Structural control of Bulqiza chromite deposits: a case history

By

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with 8 figures

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Abstract

The world famous Bulqiza ultramafic massif, in the eastern belt of the Albanian ophiolites, has produced about 20 Mt chromite ore averaging 35% Cr_2O_3, and is the host to the remaining resources and reserves of high grade ores. Traditionally, previous geological reports have described the form of the massif as an „eastward overturned anticline“, a „monocline structure“, or more recently as a „diapiric structure“. The structural control is of essential importance to the distribution of the mineralization, especially for northward extension of Bulqiza chromite deposit. This paper is based on a thorough generalization of previous exploration and mining data, and field observations. It is demonstrated that the location of the Bulqiza eastward overturned chromite antiform is conformable with planar flow structures of the homocline massif, and this is a useful guide for further exploration to the north of the boundary of the known mineralization.

1. Introduction

The Albanian ophiolites have an areal extent of over 4 000 km^2, or 1/7th of Albanian territory (the Mirdita Zone in Fig. 1), and form the connection between the Dinaric and Hellenic ophiolites.
According to SHALLO (1994) and BECCALUVA et al. (1994), the Albanian ophiolites are subdivided in two NNW-SSE trending subparallel belts: the Western and the Eastern belts. Both the Western sequence, characterized by mid-oceanic ridge basalt (MORB) ophiolites, and the Eastern sequence, characterized by island arc tholeiite (IAT) supra-subduction ophiolites, were considered to be Jurassic in age (BORTOLOTTI & PRINCIPI 2005). Recently the mid-oceanic ridge basalts have been dated as Middle-Upper Triassic and the supra-subduction ophiolites as Middle-Upper Jurassic.
The majority of chromite deposits occur within the Eastern belt of ultramafic massif ophiolites, which consist of harzburgitic mantle tectonites and thick dunitic cumulate sequences. Within these ophiolite massifs, the intensity of chromite mineralization is most intense in the Bulqiza massif with smaller occurrences in the Kukesi, Tropoja and Shebeneik massifs (Fig. 2a). The Bulqiza ultramafic massif

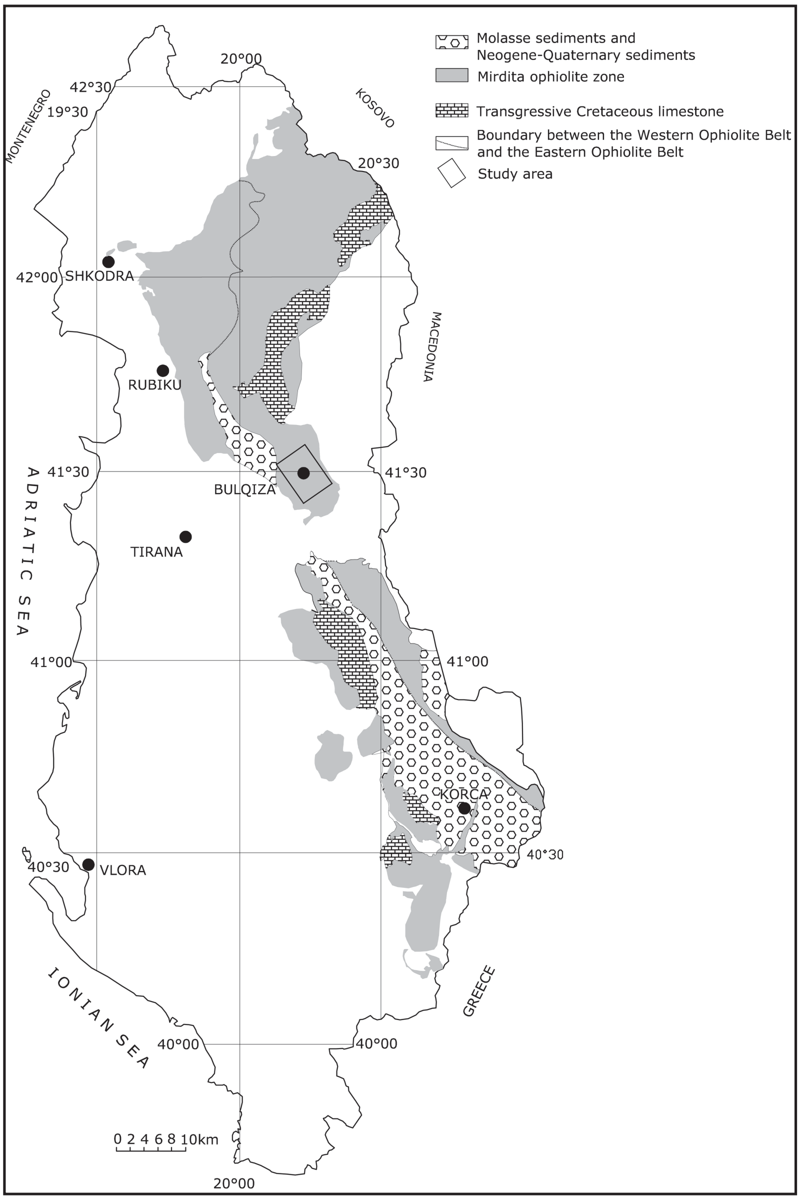

Fig. 1: Distribution of ophiolites (shaded) in Albania (after XHOMO et al. 2002). Box shows location of Bulqiza. Thick line shows boundary between Western and Eastern Ophiolite Belts.

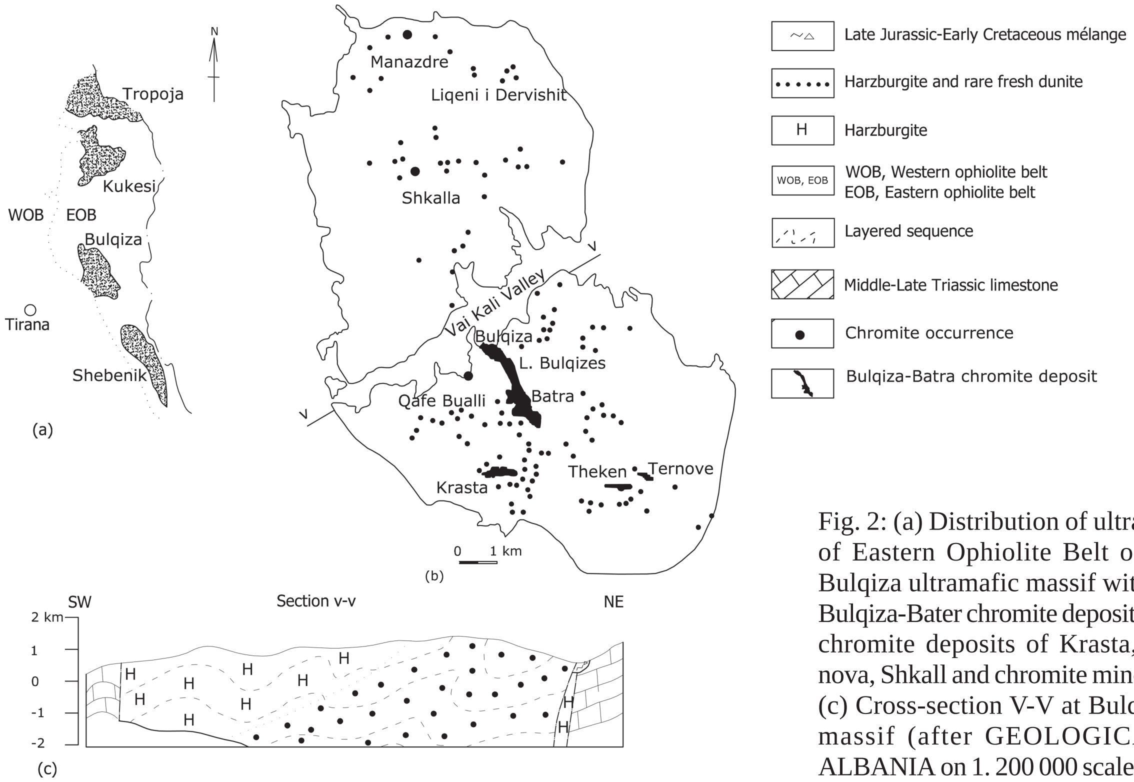

Fig. 2: (a) Distribution of ultramafic massifs of Eastern Ophiolite Belt of Albania. (b) Bulqiza ultramafic massif with plan view of Bulqiza-Bater chromite deposit and other main chromite deposits of Krasta, Theken, Ternova, Shkall and chromite minor occurrences. (c) Cross-section V-V at Bulqiza ultramafic massif (after GEOLOGICAL MAP OF ALBANIA on 1. 200 000 scale 1983).

is one of the four main ultramafic massifs in the Albanian ophiolites (Fig. 2a). It extends over an area of 370 km^2, and includes about 370 locations of chromite mineralization (Fig. 2b).

The field observations and compilation of exploration and mining data have been made since 1987, but have not been published.

Today, 18 years later, there it is unfortunately still not a unified view of both the structural setting of the massif as well as the relationships of the chromite mineralization within the country rocks.

Based on geological reserve calculation reports, and taking into account the mining data, the indicated reserves (ready for mining) were on 01.01.1987 about 8 Mt. Based on an average annual mine production of approximately 0.4 Mt, the mine life expectancy could be about 13 years long. With respect to a possible prolongation of the mine life, the extension of reserves towards the north of the Bulqiza chromite mineralization (north of Vai Kali valley) was considered to be the only target for exploration. This area is

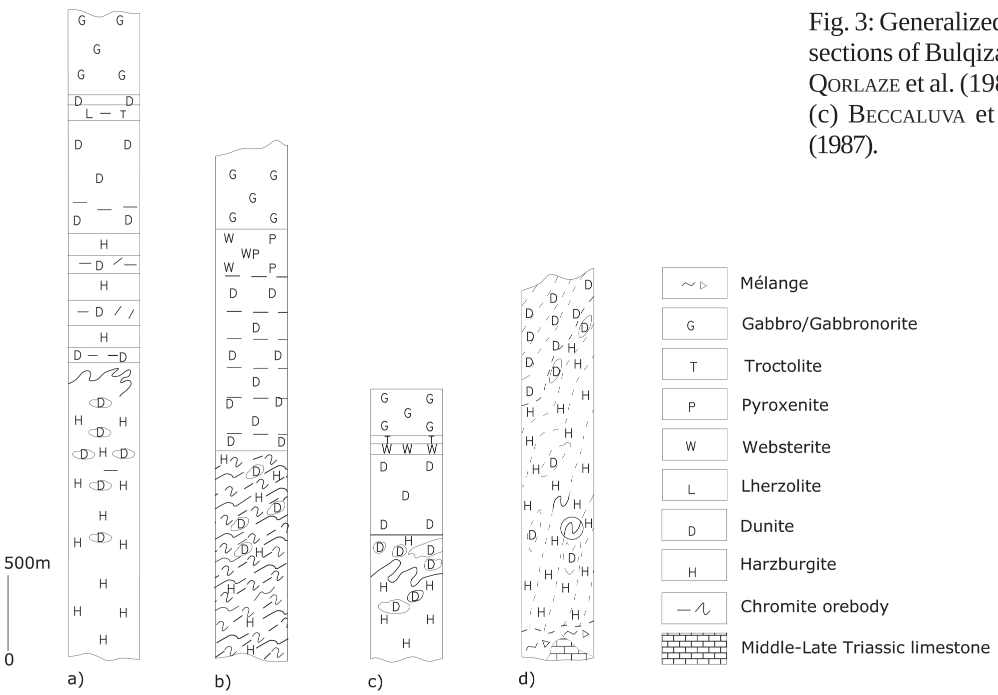

Fig. 3: Generalized lithological-stratigraphycal sections of Bulqiza ultramafic massif. After (a) QORLAZE et al. (1989); (b) SHALLO et al. (1989); (c) BECCALUVA et al. (1996); and (d) HOXHA (1987).

marked by a very steep plunge of the folded ore structure of the Bulqiza mineralization, as well as the absence of deep drilling. However, the direction and depth to be drilled remained the question of those days.

A team of geologists (QORLAZE et al. 1989) compiled and implemented a major project for a 10 km long gallery with transverses and underground boreholes. About 2 km west (Qafe Bualli) of Bulqiza mine, a thin chromite mineralization (only a few centimeters in thickness) had been intersected by drilling. Based on the accepted view of a major gentle fold through the Bulqiza chromite, the intersections were considered as natural continuation from the western limb of the Bulqiza fold. On this basis, several deep drill holes were performed at the same time as the detailed exploration programme at Qafe Bualli occurrence in order to clarify the possibility for a northward continuation of Bulqiza chromite mineralization.

The intention of this paper is to use all the available data and observations in order to clarify the influence of the structural features on chromite mineralization in the northern part of the Bulqiza deposit (Kreshta area), and to assist in successful exploration to the north of the known extend of the Bulqiza mineralization.

2. Geological setting

According to the GEOLOGICAL MAP OF ALBANIA (ISPGJ-IGJN 1983 and quoted references) and the METALLOGENIC MAP OF ALBANIA (ISPGJ-FGJM 1989), the Bulqiza Massif was considered as an overturned anticline with east vergence, and consists of layered sequences of harzburgite and rare fresh dunites at the base and harzburgite at the top. The Massif is underlain by amphibolites and bounded by almost vertical reverse faults with Middle-Late Triassic limestones and Late Jurassic-Cretaceous mélange (Fig. 2c). The mantle harzburgite – dunite complex at Bulqiza-Batra area is accepted as Middle Jurassic (XHOMO et al. 2002).

$^{40}Ar/^{39}Ar$ ages from the metamorphic sole of the central-southern part of the Bulqiza ultramafic massif date this event as Middle Jurassic (170.8± 3.2; 169.6± 2.4; 171± 1.7 Ma) (DIMO et al. 1998).

The form of the Bulqiza Massif has been described, respectively, as lopolith-like or monocline (KODRA 1982, ALLIU & LLESHI in MECO & SINOJMERI 2004),“monocline“ (homocline) structure (HOXHA 1987), and recently as „a diapiric structure“ (MESHI et al. 2005).

The lithologic-stratigraphic section of the Bulqiza Massif,

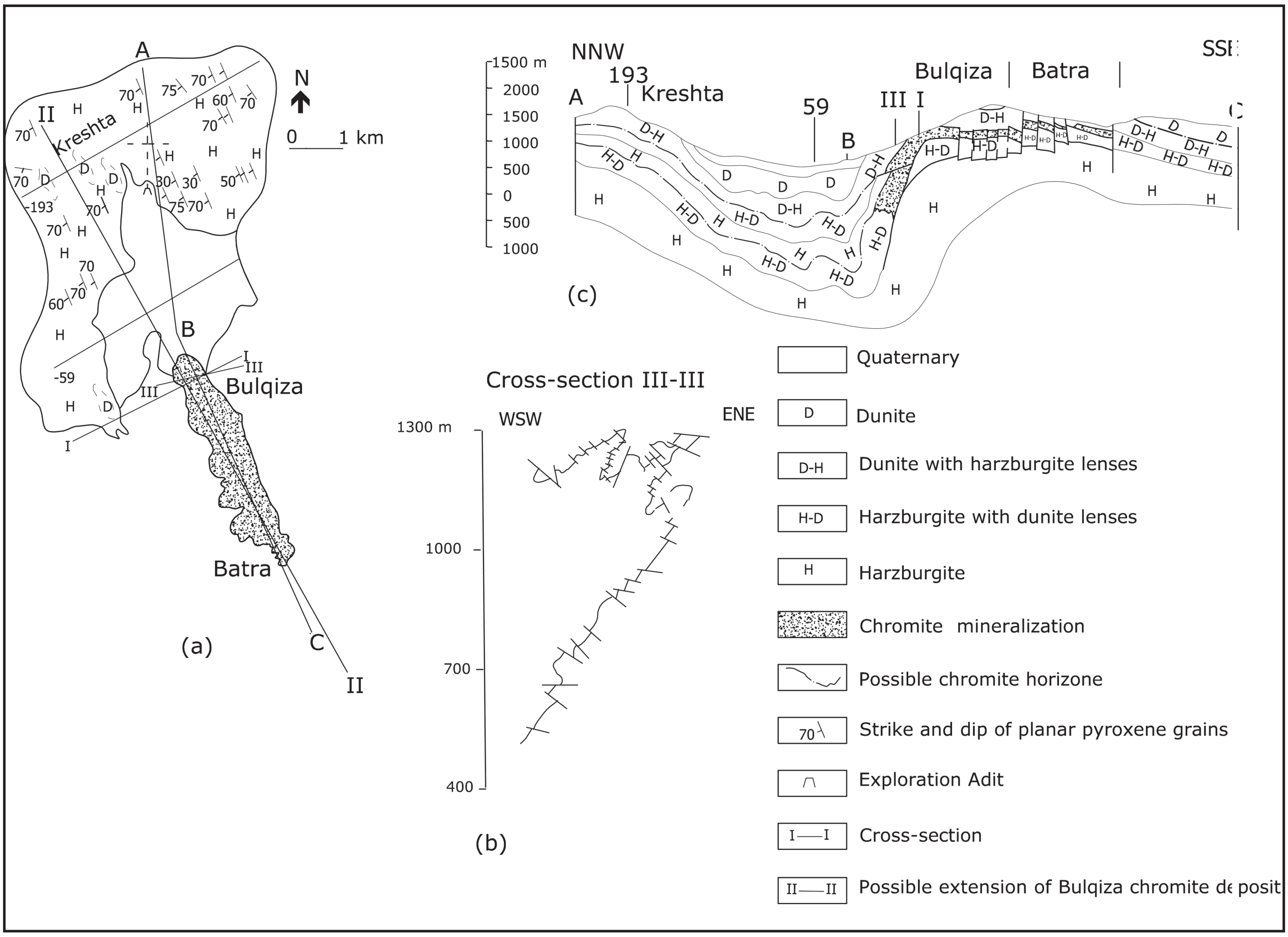

Fig. 4: Horizontal plan view of Bulqiza chromite deposit and cross-sections (after QORLAZE et al. 1989; the map of northern part, after DOBI et al. 1983, IKONOMI & KETA 1986 and processing of data base and observations from HOXHA 1987). (a) Plan view of Bulqiza-Batra chromite deposit and its northern part. (b) Vertical projection A-B-C showing Batra-Bulqiza chromite deposits, rock sequences and possible chromite horizons in northern part (after QORLAZE et al. 1989). (c) Vertical WSW-ENE cross-section III-III at Bulqiza chromite deposit, as the most representative feature.

including various chromite mineralizations, is shown on Fig. 3.
According to Qorlaze et al. (1989) and Beccaluva et al. (1994), the main overturned chromite antiform within the harzburgite-dunite sequence is complicated by intense second-and third-order folds. According to Shallo (1994), important chromitite deposits in the upper sections of the harzburgite with interlayered dunite sequence are tabular-folded, and exhibit pencil-like and podiform morphologies. According to the METALLOGENIC MAP OF ALBANIA (1989 and quoted references), the following styles of chromite mineralization are described from the Bulqiza massif: (a) tabular-concordant folded ore bodies (e.g. Bulqiza-Batra type); (b) tabular-concordant and sub-concordant ore bodies (e.g. Qafe Bualli, Ternove, Liqeni i Dervishit); (c) pipe-like, concordant to sub-concordant ore bodies (e.g. Shkalla) and; (d) podiform ore bodies (e.g.Thekna).

The Bulqiza-Bater chromite deposit is widely accepted to be hosted by an overturned antiform, with easterly vergence, 4.5 km long, 1.2 to 1.5 km wide and 0.5 to 1.7 km down dip with an axial orientation strike of 330° (Fig. 4a) and with more than 40% Cr_2O_3. At the Bulqiza deposit, the eastern and western limbs dip SW respectively with angle of dip 70-80° and 20-30° (Fig. 4b). The northern zone plunges NW with a dip 60-70° (Fig. 4c).

3. Results and Discussion

The target area in northern extension of Bulqiza deposit was mapped previously on 1: 25.000 scale (Dobi et al. 1996) and 1: 10.000 scale (Ikonomi & Keta 1986).
Field observations were made in and around Bulqiza (Bulqize-Qafe Bualli, Qafe Lame, Kreshte as well as more

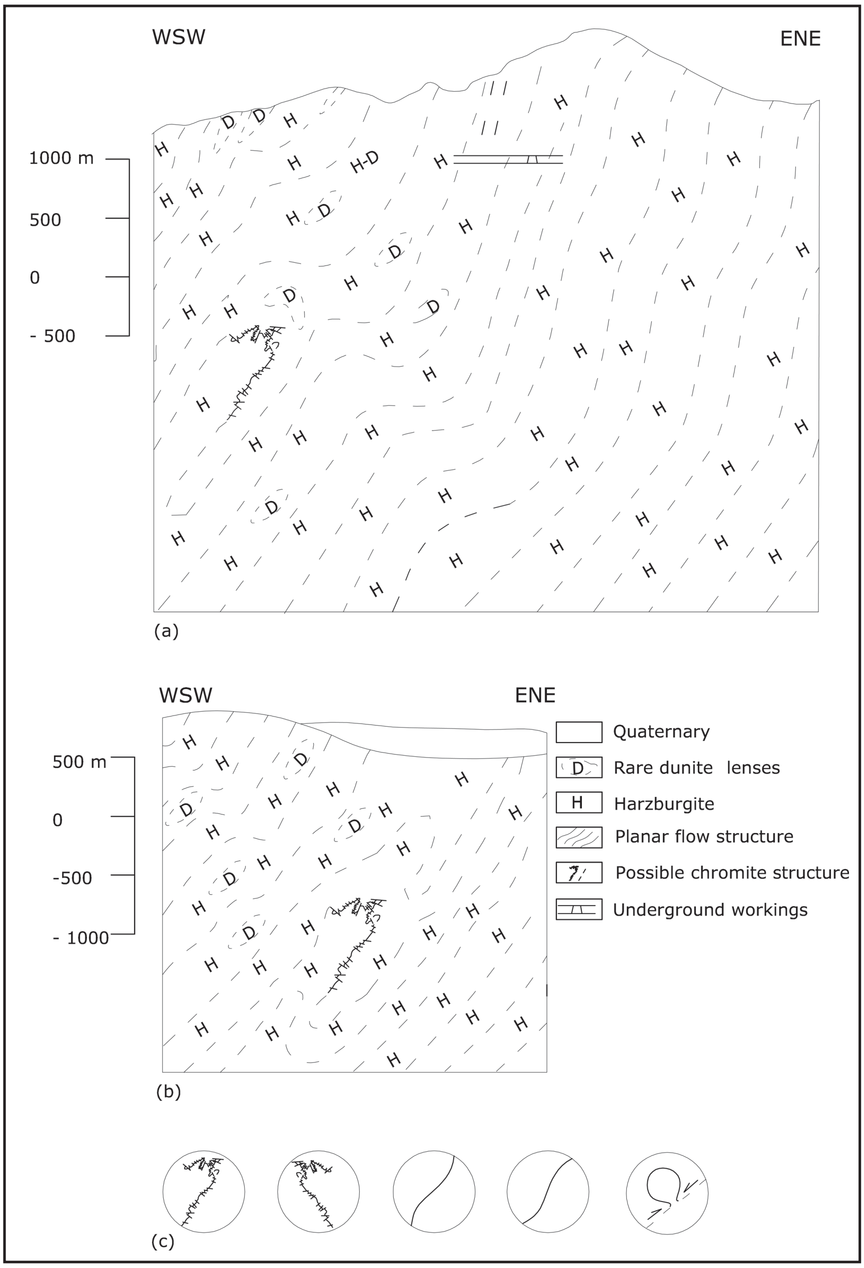

Fig. 5: (a) Vertical WSW-ENE cross-section –193 at northern part of Bulqiza massif with possible chromite structure. (b) Vertical WSW-ENE cross-section –59 at northern part of Bulqiza massif with possible chromite structure. (c) Possible fold displays of chromite layer as result of deformation.

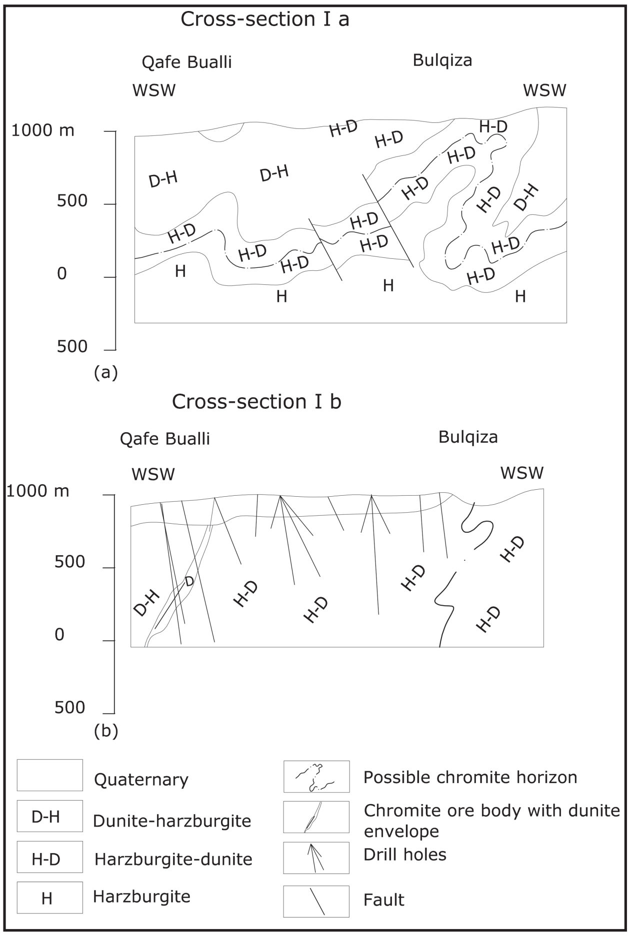

Fig. 6: Vertical WSW-ENE cross-section Ia, Bulqiza-Qafe Bualli deposit, showing possible chromite structure (after QORLAZE et al. 1989). Vertical WSW-ENE Cross-section Ib Bulqiza-Qafe Bualli deposit, showing the results of drill holes between Bulqiza and Qafe Bualli and a tabular chromite ore body encountered by drill holes at Qafe Bualli.

than 11 chromite minor occurrences), focusing in measurement of pyroxene planar flow structures, chromite schlieren, and minor chromite occurrences.

The mining data regarding the chromite ore-to-host rock contacts and relationships, grade, thickness, ore textures and genetic theories were studied. Based on this information, it is emphasized that 90.6% of the chromitite orebodies are in contact with a dunite envelope („jacket“) that may range from a few millimeters to several tens of meters in thickness, 7.1% are in contact with peridotite (harzburgite), and only 2.3% are in contact with pyroxenites (and these are probably tectonic contacts). The average thickness of the mined ore bodies was 2.259 m. The average chromite content of Bulqiza ore was about 43.37% Cr_2O_3.

Detailed cross-sections, horizontal plan views and vertical projections were compiled based on mining data and various resource calculation reports of the Bulqiza mine (Fig. 4), and compared to the new observations and field measurements.

A detailed 1: 500 horizontal plan view of the Batra- Bulqiza chromite deposits was compiled, from which the axial strike was determined to be about NNW (about 330°). The same strike was estimated from measurements of mantle foliation in the harzburgite, and chromitite schlieren in the northern part (Kreshta area), 20° west of former exploration axis (A-B) (Fig. 4a and 4b).

A representative morphology, a typical antiform (e.g. cross-section III-III, Fig. 4c), was chosen from some of the cross-sections of the Bulqiza deposit. At northern part were compiled cross-section as –193, - 59 etc. (Fig. 5).

The typical Bulqiza mineralization was inserted at an estimated depth at the intersection of the axial orientation of 330° of main Bulqiza „chromitite antiform“ with cross-sections of the northern extension (e.g. cross-section III-III).

Connecting the eastern limb of the predicted chromite ore structure with the homocline structure on the surface demonstrated the continuity between the known Bulqiza antiform ore structure (deposit) with the planar flow structures on the surface (Fig. 5). The chromite structure could be as represented as above, a gentle fold or their mirror images and if the bilateral stress along foliation had been continuous a rounded fold or pipe-like ore body (e.g.

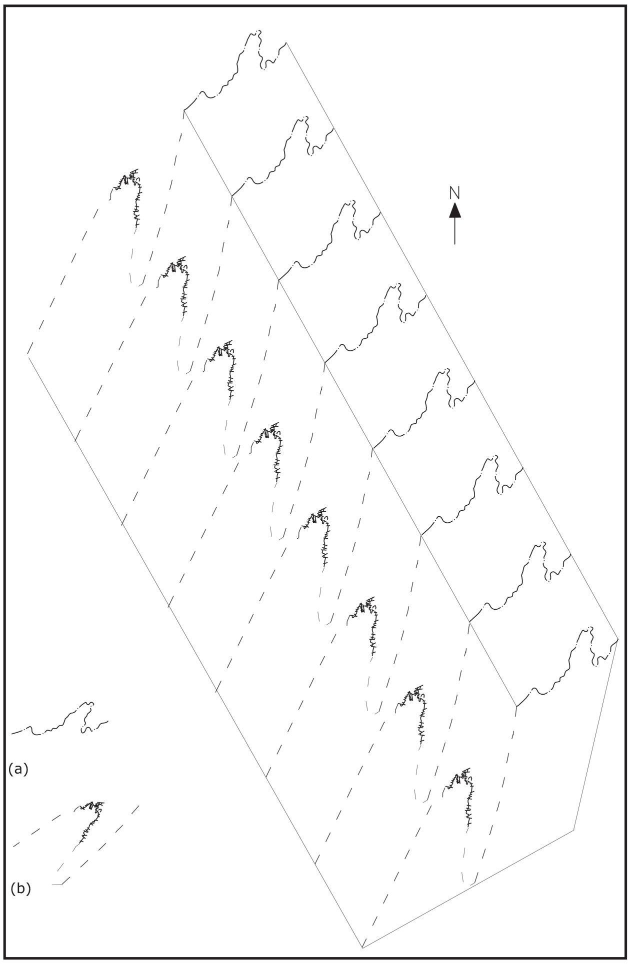

Fig. 7: 3D representation of Bulqiza chromite ore structure: (a) the chromite mineralization is supposed to be developed as eastward overturned gentle folding (see Fig. 6a) whereas at (b) the chromite structure presents an eastward overturned antiform with limbs developed in vertical plane. Note the change with a horizontal angle of almost 90° between two views.

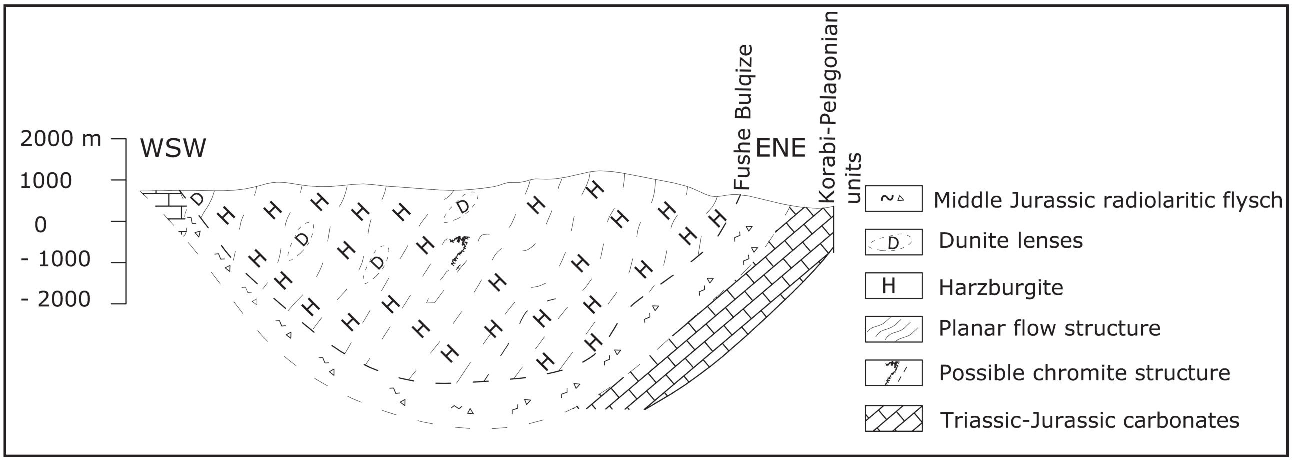

Fig. 8: Generalized vertical WSW-ENE cross-section of Bulqiza ultramafic massif showing location of Bulqiza eastward overturned chromite antiform in conformity with planar flow structures of the homocline massif.

Shkalla deposit) can be formed (Fig. 5c).
The Qaf Bualli occurrence, which is still being explored, was considered to be the westward continuation from the west limb of the Bulqiza gentle fold (Fig. 6a, cross-section Ia). The cross-sections between the western limb of Bulqiza deposit with the Qafa e Buallit deposit (still under exploration) were compiled in the same way, and demonstrate that it is an integral part of the same homocline structure (Hoxha 1987). The drill holes between Bulqiza and Qafe Bualli did not encounter chromite ores, whereas at Qafe Bualli they intersected a flat, monocline chromitite body (Fig. 6b, cross-section Ib).
The difference between the two interpretations is shown in a 3D representation of the Bulqiza chromite ore structure (Fig. 7). According to previous authors (Qorrlaze et al. 1989), the chromite mineralization was supposed to be developed as eastward overturned gentle fold (Fig. 7a) whereas in the other interpretation it is developed as an eastward overturned closed-fold with limbs formed in the vertical plane (Fig. 7b), with a change in horizontal plane of 90°, with former version.
In this context, the Bulqiza ultramafic massif is a homonocline. Mantle foliation in harzburgite strike 330°, and limbs dip 70°-80° WSW. The eastward overturned chromite antiform is its integral part, representing a fold in the plane of the dip (Fig. 8).
The Bulqiza massif is underlain by the Perlat-Kurbnesh mélange, dated as Middle Jurassic (Gawlick et al. 2005, in press) and westward emplaced onto the Korabi-Pelagonian units.
Accepting the folding as a later event, it is quite reasonable to suppose a migration of ores to the folds (antiform, synform). Taking into account the fact that the ores and mineralization so far discovered in the unique Bulqiza-Bater ore district (chromite ore structure) are all closely related to the folds (e.g. Bulqiza ore deposit), further prospecting and exploration needs to target this structural control and the predicted folds. Poorly mineralized or even barren zones can be expected in gentle folds.
The Bulqiza massif section as described above is comparable with the Semail ophiolite section, where deep mantle chromite and tabular and podiform chromites are hosted by mantle tectonites (harzburgite and dunite) and are conformable with wall rocks (Batchelor 1992).

4. Conclusions

1. The world famous Bulqiza ultramafic massif hosts the principal reserves and resources of chromite mineralization of Albania, is a homonocline and not an eastward overturned „anticline“ or a „diapiric“ structure as previously thought. The foliations in the harzburgite strike 330° and dip 70°-80° southwest.
2. The „chromite antiform“ with easterly vergence is a fold in the plane of the dip and an integral part of this homocline, showing clearly the structural control of chromite ore bodies in this deposit.
3. Further prospecting and exploration should focus on the chromite antiform since away from this structure the mineralization is either weak or absent.

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