cheshitev, 1971) or Etropole unit (Tsankov, 1995). The southern unit was characterised as

eastern part of the Svoge anticline (Kamenov, 1936) or Svoge anticlinorium (Kouykin and Milanov, 1970), northern part of Sredna Gora anticlinorium (Bonchev, 1961) or Chelopech unit (Tsankov, 1995). All authors assume that the boundary between these two units is tectonic. It has been described as Sub-Balkan deep-seated fault (Bonchev, 1961), Kashana thrust (Kouykin and Milanov, 1970) or Dzhemina reverse fault (Vrablyanski, 1971; Cheshitev, 1971).

Along the ridge of Zlatitsa-Etropole Mountain, the northern unit is represented by a large anticlinal fold, known as Etropole or Central Balkan anticline. Most of the authors (Kouykin and Milanov, 1970; Kouykin et al., 1971; Antonov, 1976 and others) consider it to be the westernmost second-order fold in the confines of the Central Balkan or Shipka anticlinorium. The data from adjacent territories (Nachev, 1963; Antonov, 1971; 1976 and others) demonstrate that it was formed at the end of the Early and before the Late Cretaceous. Its core is built up of Early Proterozoic low-grade metamorphic rocks, referred to the Berkovitsa and/or Dalgidel Groups and Grohoten Formation, as well as of granodiorites from the Late Hercynian Vezhen pluton. Several small and isolated outcrops of its Mesozoic mantle and southern limb are preserved. They comprise sandstones and limestones of Lower and Middle Triassic age (Petrohan Terrigenous and Iskar Carbonate Group).

The southern unit is a fold-and-thrust structure. It comprises small fragments of fold limbs, built up of Upper Cretaceous sedimentary rocks. Precambrian gneisses as well as Paleozoic low-grade metamorphic rocks and granitoids, intersected by Late Cretaceous subvolcanic dykes and bodies, are thrust over them along longitudinal faults.

Ductile shear zone

During the present investigation, a subequatorial ductile shear zone along the southern contact of Vezhen granodiorite pluton was recognised (Fig. 1). It will be designated further as

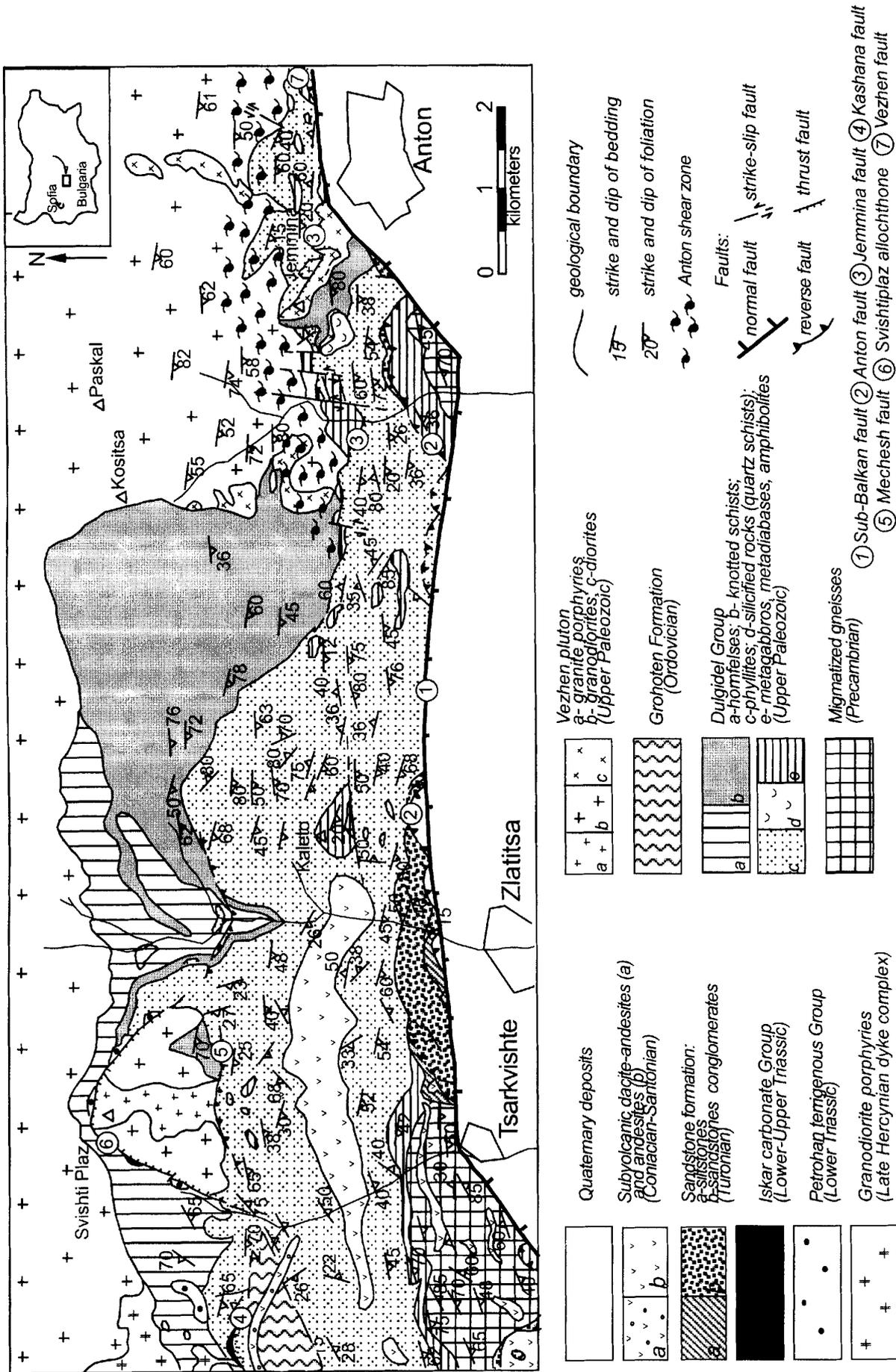


Figure 1. Geological map of the southwestern slope of Zlatitsa-Teteven mountain (Central Bulgaria)

Anton shear zone. It comprises mainly mylonites and blastomylonites and less commonly cataclasite-mylonites and protomylonites. This zone is more than 3 km long, 500-700 m thick, dipping 50-60° to the south.

Most of the previous investigators have described the rocks in this zone but failed to recognise it as an independent and important element of the regional structure. Poushkarov (1903) first mentioned "granitogneisses" north and northeast of Anton village and described them as "amphibole granitogneisses" and "chlorite granitogneisses". Bonchev (1908) confirmed their presence, but emphasised that there was no sharp boundary between them and "the typical granites". Later Mandev (1942) also mentioned that the granodiorite close to the contact with the Paleozoic rocks was "gneissified and in places mylonitized". On the maps of Kouykin and Milanov (1970) and Kouykin et al. (1971) a "zone of cataclasis and mylonitization" is shown immediately north and northwest of Dzheminski Kamak Peak. These authors assume that the zone is related to the movements along Kashana thrust. According to them "the granodiorites lying at the front of the thrust are strongly schistose at a distance of 300-800 m". This opinion is shared by Velchev et al. (1973f), who describe "cataclised and mylonitized diorites and granodiorites" as well as "striped mylonite" north of Dzheminski Kamak Peak.

The ductile shear zone is superimposed mainly on the granodiorite phase of the Vezhen pluton and partly on the green-schist rocks (metapelites and metaaleuropelites) of Dalgidel Group and the diorites of the first phase of the pluton. The northern boundary is a very gradual transition to less and less schistose granodiorites and diorites, in an interval of visible thickness 200 to 600-700 m. The southern boundary is also a gradual transition towards the low-grade metamorphic rocks of Dalgidel Group.

To the north of the shear zone, the granodiorite protolith is represented by mesocratic rocks, medium- to coarse-grained, of massive texture. Principal minerals are plagioclase, potassium feldspar, quartz, amphibole and biotite. Due to the fact that these minerals participate in different quantities, amphibole-biotite, biotite and amphibole granodiorites can be recognised. The diorite protolith is melanocratic, fine-grained, built up mainly of plagioclase, amphibole, biotite and a little quartz.

To the south of the shear zone, the rocks of Dalgidel Group crop out. They are represented mainly by metapelites and meta-aleuropelites, comprising chlorite, sericite, muscovite, quartz and albite as well as rare grains of epidot, rutile, zircon and ore minerals. Their structure is microlepidoblastic to microlepidogranoblastic. According to the quantities of the principal rock-forming minerals, phyllites (quartz-sericite schists) and quartz-chlorite-sericite schists are recognised. Meta-aleurolites are rarely observed as thin interbeds while metapsammites form single layers amongst the metapelites. In the valley of Elenska river and northwest of Dzheminski Kamak Peak, they form a packet of rhythmic flysch alternation.

The changes in the composition and the structural features along the shear zone allow the recognition of three domains: central – formed of mylonites and blastomylonites, northern – of granodiorite and partly diorite protomylonites and southern –

of mylonitized greenschist rocks. Due to the gradual changes of the deformation gradient, the boundaries between the domains are transitional zones 10-50 m thick. Only in the western part of the zone, situated between the rivers of Elenska and Madzharin, anastomically ramificated narrow shear zones are observed in the diorite protolith. Pods of slightly schistose or equigranular diorites occur amongst them.

The central domain of most intensive deformation is from 30 to 120 m thick. It is situated at a distance of several to 10-15 m north of the southern contact of Vezhen pluton. The mylonites and blastomylonites of the central domain are augen-striped rocks featured by relic magmatic mineral association comprising plagioclase (oligoclase-andesine), biotite, amphibole, single grains of K-feldspar (microcline) and rare alanite. The metamorphic association includes entirely re-crystallized quartz, sericite, epidot and chlorite. The relic plagioclase is represented by crystaloclasts and porphyroclasts. Biotite is red-brown, affected by muscovitization with separation of epidot and dusty iron-titanium products. The relic amphibole as well as the alanite form porphyroclasts as well. The metamorphogenic quartz is entirely re-crystallized and forms strips of lenticular and mosaic structure. These strips alternate with pods domains built up of fine-crystalline (due to dimension reduction) sericite, plagioclase and epidote. The boundaries of the porphyroclasts are usually resorbed but sometimes are sharp. Oval and rare angular porphyroclasts elongated parallel to the foliation prevail.

The protomylonites and cataclastic mylonites of the northern domain are distinguished by larger size and prevailing angular shape of the porphyroclasts. Plagioclase porphyroclasts possess frequently deformed crystal lattice and cataclasis developed along their periphery.

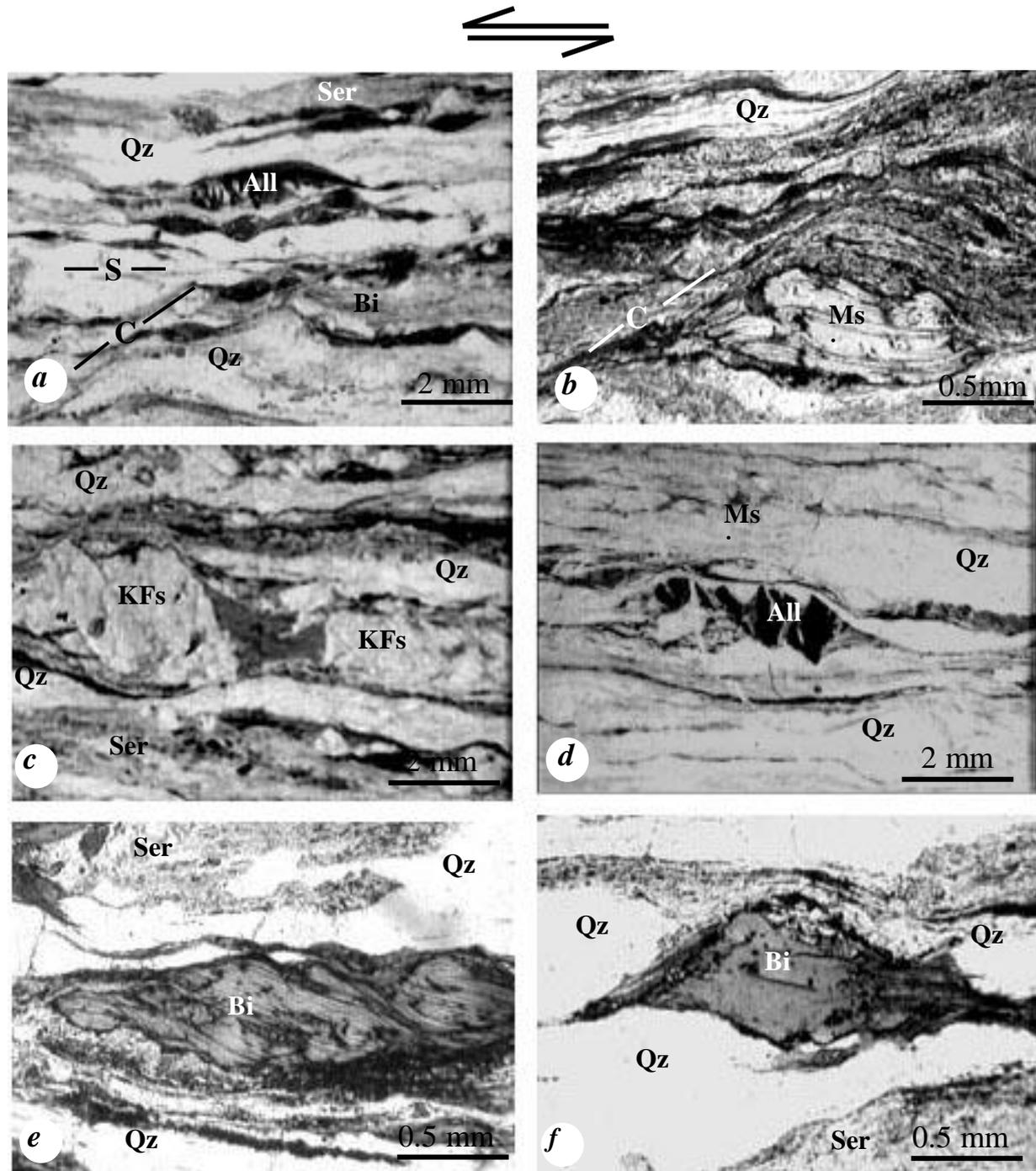
The mylonitized pelites and aleuropelites of the southern domain comprise apophyses of the granodiorite protolith, altered to protomylonites.

The ductile shear zone exhibits a distinct SL-fabric of dominating mylonitic foliation and mineral stretching lineation. They are determined by planar-parallel and linear preferred orientation of the mica minerals and mineral aggregates, the long axes of porphyroclasts and domains enriched in quartz and mica.

The orientation of the mylonitic foliation is 80-100°/50-70° to south. It almost entirely coincides with the trend of the axial cleavage of the rocks of Dalgidel Group. To the west of the valley of Elenska River and to the north of Anton Village, this foliation is folded in cm and dm kink-folds (Table 2, b). The stretching lineation lies in the planes of the mylonitic foliation. Usually it is subparallel to the dip line of the mylonitic foliation.

The shear sense was determined by means of microstructural synkinematic criteria (Passchier and Trouw, 1996), recognised in five oriented rock samples which were collected from different domains of the ductile zone. The microscopic observations of S-C' fabrics, σ - porphyroclasts, mica fish etc. in thin sections parallel to the stretching lineation and perpendicular to the mylonitic foliation demonstrate (Table 1) that a thrust shearing top-to-north took place. Additional

Table 1



Micro-photographs of thin sections at right angles to foliation and parallel to lineation (X-Z sections) looking up towards the east for the samples of granodiorite mylonites of the Anton shear zone (Qz – quartz; Bi- biotite; Ms- muscovite; KFs- K-feldspar; All- allanite; Ser- sericite; N II): a and b – S-C' fabric relationships and mica fish; c – tiling structure in K-feldspar porphyroclast with antithetic micro-faults; d – fragmented allinite porphyroclast, intersected by synthetic and antithetic micro-faults; e – mica fish intersected by antithetic micro-shears; f – mica (biotite) fish

detailed investigations are required to clarify the kinematics of the ductile deformation.

The ductile shear zone between Dzheminski Kamak Peak and the ridge separating the rivers of Madzharin and Bouchoum is obliquely cut and covered by the allochthone of Dzhemina thrust. This zone was probably formed at the end of the Hercynian tectonic cycle, because it is intersected by undeformed aplitic veins of the Vezhen pluton (Table 2, c).

Brittle faults

Several small and isolated outcrops of rocks from the Turonian sandstone formation are exposed amongst the schists and phyllites of Dalgidel Group in the southern foot of Zlatitsa Mountain. They mark the traces of Late Alpine faults. These outcrops are relics of Late Alpine fold limbs, which are cut by longitudinal faults. From south to north, three relatively larger faults are traced – Anton reverse fault, Dzhemina reverse fault-thrust and Kashana reverse fault-thrust, as well

as two smaller faults – Mechesh reverse fault and Svishtiplaz allochthone.

The Anton reverse fault was recognised and nominated by Kouykin and Milanov (1970) as “Anton thrust”. During the present study, the fault was traced more accurately in the field. It continues to the west across Sanardere valley and ends into Balamdere valley. The fault trends 80-85° and dips 60-70°S. Its hanging wall, built up of migmatized gneisses and rocks of Dalgidel Group (metabasites, metagranites, felsites, quartz-chlorite-sericite schists and phyllites) is cut by the longitudinal Sub-Balkan normal fault. The footwall comprises mainly phyllites of Dalgidel Group and only locally, immediately beneath the reverse fault plane, the rocks of the sandstone formation (Turonian) are preserved.

The Dzhemina reverse fault-thrust was established and nominated by Milanov et al. (1964f) as “Dzhemina reverse fault” and described by Vrablyanski (1971). Later it was considered by Kouykin and Milanov (1970) and Kouykin et al. (1971) as the easternmost part of “Kashana thrust”. Velchev et al. (1973) named it “Kashana reverse fault”. The fault is traced reliably from the western end of Anton village to the valley of Bochoum River to west. That is why it is assumed here as an independent rupture. The fault trace, mapped during the present study only in separate areas, coincides with the fault lines given by the previous investigators. From Anton village, where the fault is cut by the Sub-Balkan normal fault, to the valley of Kalimandere (southwest of Dzheminski Kamak Peak), the fault zone dips 30°S (Table 2, d). To the west it becomes steeper – up to 45-50°S. The zone includes banded tectonic breccia and tectonic clay (Table 2, e, f). Its thickness varies from 0,5 to 8-12 m. Maximum thickness was measured in Mandzharindere and Kalimandere River. There, the diameters of the breccia polygenic clasts are 1-5 cm. They are well polished and well rounded. (Table 2, f).

The hanging wall, i. e. the allochthone is built up mainly of phyllites and knotty schists of Dalgidel Group. Quartzdiorites and very small outcrops of granodiorites are exposed in the massif of Dzheminski Kamak Peak and to the east forming a lower imbrication plate along the left (north-northeastern) riverside of Zhitnitsa river (Table 2, e). The foot wall, i. e. the autochthone, comprises phyllites, quartz-chlorite-sericite schists and a flysch alternation of Dalgidel Group. Northwest of Dzheminski Kamak Peak it includes mylonites of the ductile shear zone.

West of Dzheminski Kamak Peak, the reverse fault–thrust is replaced by five small transversal faults of probable strike-slip character. The strike-slip with largest visible horizontal amplitude of about 500 m is traced immediately to the east of Elenska River. Its trend is subequatorial (10°) and the length is more than 1 km.

The Vezhen thrust was recognized by Mandev (1942) and later was considered as a western continuation of the Stara Planina granite nappe (Bonchev, 1961; Bonchev and Karagyuleva, 1961) or Central Balkan thrust (Yordanov et al., 1965). It was described by Kouykin et al. (1971) as “Vezhen part of the thrust” or “Vezhen allochthone”. A small segment (about 300 m long) of the western termination of the thrust is exposed in the western part of the region studied. Along this

segment east of Gusheva River, migmatized gneisses are thrust over the rocks of Dalgidel Group.

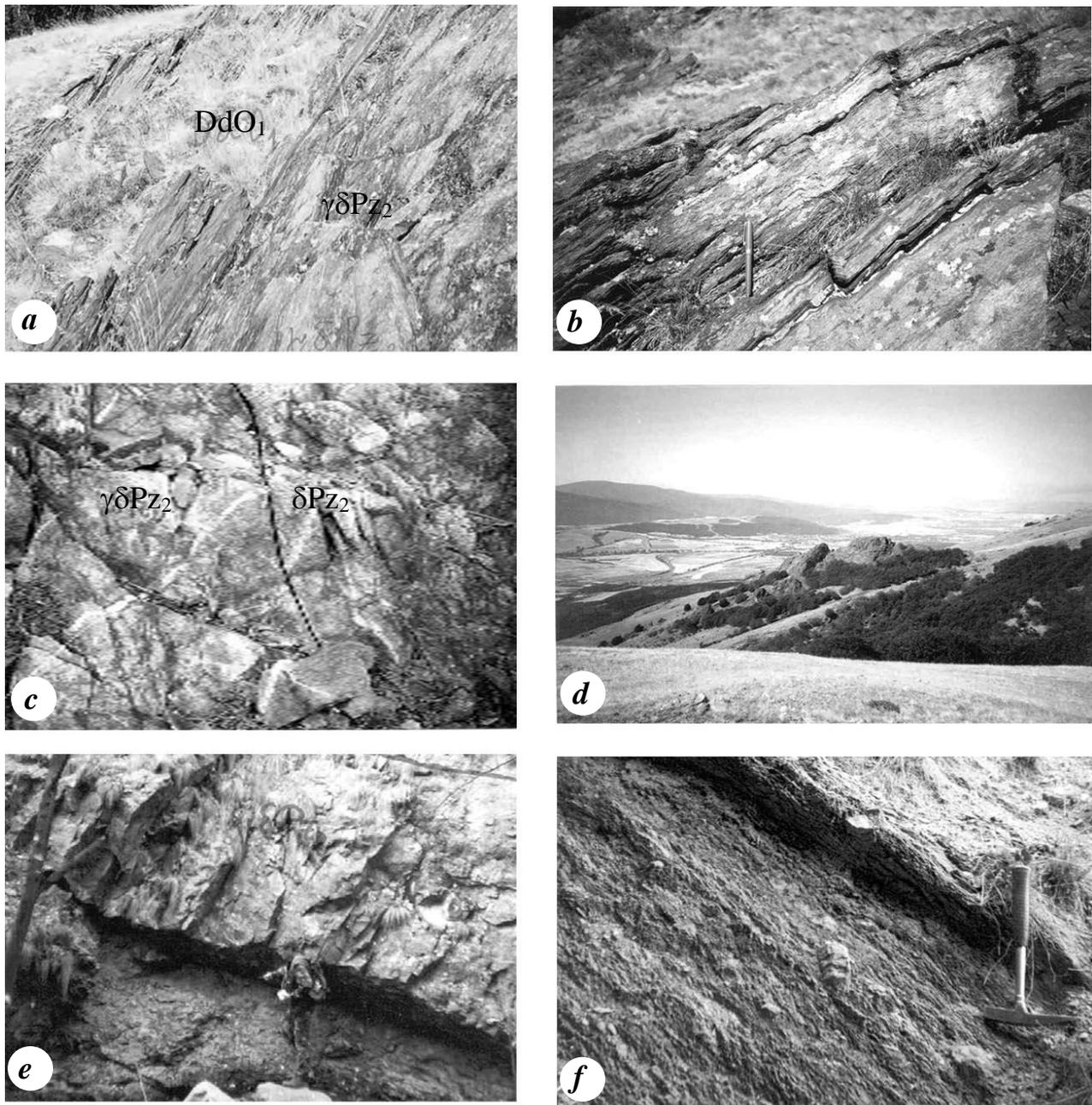
The Kashana reverse fault-thrust was recognised by Trashliev and Trashlieva (1956f) and Trashliev (1961) and described as a “deep dislocation line”, but it was named by Milanov et al. (1964) as “Kashana dislocation” and “Kashana thrust” (Kouykin and Milanov, 1970; Kouykin et al., 1971). According to Milanov et al. (1964), the “Kashana dislocation” may be traced to the east along the northwestern, northern and eastern slopes of Svishtiplaz Peak and across the valley of Kouroudere River to the southwest of Balkan Chalet. Kouykin and Milanov (1970) and Kouykin et al. (1971) continue the fault trace to the west of Anton Village, assuming the Dzhemina reverse fault–thrust to be its easternmost part.

Despite the detailed observations around Kashana mine and along the ridge of Svishtiplaz Peak during the present investigation, reliable field criteria to trace the Kashana reverse fault–thrust to the east of Kashana Chalet and in the valley of Klissekyoi River could not be found. That is why its identification with the thrust along the ridge of Svishtiplaz Peak, assumed to be part of the Etropole thrust (Antonov, 1976) or with the thrust traced north of Mechesh Peak, is still problematic. In the area around Kashana mine, the reverse fault–thrust trends east – west, dipping 40-50° to south. There, it was proven by a number of boreholes along several profile lines (Trashliev, 1961).

The Mechesh reverse fault was established by Kouykin and Milanov (1970) and Kouykin et al., (1971), who showed it on their maps and sections as a small satellite fault, intersecting “the allochthone of Kashana thrust”. During the present study the fault was traced reliably only to the north of Mechesh Peak at a distance of about 700 m along the contact between the rocks of Dalgidel Group and a granite-porphry body. Its trend is subequatorial (80-90°) and its average dip is about 60° to south. The tracing of its continuations to the west and east is obstructed both by the lack of exposures and the uniform character of the rocks of Dalgidel Group.

The Svishtiplaz allochthone was recognised by Kouykin and Milanov (1970) and Kouykin et al. (1971), who argued that this fault was the eastern continuation of Kashana thrust. Later it was assumed to be part of the Etropole thrust (Antonov, 1976). The thrust plane is traced along the northwestern and northeastern slopes of Svishtiplaz Peak. It is distinctly marked by the boundary between contact-metamorphic rocks of Dalgidel Group (knotty schists and hornfelses) and allochthonous granitoids and granite-porphyrines, where thin lenses of Triassic sandstones (Petrohan terrigenous Group) and very small outcrops of limestones (Iskar carbonate Group) are preserved (Fig. 10). The thrust plane dips gently 15-25° to SSE. As mentioned above, there are no reliable field data in the valleys of Klissekyoi and Kouroudere River in order to relate Svishtiplaz allochthone with Kashana thrust. In the valley of Kouroudere river, southeast of Svishtiplaz Peak, a subequatorial fault zone determined as reverse fault–thrust was observed. It could be reliably traced only at a distance of 250 – 300 m. This zone dips 45-55° to south and could be the eastern continuation both of Svishtiplaz allochthone or of Mechesh reverse fault.

Table 2



a – contact between milonite aleuropelites of Dalgidel Group (DdO₁) and granodiorite mylonites ($\gamma\delta Pz_2$) NE of Jeminski Kamak peak (look to west); b – crenulated mylonite foliation in the central domain of the ductile shear zone NNW of Anton village (look to west); c – diorite (δPz_2) and granodiorite ($\gamma\delta Pz_2$) protomylonites, intersected by undeformed vein of aplite NW of Elenska river (look to northwest); d – general view of Jemmina reverse fault-thrust and Jemmina peak (look to west); e – tectonic breccia in the base of a granodiorite allochthonous flake of Jemmina reverse fault-thrust in the valley of Zhitnitsa river; f – banded tectonic breccia of Jemmina reverse fault-thrust in the valley of Madzharin river (look to east)

East of Govedarnika locality to the river of Bochoum, phyllites and knotty schists crop out. In the valleys of Sanardere and Slavtsi rivers, their scarce exposures are affected by landslides and rock-falls, which make the tracing of fault zones practically impossible.

DISCUSSION AND CONCLUSION

The Anton shear zones is characterised by: 1) distinct SL-fabric and constant trend of mylonitic foliation and stretching lineation; 2) identical shear sense in the three domains; 3) the central domain is most intensively deformed and is related mainly to the southern contact of Vezhen pluton; 4) within the diorite protolith and the green-schistic rocks of Dalgidel Group,

this domain transitionally passes into narrow, anastomosing shear zones with preserved, slightly deformed or undeformed pods of the protolith among them; 5) undeformed aplitic veins of the pluton intersect the mylonitic foliation; 6) the ductile shear zone is obliquely or transversally cut by Late Alpine brittle faults.

On the basis of the features mentioned above, it could be assumed that the inhomogeneous ductile deformation of the Anton mylonitic zone took place at significant crustal depth, during a single, probably Late Hercynian deformation event, immediately after the intrusion and cooling of the Vezhen pluton. The primary cataclastic deformation of the granodiorites and diorites lead to reduction of the grain size in microscopic shear zones and subsequent ductile deformation.

The Late Alpine reverse faults and thrusts are concentrated in two strips. The southern one comprises the Anton reverse fault and the small reverse fault north of Tsarkvishte Village. The northern strip includes Vezhen thrust, Dzhemina reverse fault-thrust, Mechesh reverse fault, Kashana reverse fault-thrust and Svishtiplaz allochthone. It is problematic to treat them as an uninterrupted fault zone due to lack of reliable field criteria. They probably represent independent en-echelon reverse faults and thrusts with imbricated frontal parts. The use of faults from the northern strip to distinguish Early Alpine and Late Alpine tectonic units is well argued by the field data.

ACKNOWLEDGMENTS

We are much obliged to the management of Navan Chelopech Plc, both for the sponsorship of this study and permission to publish part of the results. We are also grateful to St. Pristavova for the petrologic characteristics of rocks from the ductile shear zone and to K. Shipkova for the preliminary discussions concerning the shear sense criteria.

REFERENCES

Antonov, M. 1971. Notes on the character of the Stara Planina front line between Pravets pass and Cherni Vit river. *Bull. Geol. Inst., ser. geotectonics*, 20, 57-68. (In Bulgarian)

Antonov, M. 1976. Structure of the Etropole thrust. *Review Bulg. geol. soc.*, 37, 1, 37-47. (In Bulgarian)

Bonchev, G. 1908. Contribution to the petrography of the southern slopes of the Balkan from Arabakonak pass to Maresh-Varbitsa pass. *Ann. Sofia univ., FMF*, 3-4, 3-147. (In Bulgarian)

Bonchev, E. 1961. Notes on the main fault structures of Bulgaria. *Contr. Geol. Bulg., ser. stratigraphy and tectonics*, 2, 5-29. (In Bulgarian)

Bonchev, E. 1971. Problems of Bulgarian geotectonics. *Technika, Sofia*, 203. (In Bulgarian)

Bonchev, E., Y. Karaguleva, 1961. Srednagora anticlinorium and Staraplanina granite thrust. *Contr. Geol. Bulg., ser. stratigraphy and tectonics*, II, 31-42. (In Bulgarian)

Velchev, V., S. Belev, N. Stefanov, P. Pelov, P. Tuparev, P. Antonov, Y. Malyakov. 1973. Study of the goldbearing formations in the Central Balkan from Zlatitsa pass to Anton village. *National geofund*. (In Bulgarian)

Vrablyanski, B. 1971. Svoje anticline. – In: (Yovchev, Y., ed.) Tectonic structure of Bulgaria. *Technika, Sofia.*, 290-293. (In Bulgarian)

Jelev, V., M. Antonov, D. Sinnyovsky, Ch. Christov. 2000. Report on the completed revisional mapping in scale 1:25 000 and lithochemical mapping of “Anton” district of “Chelopech” licenced area. *National geofund and geofund of Navan-Chelopech Plc*. (In Bulgarian)

Ivanov, J., K. Kolcheva, S. Moskovski, D. Dimov. 1987. On the peculiarities and character of the “diabas-phyllitoid formation”. *Review Bulg. geol. soc.*, XLVIII, 2, 1-24. (In Bulgarian)

Yordanov, M., D. Chunev, I. Stanev. 1965. Brief characteristic of the Sub-Balkan deep seated fault between Maglizh village and the state frontier with Yugoslavia. *CBGA, VII Congr., reports 1 – geotectonics*, 33-40. (In Russian)

Kamenov, B. 1936. Geology of Etropole area. *Review Bulg. geol. soc.*, 8, 2, 30-137. (In Bulgarian)

Kouikin, S., L. Milanov. 1970. Notes on the geological structure of Zlatitsa Stara Planina. *Review of Bulg. geol. soc.*, 31, 1, 120-126. (In Bulgarian)

Kouikin, S., L. Milanov, Y. Gercheva, S. Christov. 1971. Geological structure of Stara Planina between Zlatitsa pass and Troyan pass. *Jub. Ann.*, 179-200. (In Bulgarian)

Mandev, P. 1942. Geology of Zlatitsa mountain and its formantain parts in the embrace of the upper part of Vit river. *Review Bulg. geol. soc.*, 13, 145-147. (In Bulgarian)

Milanov, L., N. Dimitrova, S. Kouikin, Y. Milanova, M. Simeonova, S. Christov. 1964. Report on the results from the geological mapping in scale 1:25 000 carries out in Zlatitsa-Teteven maountain during 1963. *National geofund, IV* - 191. (In Bulgarian)

Nachev, I. 1963. Jurassic system in Gabrovo area and catchment area of Gabrovnitsa and Leshnitsa rivers. *Contr. Geol. Bulg., ser. stratigraphy and tectonics*, V, 147-169. (In Bulgarian)

Poushkarov, N. 1903. Contribution to the petrigraphy of the high Balkan between the peaks of Yaldaz Tabia and Vezhen. *Nauka i knizhnina*, 19, 1-38. (In Bulgarian)

Poushkarov, N. 1927. Study of the geological structure of the western link between the Balkan and Sredna Gora mountain. *Contr. Bulg. sci. agricult. Inst.*, 14, 1-44. (In Bulgarian)

Trashliev, S. 1961. On the genesis and age of Kashana barite deposit, Pirdop district. *Review Bulg. geol. soc.*, 22, 3, 245-252. (In Bulgarian)

Trashliev, S., J. Trashlieva. 1956. Report on the geological prospecting of Kashana barite deposit (Pirdop district) carried out during 1954–1955. *National geofund, II* – 354. (In Bulgarian)

Tsankov, Ts. 1961. Notes on the tectonics of Galabets area and its adjacentt lands. *Contr. Geol. Bulg., ser. stratigraphy and tectonics*, 2, 183-202. (In Bulgarian)

Tsankov, Ts. 1995. Alpine structural settings. – In: (Yanev, S. and D. Chounev, eds.) Explanatory note to the geological map of Bulgaria in scale 1:100 000 (Botevgrad sheet). *Geol. Inst. Bulg. Acad. Sci., “Geology and geophysics” – Plc, Sofia*, 85-102. (In Bulgarian)

Cheshitev, G. 1971. Shipka Stara Planina. - In: (Yovchev, Y., ed.) Tectonic structure of Bulgaria. *Technika, Sofia*, 294-299. (In Bulgarian)

Cheshitev, G., V. Milanova, I. Sapounov, P. Choumachenko. 1995. Explanatory note to the geological map of Bulgaria in

scale 1: 100 000 (Teteven sheet). *Geol. Inst. Bulg. geol. soc. and "Geology and geophysics" Plc*, Sofia, 94 c. (In Bulgarian)

Passchier, C. W., R. A. Trouw. 1996. *Microtectonics*. Springer, 289 pp. (In English)

*Recommended for publication by Department
of Geology and Paleontology, Faculty of Geology*