3rd International Conference - Geosciences and Environment (3ICGE) 27-29 May 2012 Belgrade, Serbia
Lecture

PROBLEMS DURING GEOPHYSICAL EXPLORATION OF CHROMITE DEPOSITS

Many geophysical studies carried out in the ultrabasic massifs of Albania (as in Bulqiza, Tropoja, Kukesi, Shebeniku, Pogradeci etc) for the search for chrome deposits, which have been successful in many cases. They demonstrated that the geophysical methods are a part of the integrated methods for the search for this mineral ore. A long list of many scientific publications, on this item, is presented in the references.

4.1. Exploration for chrome ore bodies

The main principle for the application of the geophysical methods for the search for chrome ores, has been to start with the mapping in well known zones of the mineralization and to extend this mapping further to unknown zones, on surface and in the depth.

The works carried out only in Bulqiza ultrabasic massif can illustrate the effectiveness of the geophysical search for chrome ores. Geological and geophysical mappings, at scale 1:2000 have been conducted in total over 65 km^2 or in 15% of surface of the Bulqiza massif (Ll. Langore tec. 1989). There are observed 215 geophysical anomalies have been fixed. Among them, 191 anomalies have been observed by only of one geophysical method, and 24 ones present complex anomalies: gravity, magnetic or IP. From 64 anomalies, 51 anomalies were fixed over the known chromite bodies/occurrences and have contributed for their development in the strike direction. Thirteen anomalies have been discovered buried chromite bodies without surface outcrops, which have been explored by trenches, galleries and drill holes. Thirty-five anomalies have been evaluated as very important for exploration and development works. Based on them the possibility of following their extension was achieved. Hundred fifty-one have been non-mineralised anomalies; but they are caused by particular rocks, tectonic faults, and topographic effects or by the change of the thickness of the deluvion.

Based on these integrated geological-geophysical studies, industrially useful bodies (or deposits) were discovered in Ternove, Liqeni i Sopeve, 10 Korriku, Lugu i Gjate, Jugu i Batres (M-5 anomaly), Qafe Lame etc. Important results were achieved in other zones such as in Liqeni i

Dhive, Maja e Thekres, Kaptine, 80 Vjetori, Tri Gjepra, Bishti i Kalit etc.

The efficiency of geophysics is still relatively low in comparison with copper deposit exploration. By integrated geological-geophysical surveys in the 35 objects in the Bulqiza ultrabasic massif to check the anomalies have projected 356 boreholes. From these boreholes, 145 have discovered chromite ores, and 211 have been negative. The ratio of the success was 1/1,4. Many studies must performed before can be reached proper results for chrome exploration.

a) <u>Ore anomalies</u>

Geophysical anomalies caused by ore bodies have been observed in several areas.

Over the ore bodies, weak gravity anomalies are observed, with amplitude, about 0,1-0,2 mGal. These anomalies are more evident after the field transformation (fig. 4-7, 4-9, 4-10). In the gravity Bouguer anomaly map doest not present visible anomalies. After the recalculation have been prepared residual gravity anomaly map. In this map, are observed an anomaly over the chromite ore body Nr. 6 (anomaly No. I). Some others anomalies at northeastern direction are evidenced (fig. 4-2). In the exploration line III over the anomaly No. II have been projected drilling of three boreholes to check this gravity anomaly (fig. 4-3). There is observed also a complicated magnetic anomaly. All three boreholes have discovered two chromite ore bodies (fig. 4-3). In Kami deposit, are observed some negative magnetic anomalies with amplitude –700 nT over the outcrop of the massive ore body (fig. 4-5). Fig. 4-6 show weak negative anomaly that is observed over disseminates chromite ore body.

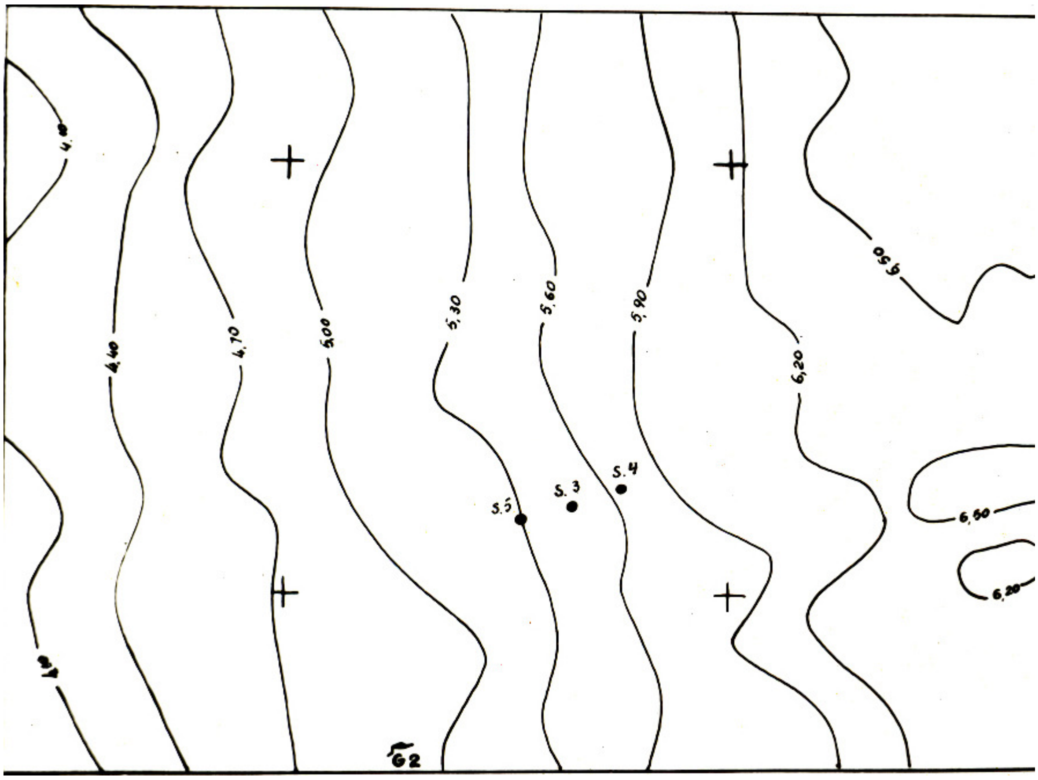

Fig. 4-1. Gravity Bouguer anomalies map, Kami deposit, and boreholes projected to check residual gravity anomaly. Iso-anomalies every 0,3 mGal. (Mihajllovsky Ja.M. 1960).

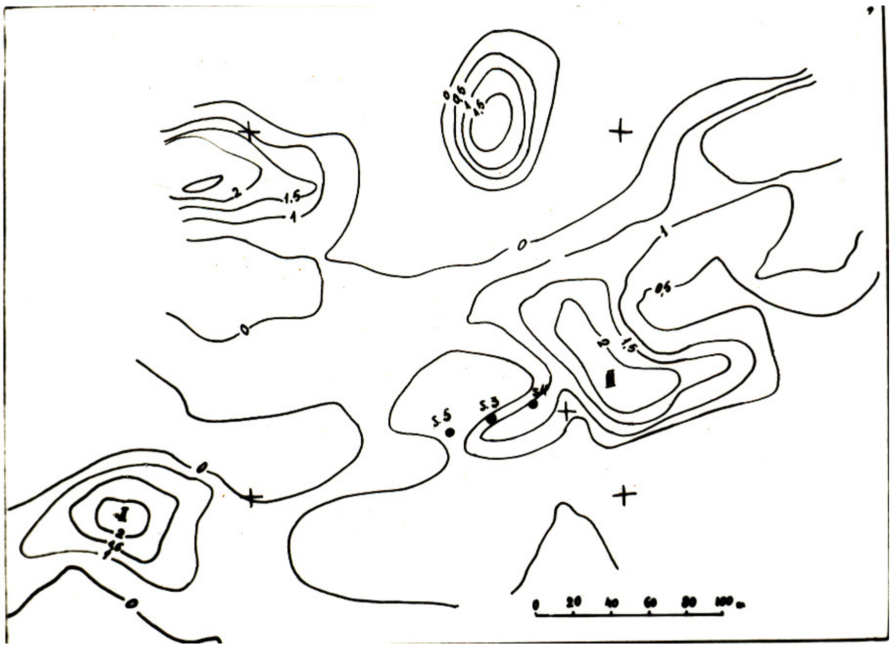

Fig. 4-2. Gravity residual anomalies map, Kami deposit, and boreholes projected to check residual gravity anomaly. Iso-anomalies every 0,5x10^{-8} mGal/cm. (Lubonja L. et al. 1973).

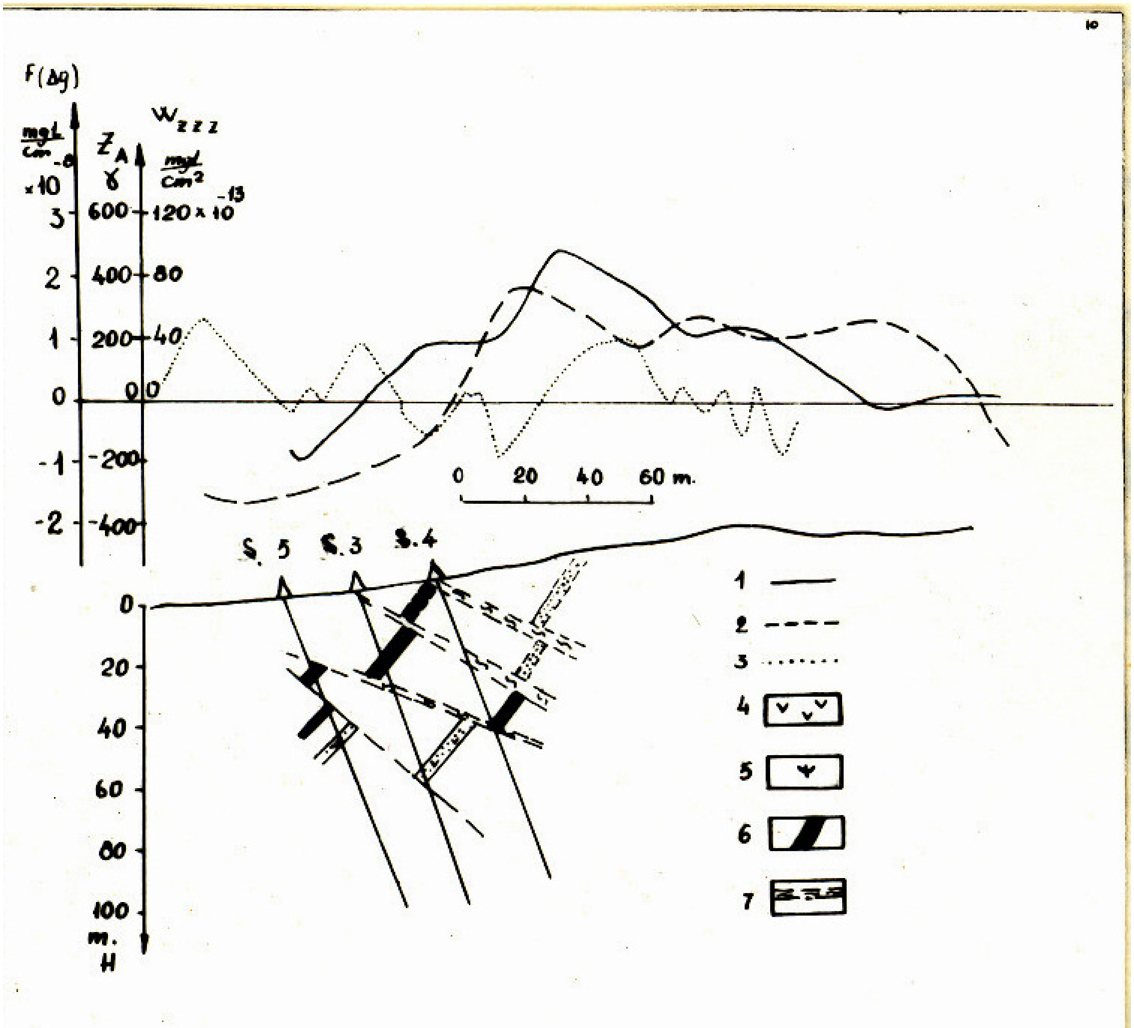

Fig. 4-3. Geological-geophysical section III-III for projecting of the boreholes to check the residual gravity anomaly, Kam deposit. (Lubonja L. et al. 1973).

1- W_{zzz} profile; 2- F(Δg) profile; 3- ΔZ profile; 4- Dunites; 5- Harcburgites; 6- chromite ore body discovered by projected boreholes; 7- Disjunctive tectonics.

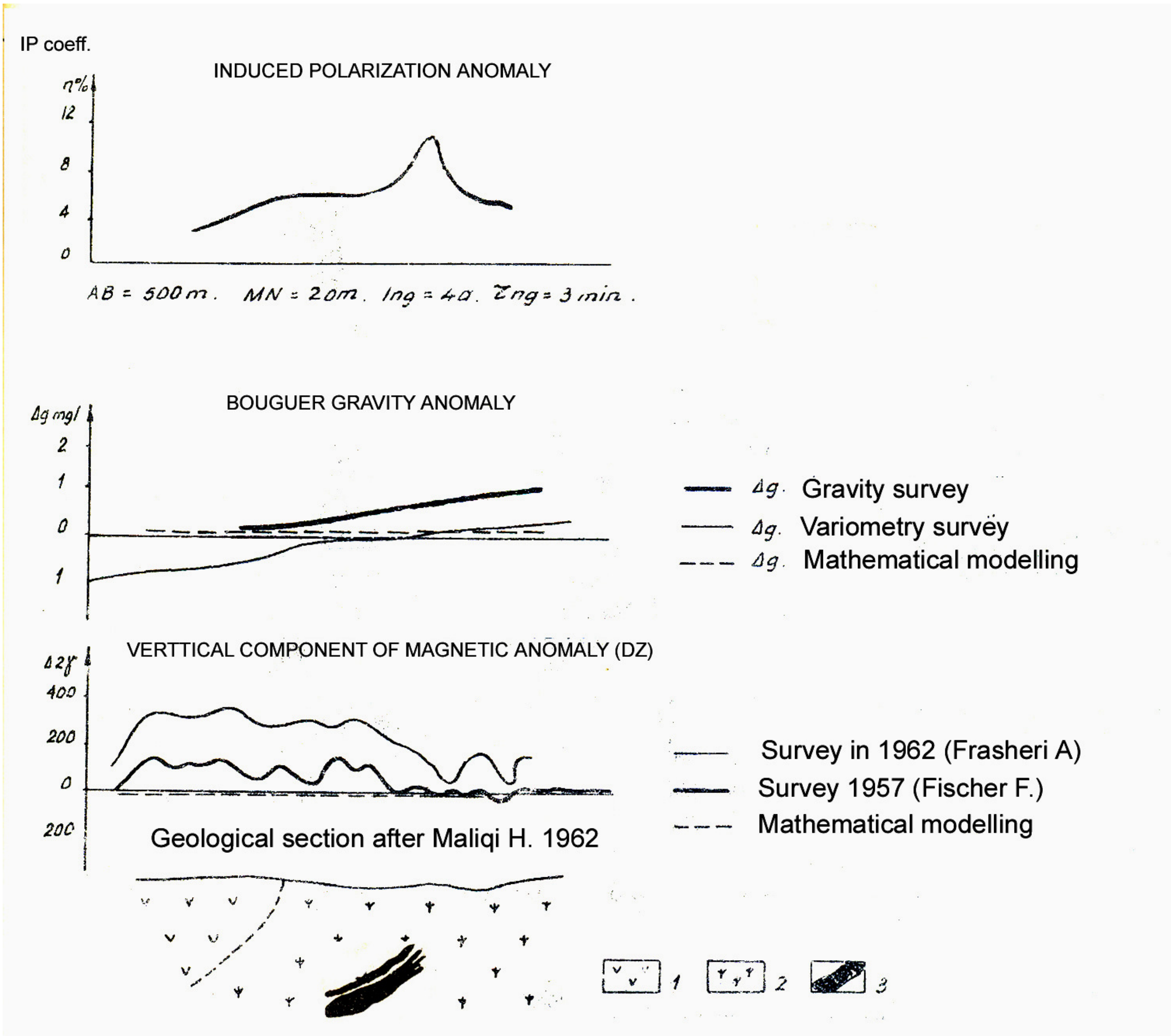

Fig. 4-4. Geological-geophysical section, Kami chromite deposit, Tropoja ultrabasic massif. (Frasheri A. et al. 1971).
1- Peridotites; 2- Dunites; 3- Chrome spinel ore body.

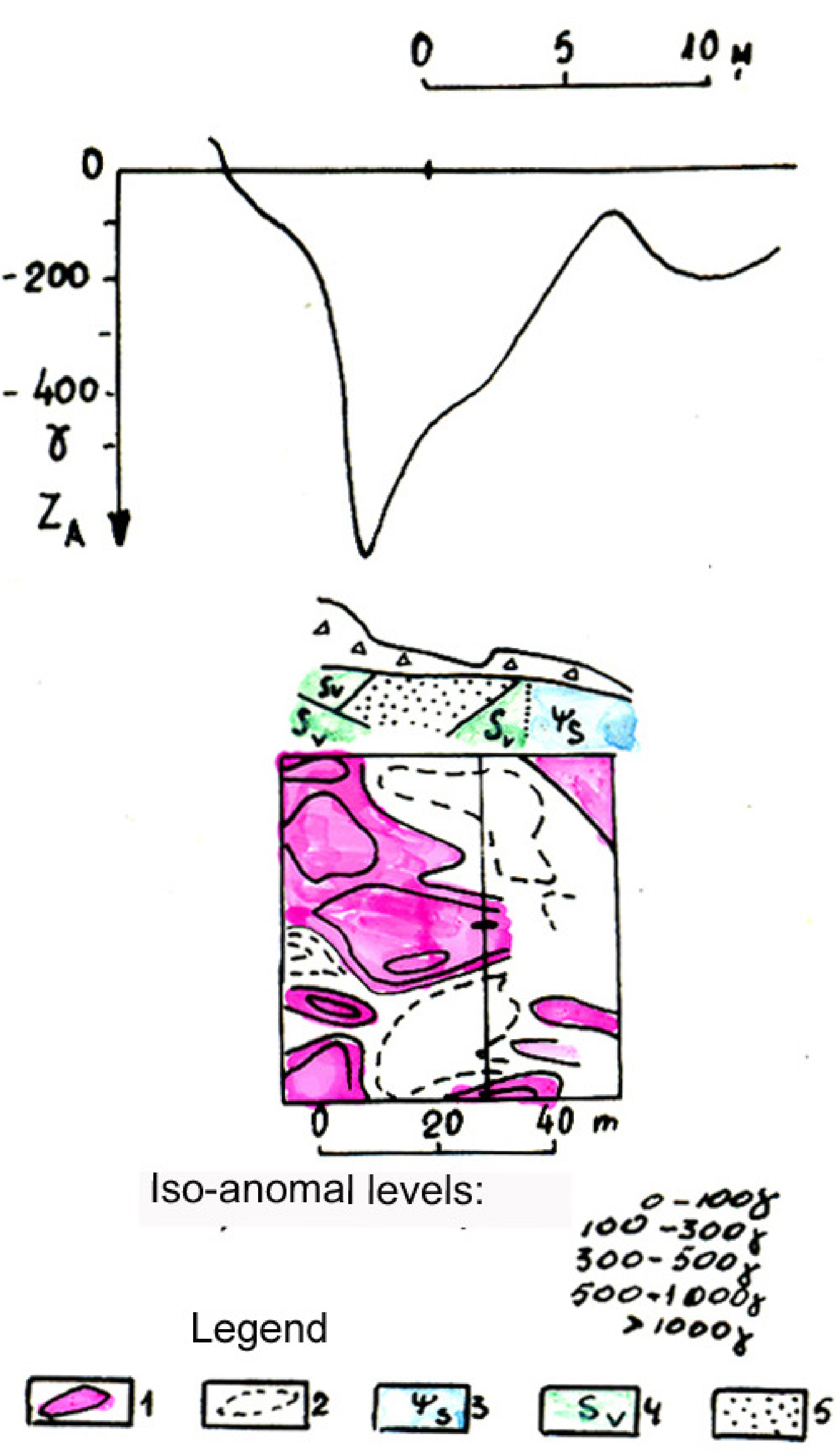

Fig. 4-5. Magnetic anomaly (ΔZ), over chromite body, Kami deposit. (Fischer F., 1957)
ΔZ<0; 2- ΔZ>0; 3- Hartzburgite; 4- Serpentinite from dunites; 5- Chromite ore body.

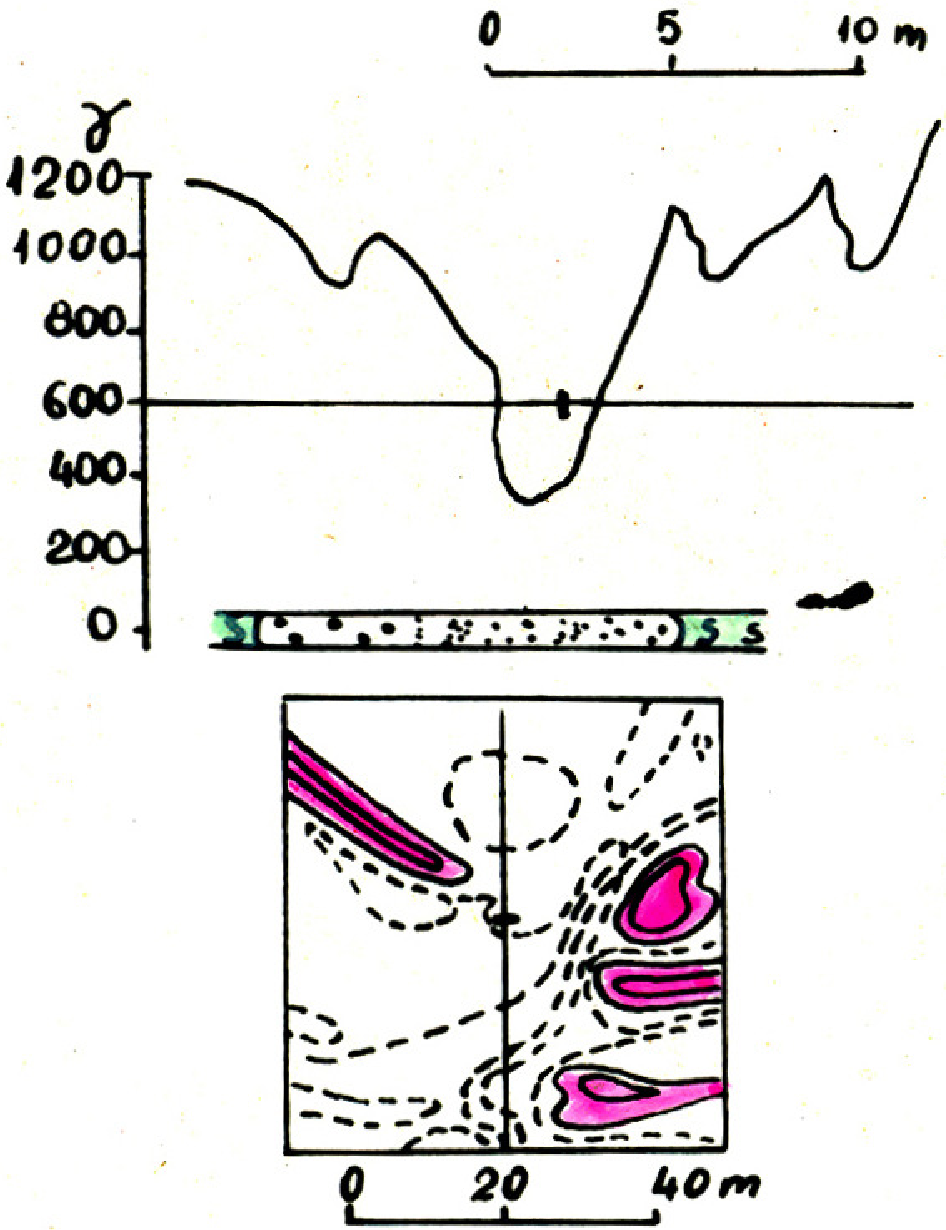

Fig. 4-6. Weak magnetic anomaly (ΔZ), over a chromite disseminates ore body (Fischer F., 1957).
Legend: as in the fig. 4-5.

The gravitational anomaly is expressed in the Bouguer anomaly graph but it is better expressed in the residual gravity anomaly calculated by Saxov-Nygard formula F (Δg) and in the residual local anomaly (Δg) plots. In this cross section, the gravitational and magnetic anomalies were fixed not only on the ore body but also around it.

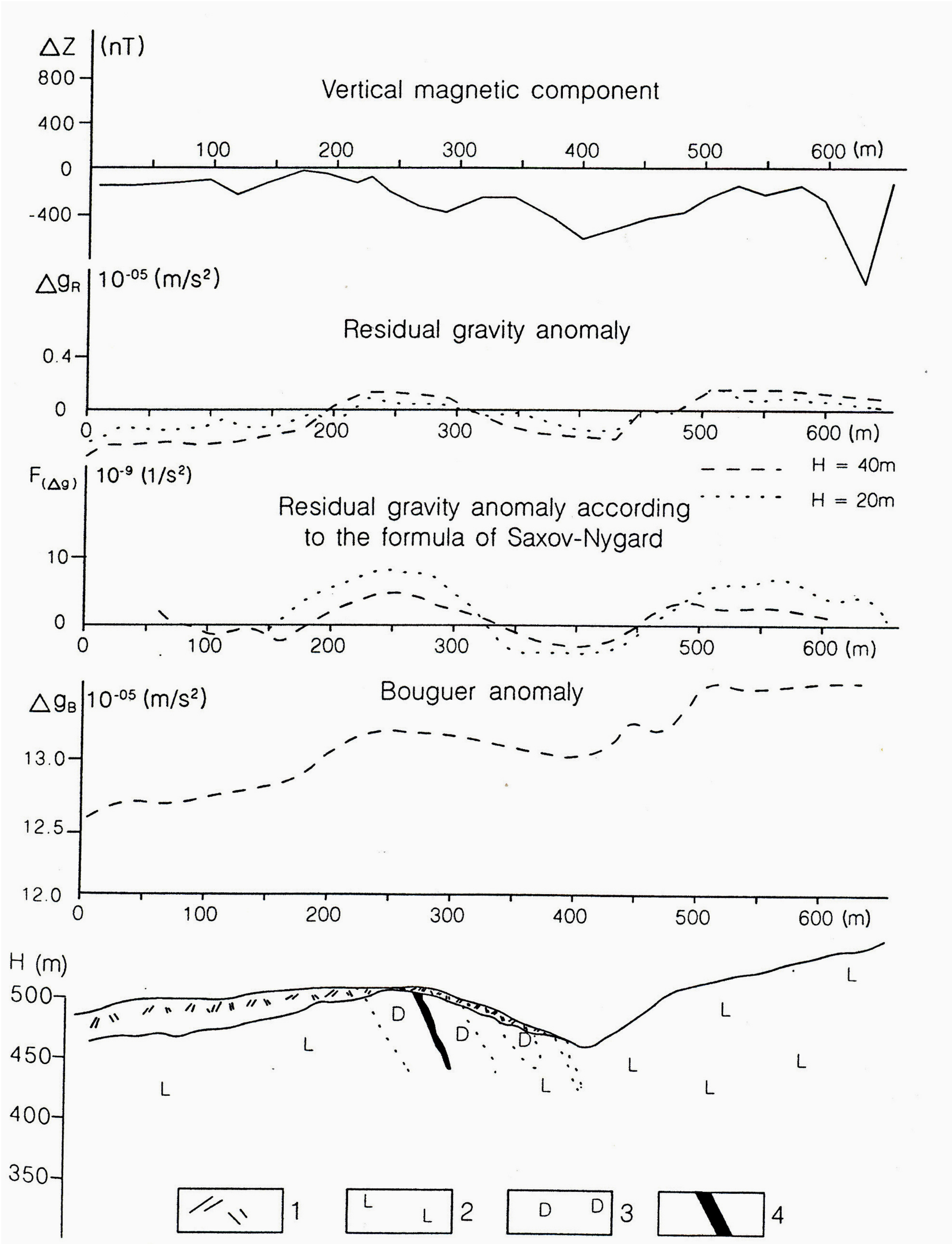

Fig. 4-7. Gravity and magnetic anomalies, Kepeneku deposit in Tropoja ultrabsic massif. (Lubonja L. and Kosho P. 1974). 1- Overburden; 2- Harzburgite; 3- Dunites; 4- Chromite ore body.

In fig. 4-8 is presented a weak negative magnetic anomalies are observed over disseminates chromite ore body No. 4 in Kepenek deposit.

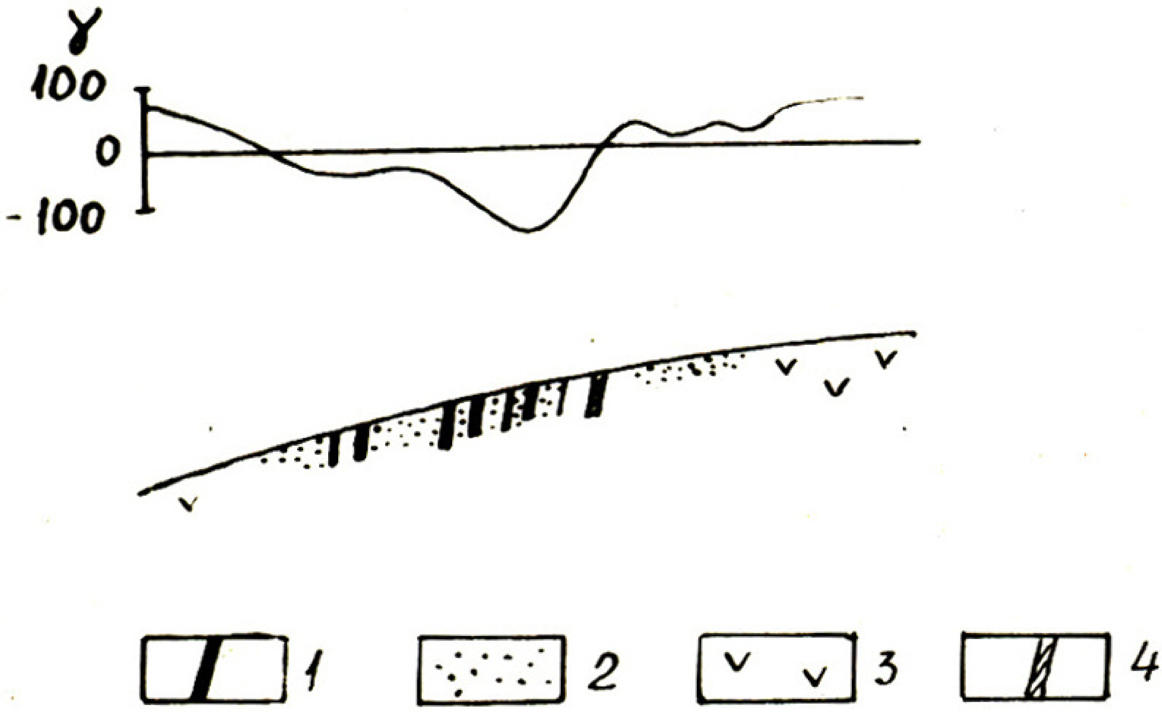

Fig. 4-8. Magnetic anomaly (ΔZ) over chromite ore body No.4, Kepenek deposit. (Fischer F., 1957)
1- Massive chromite ore; 2- Disseminates chromite ore; 3- Dunites; 4- Disjunctive tectonics.

Field transformation of Bouguer gravity anomalies (Δg) in vertical derivatives of second (W_{zz}) and thirty (W_{zzz}) orders of the gravity field potential in the Krasta and Surroi deposits have presented the anomalies with greater amplitudes (fig. 4-9, 4-10).

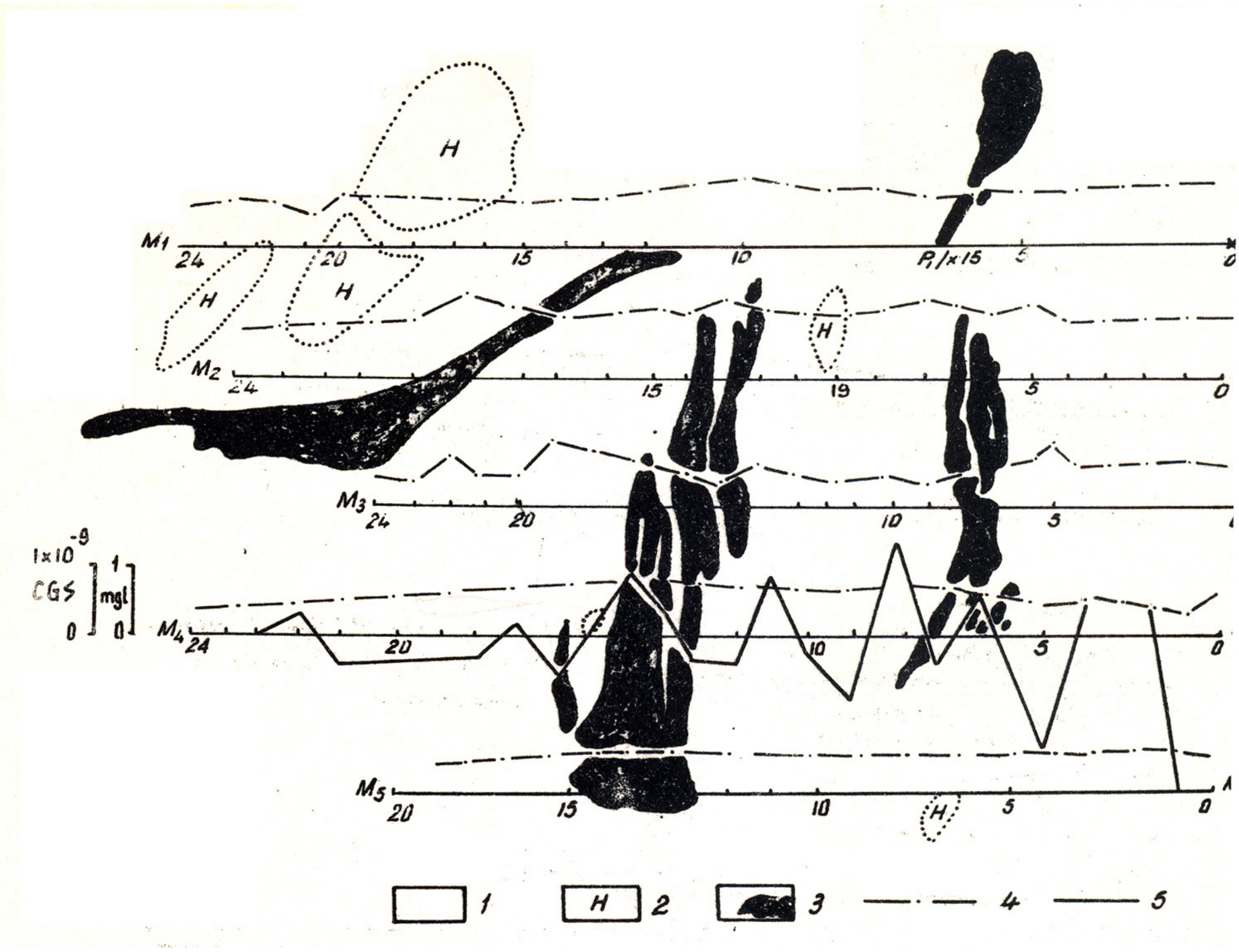

Fig. 4-9. Map of the Bouguer gravity anomalies (Δg) transformation in vertical derivatives of second and thirty orders W_{zzz} gravity field potential in M-4 line, Krasta deposit, Bulqiza ultrabasic massif (Lubonja L. & Frasheri A. 1976).
1- Dunites; 2- Hartzburgites; 3- Chromite ore body; 4- (Δg) profils; 5- W_{zzz} profils.

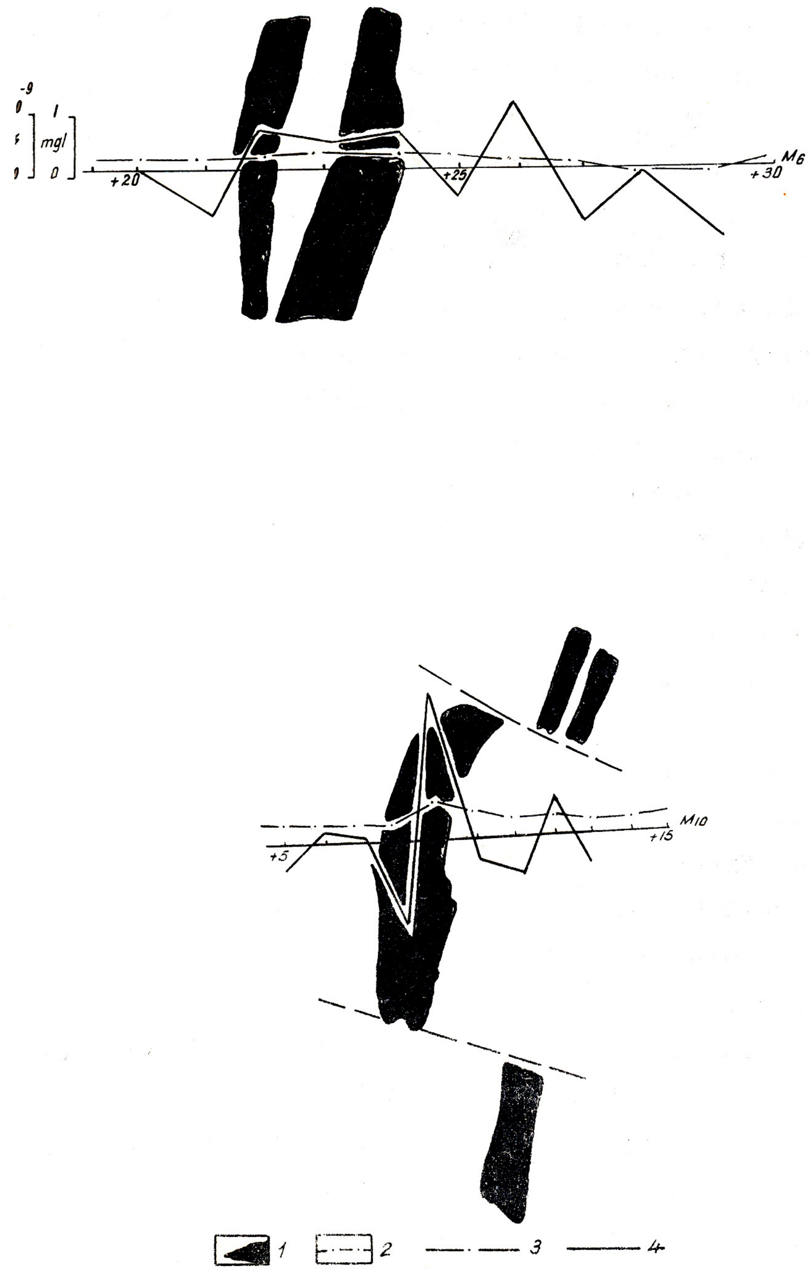

Fig. 4-10. Map of the Bouguer gravity anomalies (Δg) transformation in vertical derivatives of second and thirty orders W_{zzz} of gravity field potential, Surroi deposit, Kukesi ultrabasic massif (Lubonja L. & Frasheri A. 19676).
1- Chromite ore body; 2- disjunctive tectonics; 3- (Δg) profil; 5- W_{zzz} profil.

In the W_{zzz} graphics can detect not only ore bodies, but their apophyses, too. Such transformations are created possibilities not only to amplify weak Bouguer anomalies, but also to select superimposed anomalies over bodies, which are located near each other.

Transformations of the Δg anomalies in vertical gradients of the gravity potential W_{zz} and W_{zzz} must not create the wrong impression that through recalculations is possible to get anomalies even in the cases where there are no Δg anomalies over the chromite body. Transformations and recalculation of the W_{zz} and W_{zzz} only may show up some peculiarities of the Bouguer gravity anomalies map and in the same time diminish and eliminate some peculiarities that don’t permit to read the map.

The distribution of the magnetic field in the Kami deposit is turbulent. With great attention has been possible to select the anomalies over the chromite ore bodies (fig. 4-5, fig. 4-6). Ore body Nr.6 of the Kami deposit has created very clear IP anomaly (fig. 4-4)/

Figs. 4-11 and 4-12 shows the result of the geophysical exploration in the Tërnova deposit in the tectonic sequence, Bulqiza ultrabasic massif.

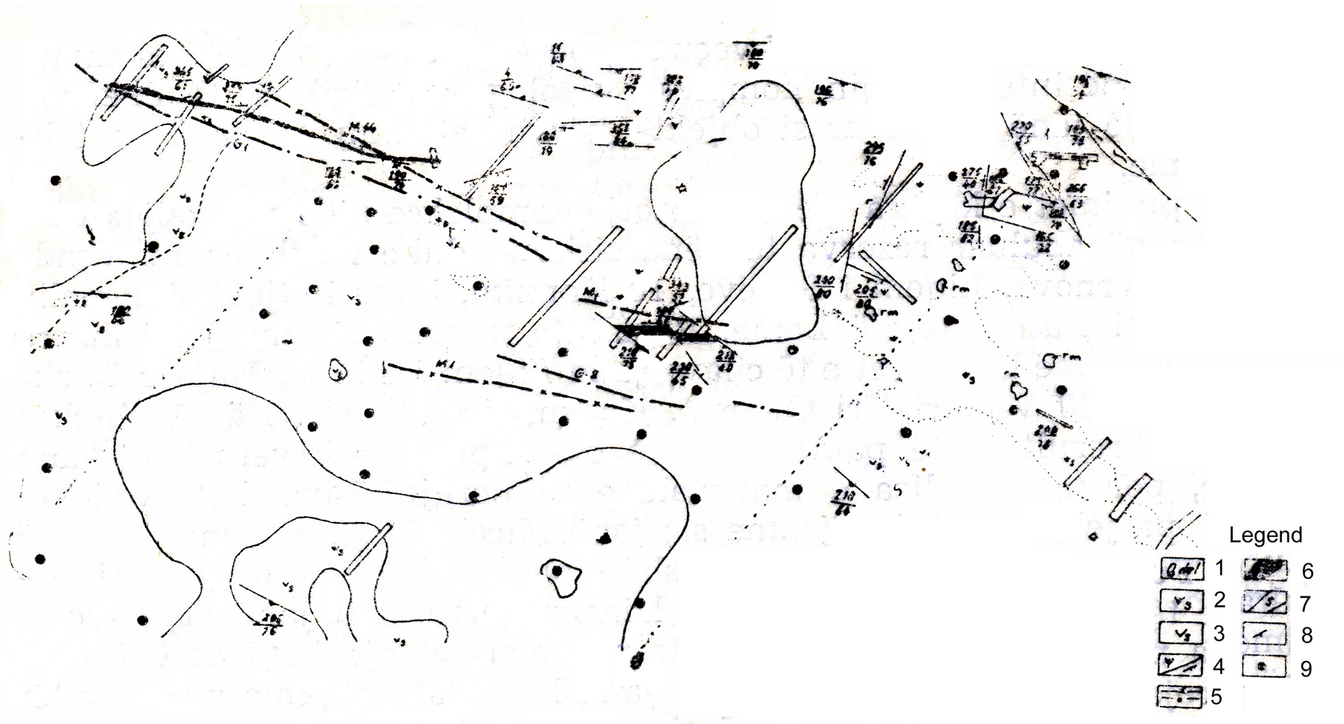

Fig. 4-11. Integrated geological-geophysical map of Tërnova deposit. (Langora Ll. et al. 1989).
1- Overburden; 2- Serpentinized dunites; 3- Serpentinized hartzburgites; 4- Pyroxenite veiny serie; 5- Gravity and magnetic anomalies; 6- Chromite ore body; 7- Serpentinized, schistized and brachiated tectonic zone; 8- Textural elements in the pyroxenite bands; 9-0 Boreholes.

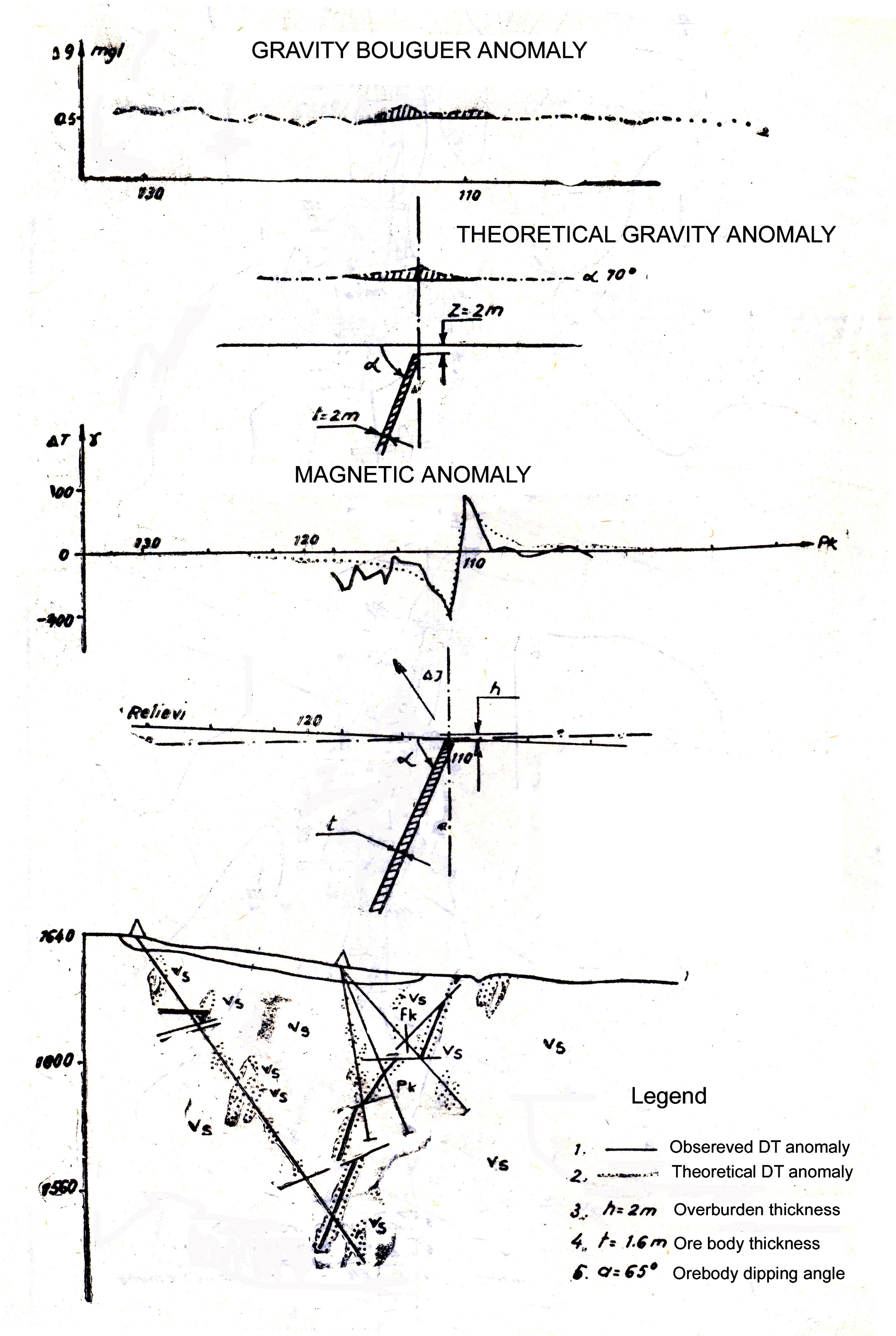

Fig. 4-12. Integrated geological-geophysical section, Tërnova deposit. (Langora Ll. et al. 1989).

1- Observed magnetic anomaly (ΔT); 2- Mathematical modelling magnetic anomaly (ΔT); 3- Overburden thickness h=2 m. ; 4- Ore body thickness t=1,6 m.; 5- Ore body dipping angle, α=65^{0}.

In the map, presented in the fig. 4-11, in Tërnova area are outcropped two chrome spinel occurrences. Over the northwestern occurrence were observed complex gravity and magnetic anomalies, with amplitudes respectively 0,15-0,20 Mgal and 400-600 nanoTesla. Over other outcropped body is observed only magnetic anomaly. The fig. 4-12 shows that under the overburden were discovered massive chromite ore body, with thickness about 1,6 m, and 220 m long, which presents the one of ore bodies of the Tërnova deposit.

South Batra area is characterizad by absence of chromite mineralization outcrops. In the total intensity of magnetic field (ΔT) there are observed a negative anomaly with amplitude –650 up to –670 nanto Tesla, 320 m long and 80 m width (Fig. 4-13, 4-14, 4-15).

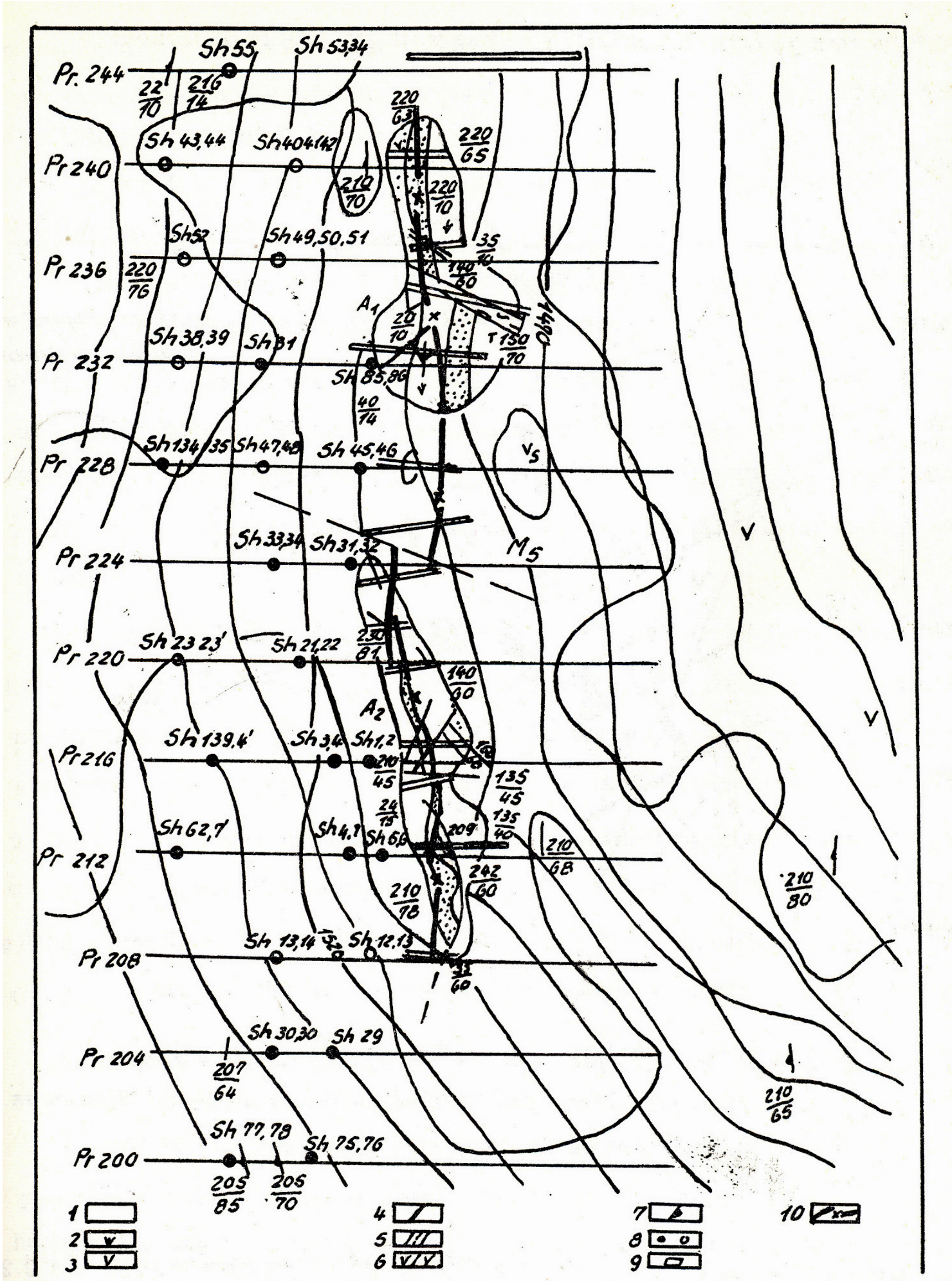

Fig. 4-13. Complex geological-magnetic map, South Batra area, Anomaly M-5. (Langora Ll. et al. 1989).

1- Overburden; 2- Serpentinized dunites; 3- Serpentinized hartzurgites; 4- Pyroxenite vein serie; 5- Chrome ore body; 6- Serpentinized, schistized and brecciated tectonic zone; 7- textural elements of the pyroxene bands; 8- Boreholes; 9- Magnetic anomaly.

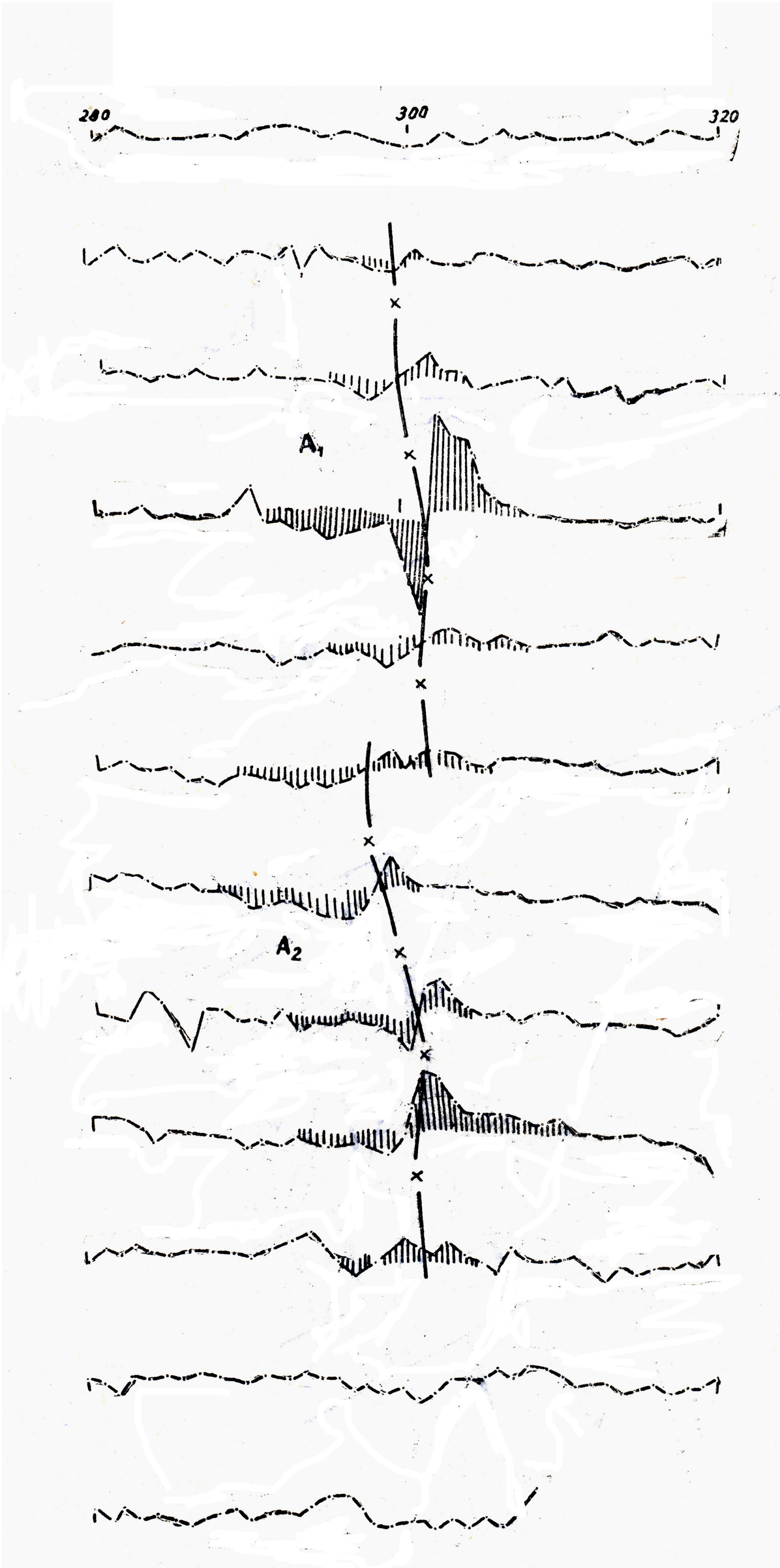

Fig. 4-14. Total intensity of magnetic field (ΔT) graphics map, South Batra area, anomaly M-5 (Langora Ll. et al. 1989).

TOTAL MAGNETIC INTENSITY (DT)

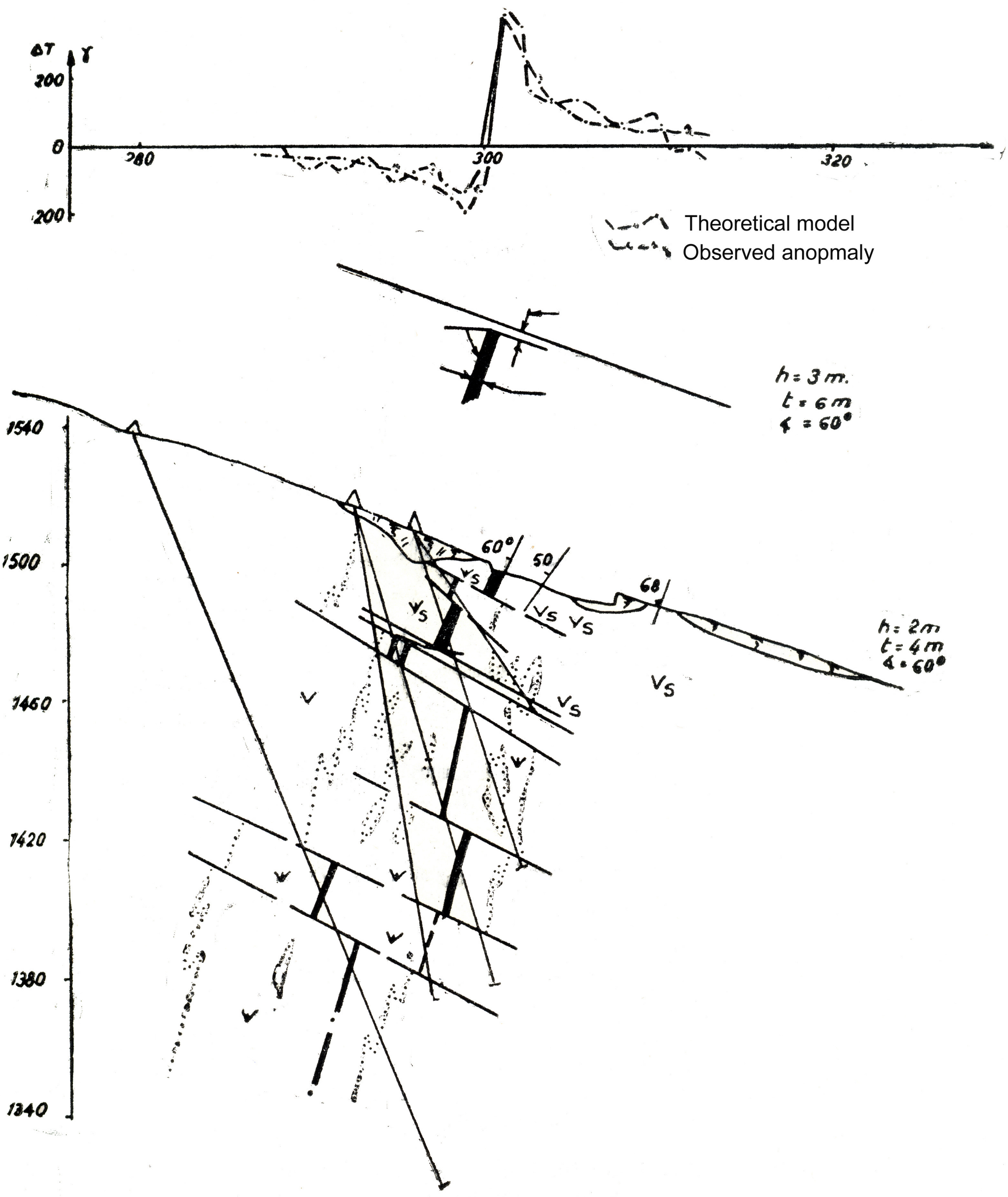

Fig. 4-15. Geological-magnetic section, South Batra area, anomaly M-5. (Langora Ll. et al. 1989).

In the case of the South Batra area, because of inverse remnant magnetization of the chrome ore body, anomaly is very complicated: anomaly presents a negative minimum together with a positive maximum (fig. 4.15). The lowest intensity values for the anomaly were observed where the depth of the ore body was 8 m (fig. 4.15). A horizontal displacement of the extremities of the axis of an anomaly and two maximums were observed in the profile No. 224 (fig. 4.14). This anomalous behaviour can be explained by the existence of a transverse tectonic fault, which divides the body into two parts along its strike. The southern extremity of its northern part and the northern extremity of its southern part are shown in the profile No 224. That means that there were two ore bodies and consequently two maximum points.

As can be seen from the map on figure 4.13, all trenches performed to verify the anomaly, intersected ore bodies, except those presented in the profiles 224, 228. The ore bodies in the profiles No. 224 and 228 were intersected by bore holes in great depths. In the axis of this anomaly 23 bore holes and 3 galleries were projected at different topographic levels. All bore holes and galleries have intersected the ore body, which runs alongside the anomaly, with a strike about 400 m. The thickness of the body is 2-3 m and its Cr_2O_3 content reached 30-40 %. Dipping ore body has a length of 180 meters.

The search for chrome ore body in the M-5 anomaly, South Batra zone, illustrates the high effectiveness of magnetic surveying.

Intensive and wide magnetic anomalies have been observed over a chromite ore body in the Leshnica and Vlahna deposits, at Kukesi and Tropoja ultrabasic massifs (Fig. 4.16, and 4.17).

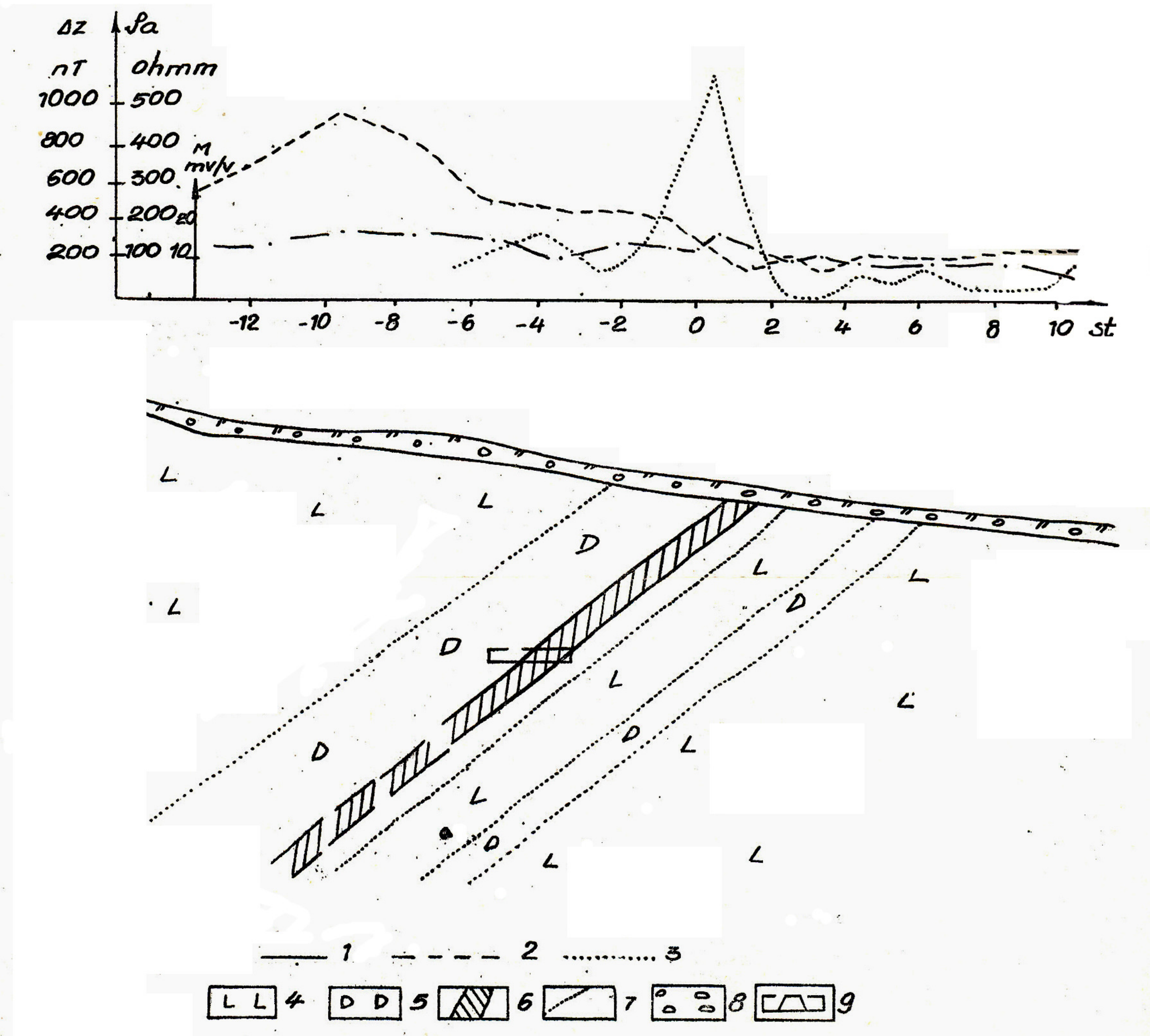

Fig. 4.16. Geological-geophysical section with a positive magnetic anomaly over a chromite ore body, Leshnice area, Kukesi ultrabasic massif (Frasheri A. et al. 1963).
1- IP coefficient profile; 2 - Apparent resistivity profile;
3 - Vertical component (DZ) of magnetic field profile; 4 – Hartzburgites; 5 – Dunites; 6 - Ore body; 7 – Gradual geological boundary; 8 – Deluvion; 9 - Gallery.

The chromite spinel ore of the Leshnica deposit is very magnetic. But, there don't existing IP anomaly. Such absence of the IP anomalies is conditioned by very high humidity of chromites, which are located in the disjunctive tectonic zone, with intensive underground water flow. In such conditions, the magnetic chromite ore is non-polarizable.

Negative magnetic anomaly of the vertical component (ΔZ) of –540 nanoTesla amplitude, and a clear IP anomaly, with amplitude of 35 - 50 mV/V, which is about 3 times over the background level, have been observed over the Vlahna chromite ore body (Tropoja massif) (fig. 4.17). Two anomalous effects superimposed this magnetic anomaly: effect from ore body over an effect from the surrounding non-magnetic serpentinites belt. Such phenomenon makes very difficult anomaly interpretation.

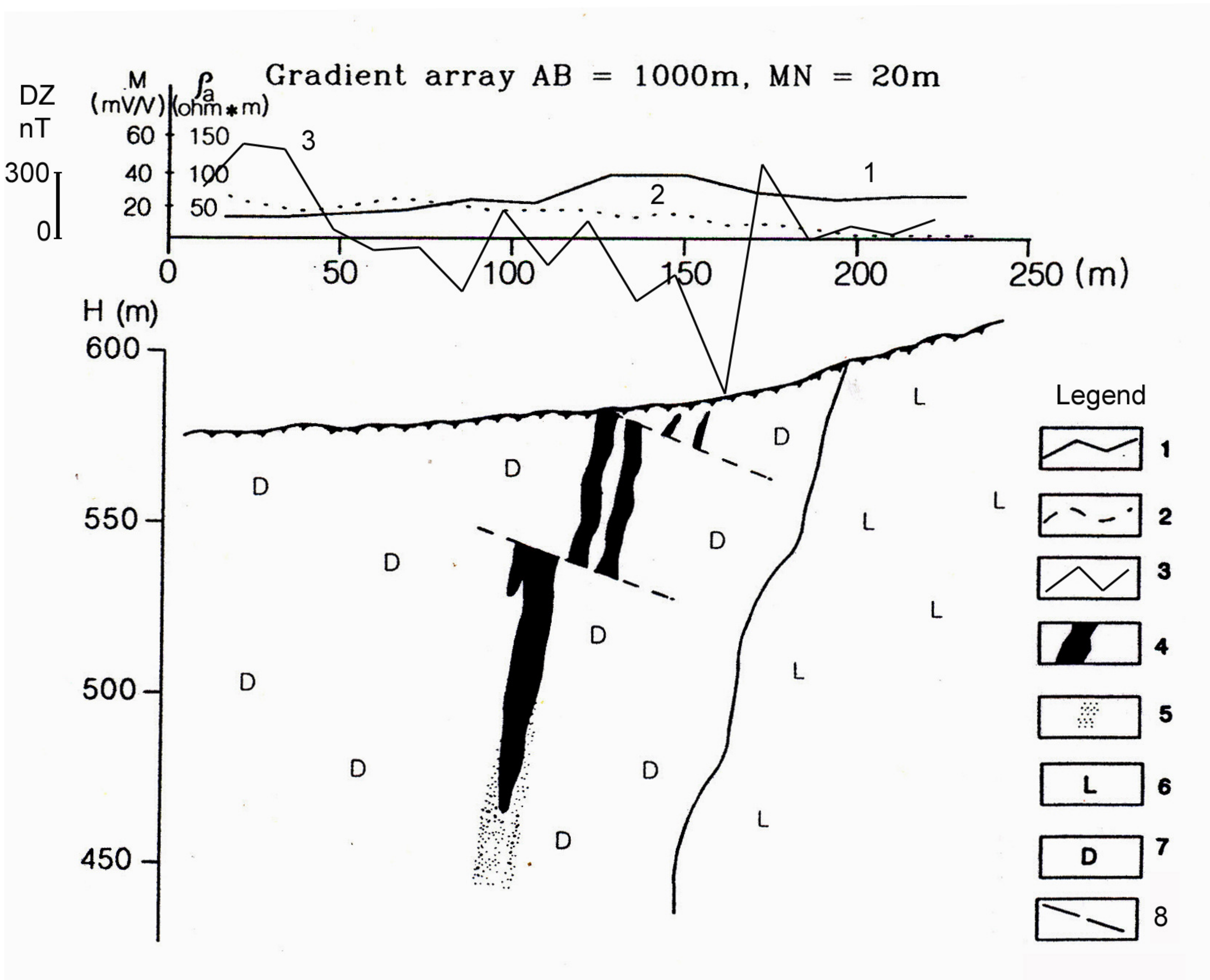

Fig. 4.17. Magnetic and IP anomalies over the Vlahna deposit (Tropoja massif) (Frasheri A. et al. 1963, Lubonja L. & Frasheri A. 1966).
1- IP coefficient profile; 2 - Apparent resistivity profile; 3- Magnetic anomaly (ΔZ); 4 – Masive chromite ore body; 5- Disseminates chromite; 5 – Hartzburgites: 6 – Dunites; 7 - Disjunctive tectonics.

In Tri Gjepra area (Bulqiza ultrabsic massif) has observed IP anomaly (fig. 4.18).

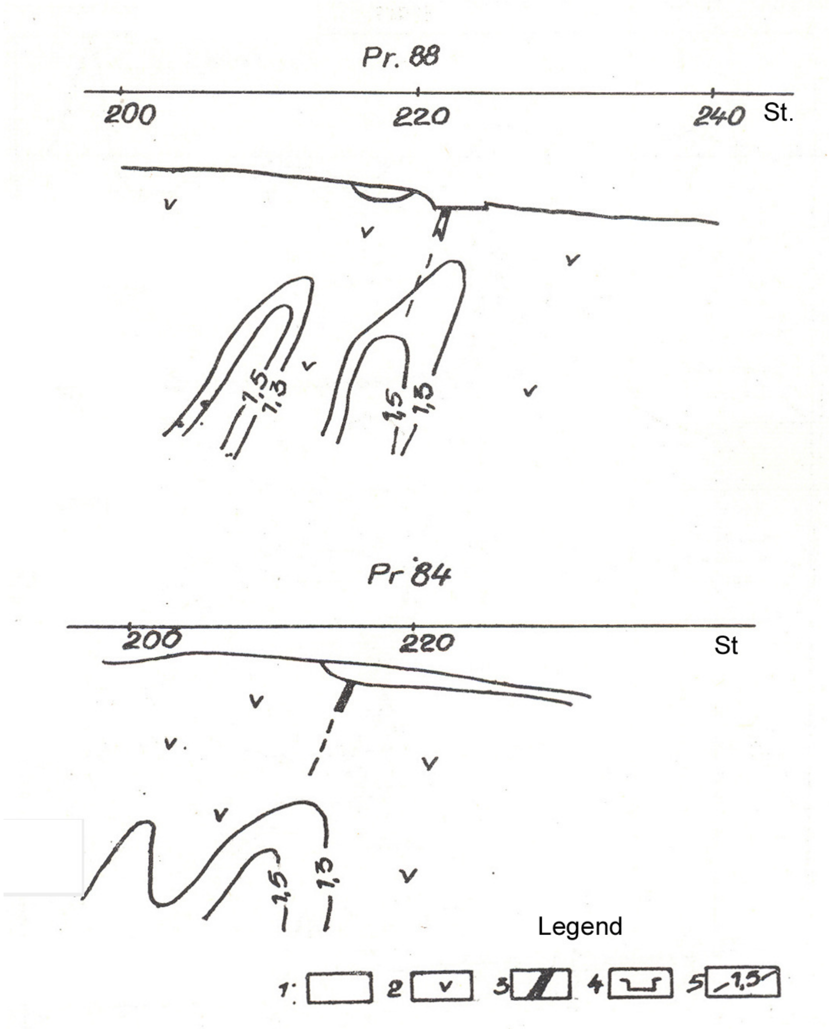

Fig. 4.18. IP real section with multiple gradient arrays in Tri Gjepra zone (Bulqiza). The arrays AB = 200, 400, 600 m; MN = 20 m, (Prenga Ll. Et al. 1986).
1 – Deluvion; 2 – Hartzburgites; 3 - Ore body; 4 – Trench; 5 - IP coefficient contours (in % units).

From the IP sections shown in fig. 4-18, can be seen that the IP anomaly is contoured by a line with value of 1.4% over the background level. This level is 1-1.2% for hartzburgites and 1.5-1.8% for dunites. The anomaly has amplitude of 1.5-2.5% at the width of 30-40m. Since the ore body layout is underneath the shallow deluvion, these anomalies can be discriminated better by using of pol dipole array A20M20N,B→∞. Many boreholes and trenches intersected this anomaly, which a length about 280 m.

The chromite ore in the Qafe Gjelas deposit in the Bulqiza massif has a predominant density value of 4000 kg/m³, which is higher than the density of the surrounding rocks. This is a magnetic ore and has a predominant IP coefficient value of 1.7%. The dunites and hartzburgites have an IP coefficient of 0.7% and 1.2% respectively. For this reason clear gravitational, magnetic and IP anomalies have been observed over this ore body (fig. 4-19).

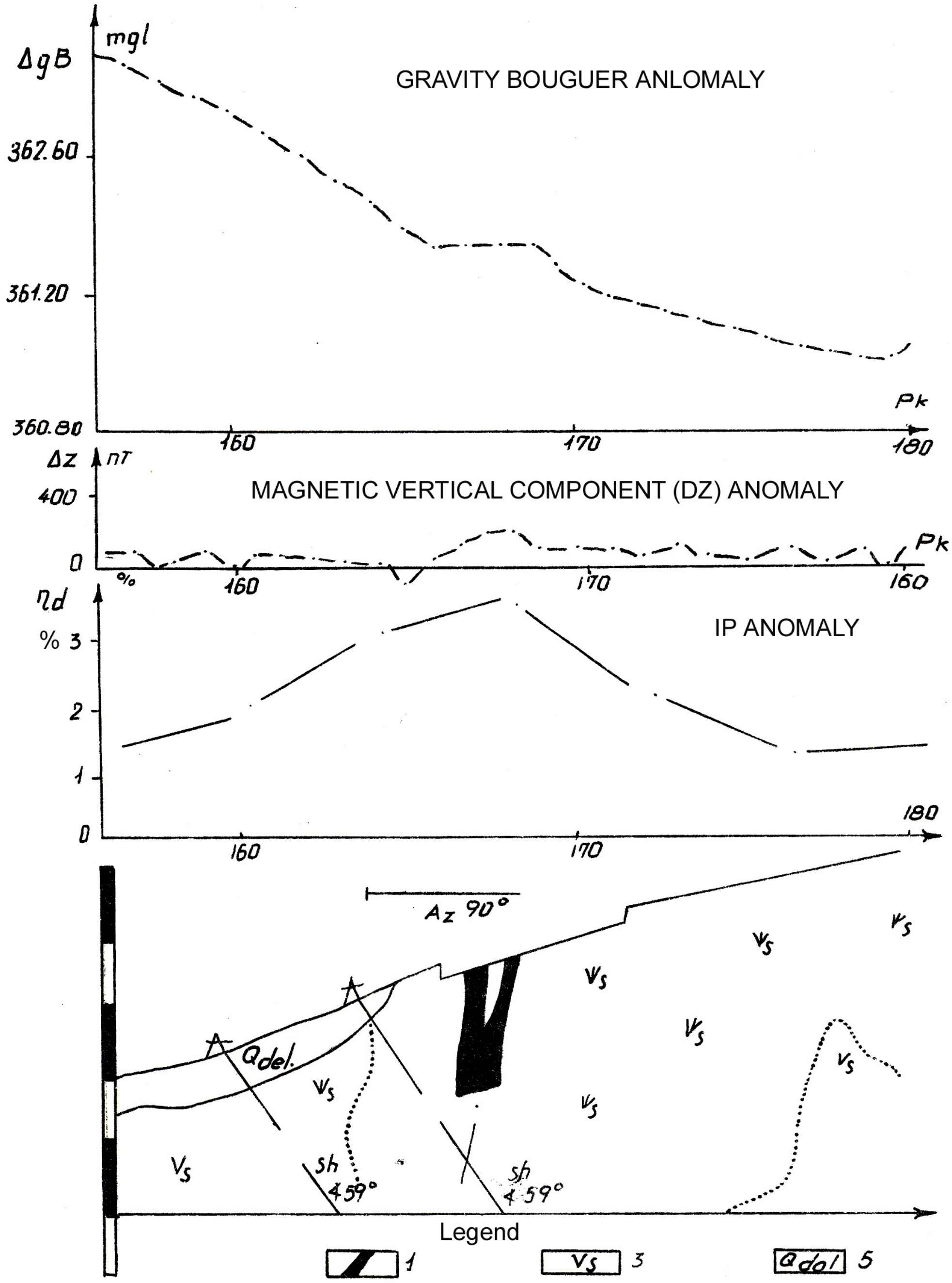

Fig. 4.19. Geological-Geophysical section in Qafe Gjela deposit (Bulqiza massif) (Prenga Ll. et al. 1983).

1 - Ore body, 2 - Serpentinized dunite, 3 - Serpentinized hartzburgite, 4 - Smooth-rock border, 5 - Deluvion, 6 - Tectonic fault.

From this section can be seen that the IP anomaly is a rather wide one. This is due to the influence of ore body and its dunite envelope (fig. 4.20). Consequently a complicated wide anomaly is observed.

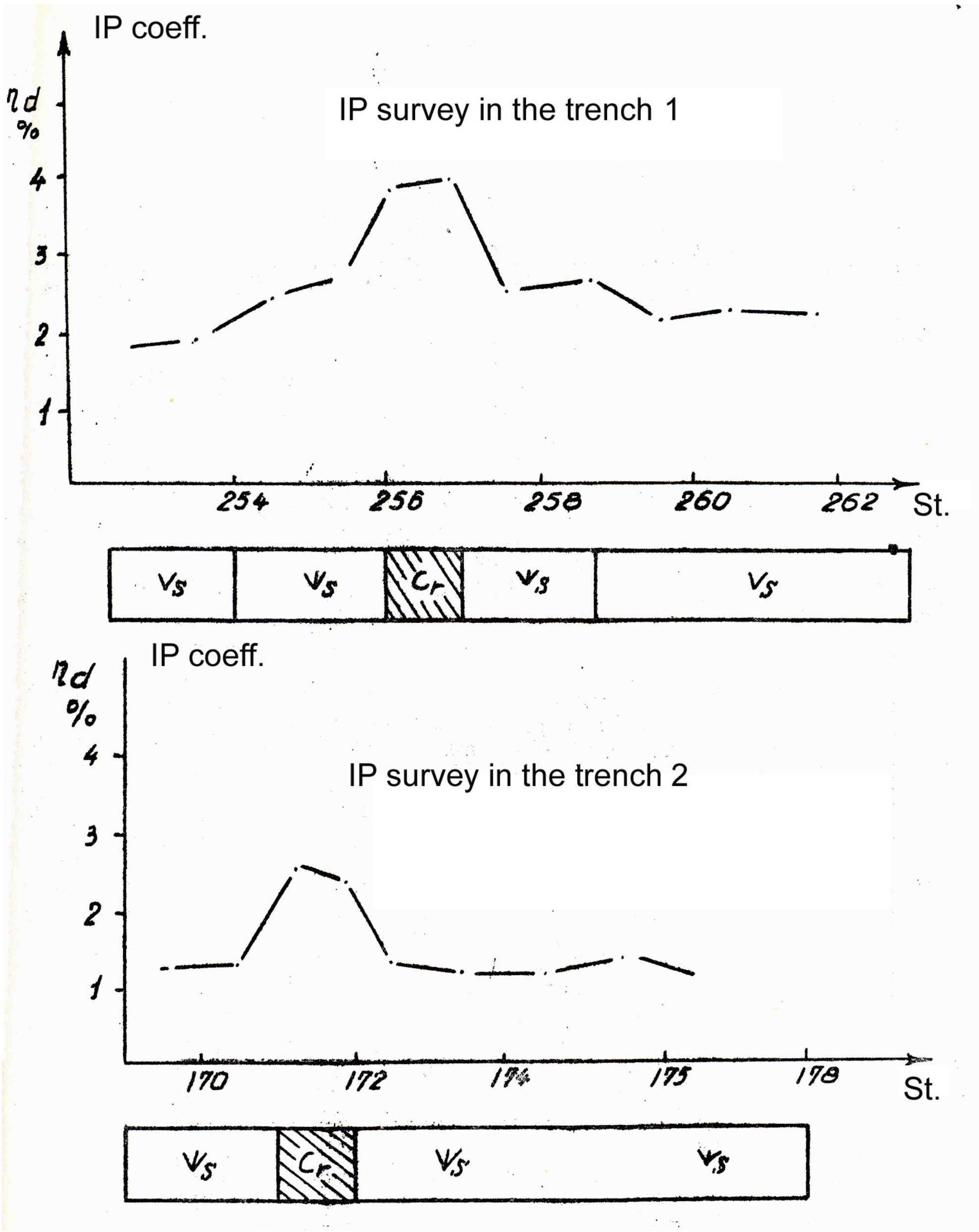

Fig. 4.20. IP anomalies according to parametric measurements over two trenches at Qafe Gjelas chrome deposit (Prenga Ll. et al. 1983).

a - Complicated anomaly over the ore body and dunitic envelope, b - Single anomaly over the ore body.

Fresh dunites and hartzburgites are extended in Tplana area. Consequently, magneti field is relatively quiet. Negative magnetic anomalies over massive chromite ore body (fig. 4-21). There are observed other negatiuve anomalies, which can be are caused by unknown ore chromite ore bodie, or over a paramagnetic gabbro-pegmatite/pyroxenite vein.

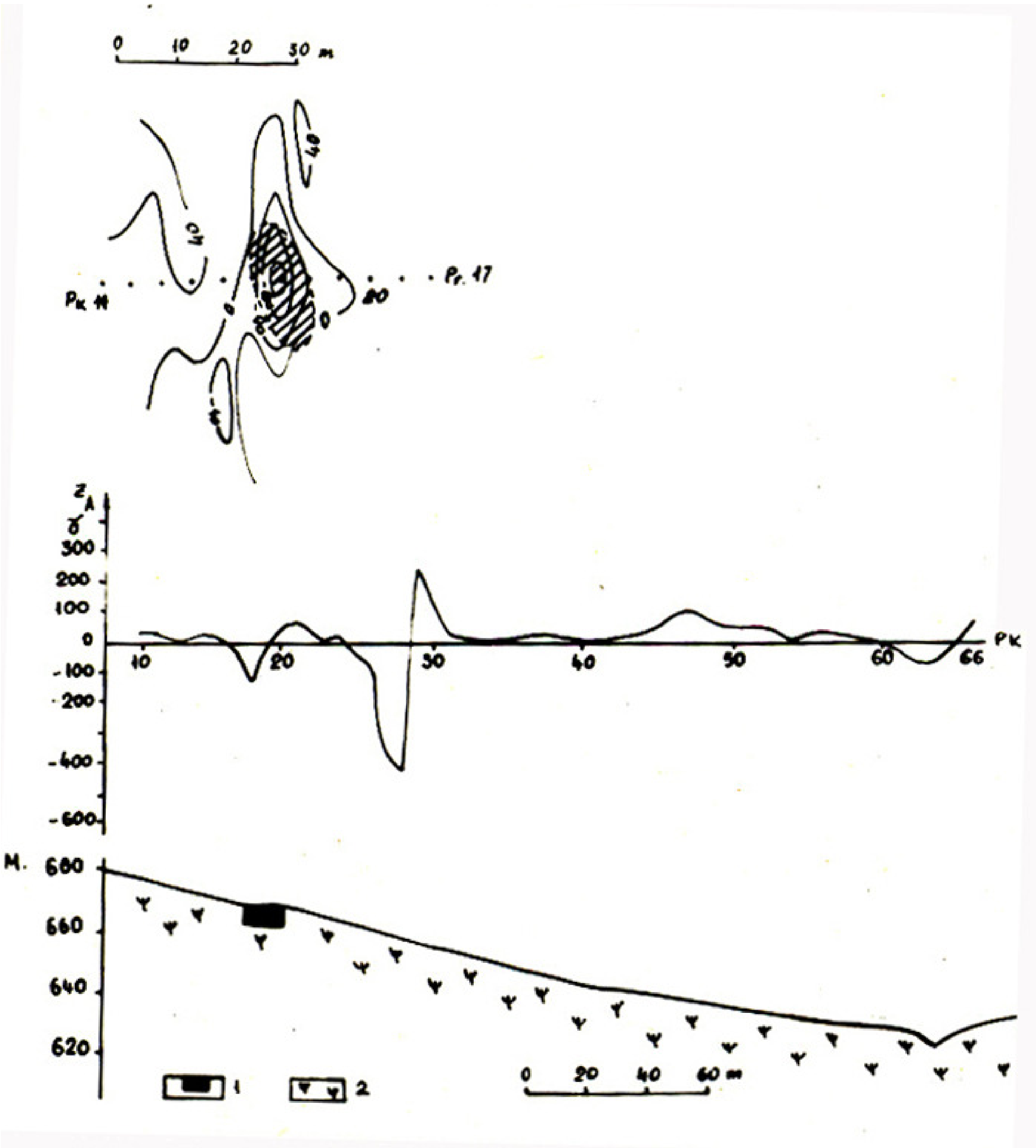

Fig. 4-21. Magnetic anomalie (ΔZ) over a chromite pore body in Tplanë area. (Frasheri A., et al. 1963).
1- Chromite ore body; 2- Hartzburgiyte.

b) Non-ore anomalies

During the geophysical mapping for the search for chrome ores, have been observed a lot of non-ore anomalies, due to many factors such as:

- Fresh rock inclusions between serpentinized rocks, which may create gravitational anomalies.
- Serpentinized rocks with high content of magnetite which can create magnetic anomalies, or indueced polarization.

For example a magnetic anomaly of the amplitude -200 and +200 nT was caused by highly serpentinized dunites (fig. 4.22). IP anomalies can be observed, in these zones, as well.

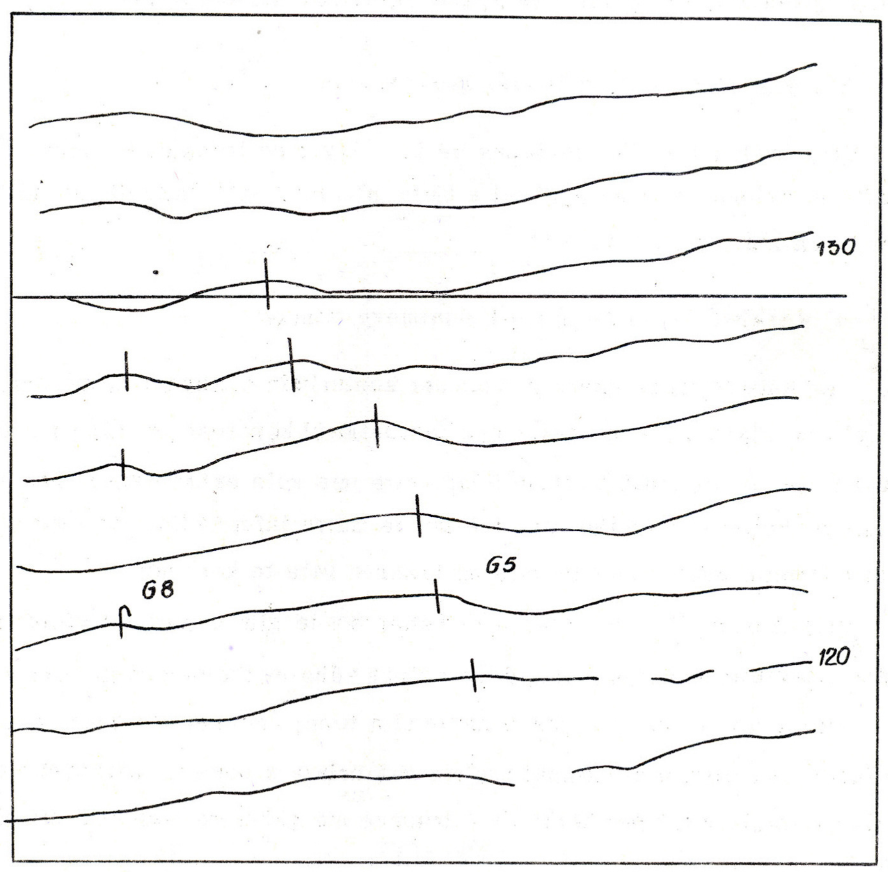

Fig. 4.22. The map of profiles of the total magnetic field intensity (ΔT) at Fushe Kalti zone (Bulqiza massif), where magnetic anomaly is observed over highly serpentinized belt and crushed dunitic inclusions have been observed (Sharra Xh., Rrenja A. et al. 1987).

Gravitational anomalies have been observed in zones with thin cover of soft overburden and compact bedrocks close to surface (fig. 4.23).

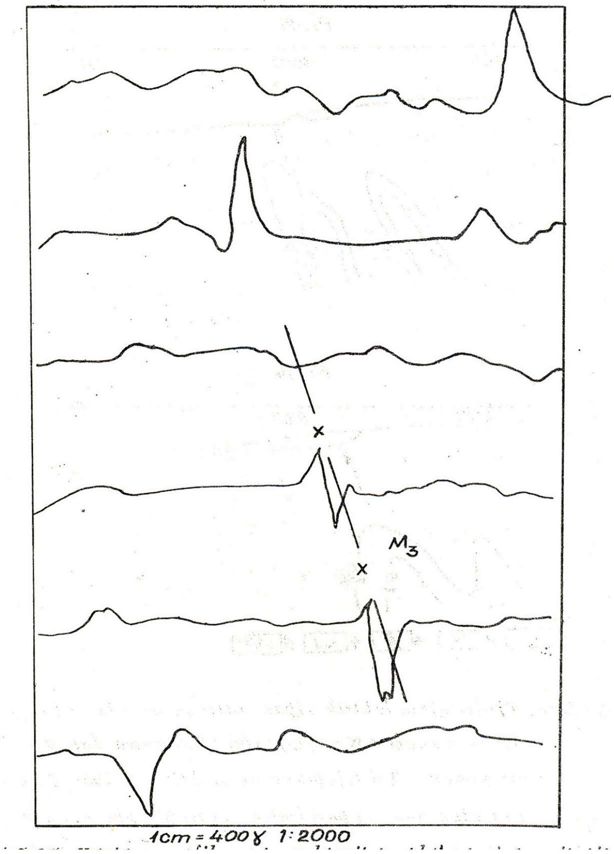

Fig. 4.23. The map of profiles of the Bouguer anomaly in Fushe Kalti (Bulqiza massif), in a sector where are decreased the thickness of the soft overburden. (According to the Sharra Xh., Rrenja A. et al. 1987).

Prior to Bouguer anomaly interpretation, the thickness of soft sediments (deluvion and eluvion) was determined by apparent resistivity soundings. The main task of the interpretation was to selected the anomalies caused by ore bodies.

Intensive negative magnetic anomalies is observed over non-magnetic rock individualizations or gabbro-pegmatites/pyroxenite dykes. Fig. 4-24 shows an anomaly with amplitude –500 nT over non-magnetic serpentinized hartzburgites and serpentinites in Kami deposit area.

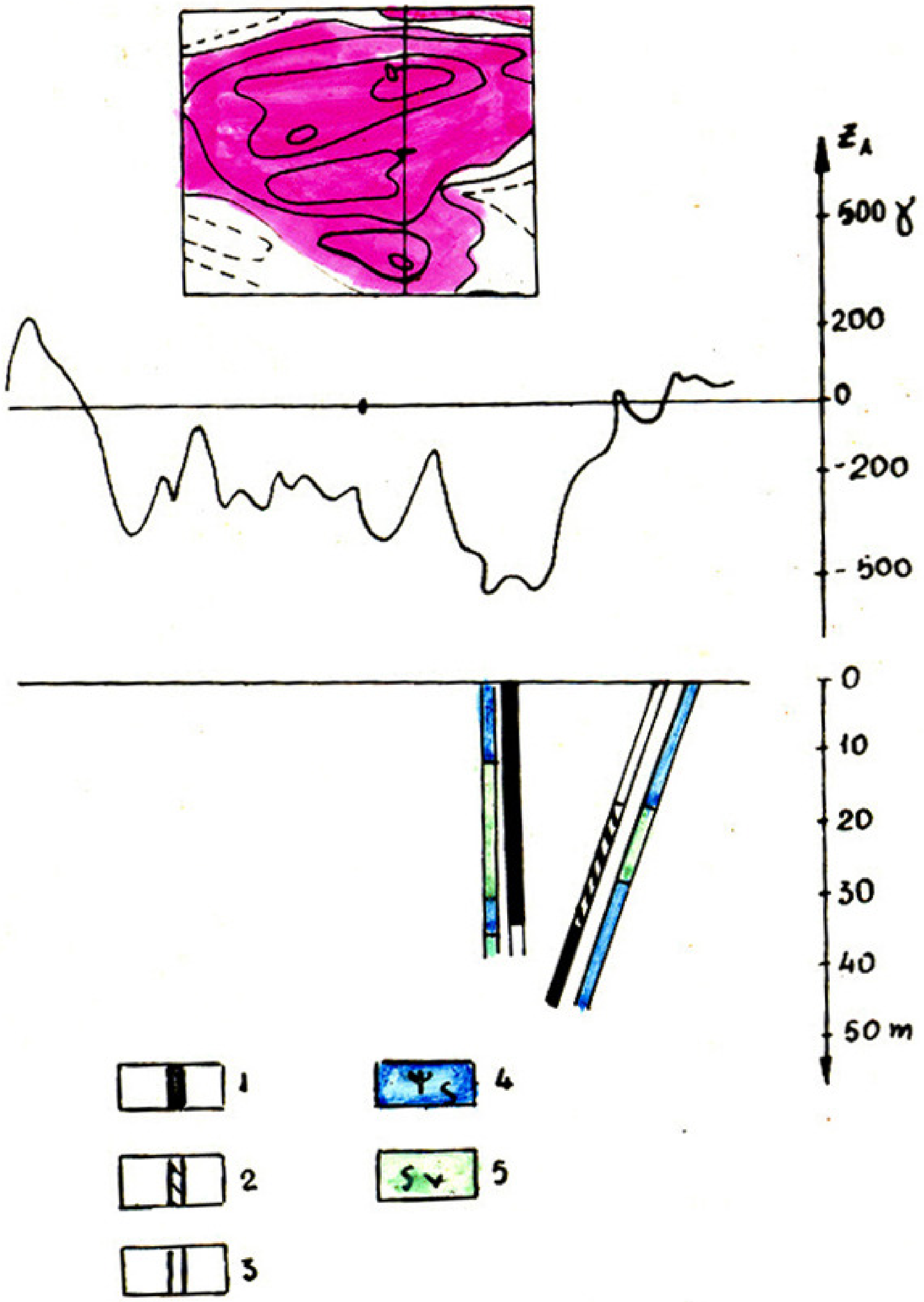

Fig. 4-24. Magnetic anomaly (ΔZ) opver non-magnetic rock individualisation, kam deposit. (Fischer F. 1957)
1- Magnetic susceptibility x=250x10-5 units SI; 2- x=350x10-5 units SI; 3- x=400x10-5 units SI; 4- Serpentinized hartzburgites; 5- Serpentinite from dunites.

A typical narrow and intensive magnetic anomaly, with amplitude of -16.000 nT is observed over a pyroxenite vein in the Kam deposit area (fig. 4-25).

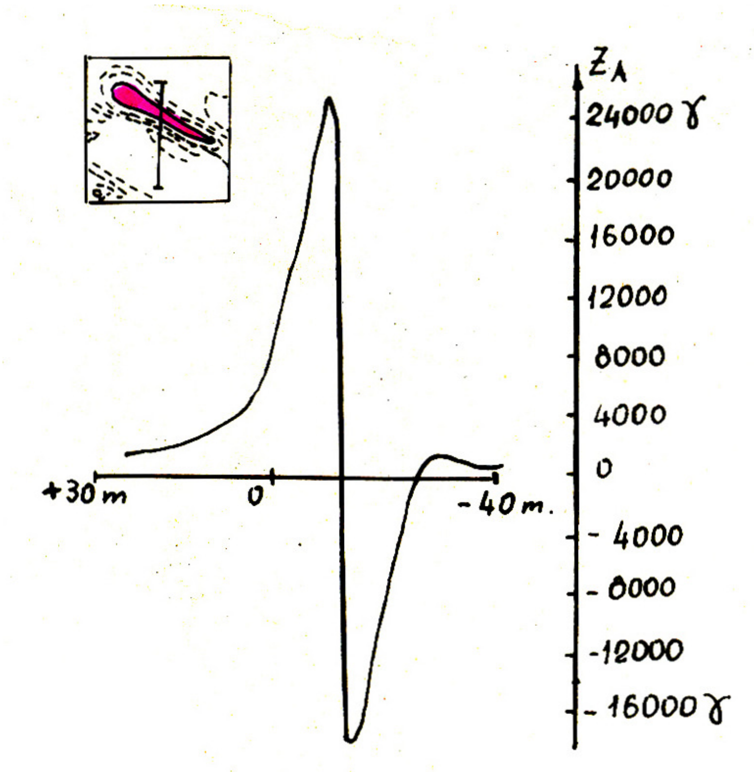

Fig. 4-25. Magnetic anomaly (ΔZ) over a pyroxenite vein, Kami deposit. (Fischer F., 1957).

4.2. Underground geophysical surveys

Underground geophysical surveys have been carried out in boreholes, in galleries and other mine works to solve the following problems:

a) <u>The search around mine works</u>

The search around mine works has been conducted in order to contour known ore bodies, especially those that are effected by tectonic faults, and to search for new ore bodies located around mine works. The goal was to increase the search depth and to get the available information for a sparse network of mine works at the first stage of the exploration.

Underground surveys can be made by all geophysical methods, which are used also by surface mapping. Radio wave floodlighting method can be used as additional ones.

The experience gained, especially during the eighty years period in Albania showed that the three components magnetic borehole method can be implemented successfully and efficiently for the search for magnetic chrome ore bodies. Typical example is presented the underground magnetic surveys in four boreholes in the Shkalla area, Bulqiza ultrabasic massif (Fig. 4-26) (Gjevreku Dh. 1984, Langora Ll. et al 1988). In the borehole No. 141 are observed two anomalies, at the depth 100 m and 140-180 m (fig. 4-17). The anomalies, respectively have an amplitudes: ΔZ=7 500 nT, ΔH=8 500 nT, and ΔZ=5000 nT, ΔH=8000 nT.

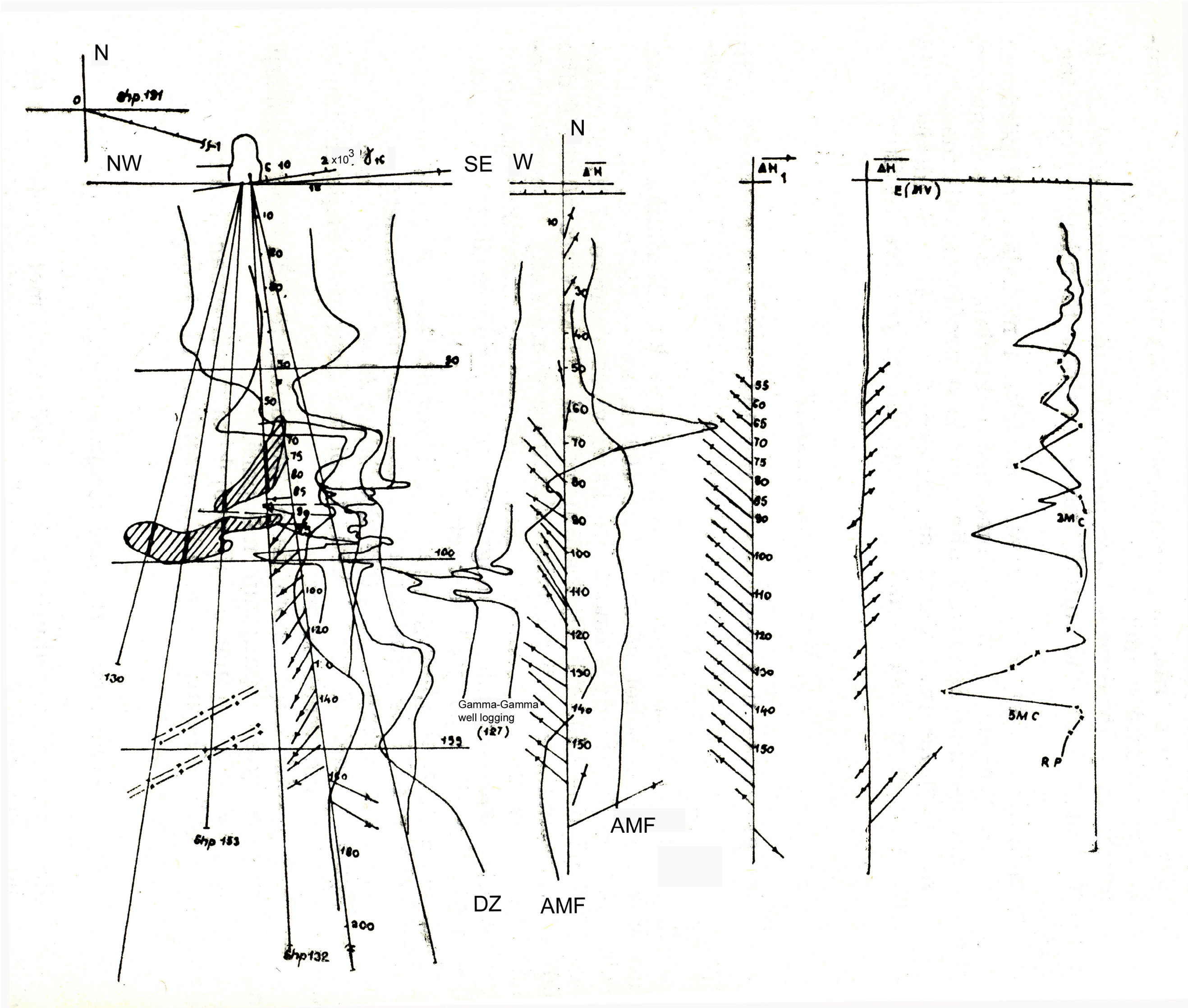

Fig. 4.26. Geological-geophysical section in L-L 5 underground magnetic survey line, Shkalla deposits, Bulqiza ultrabasic massif. (Langora Ll. Et al. 1989)

According to the geological-geophysical interpretation of the data in the L-L 5, and L-L 6 lines result following conclusions:

- Chromite ore body must located about 30-40 m from line L-L 6.
- Northern prolongation of the ore body is about for 40 m.
- Other ore body causes second anomaly.

Projected boreholes have discovered ore bodies.

Fig. 4-27 shows the undeground magnetic surveys in boreholes at Bulqiza deposit. The observed magnetic field in the borehole Sh. 4 represents an anomalous field above and underneath levels. Borehole Sh.3 has intersected the ore body. The interpretation of the plots of the three component magnetic component Z and total magnetic component T showed that the ore body intersected by the bore hole Sh.2 in the forms of flexure, is connected with the ore body intersected by the bore hole Sh.3.

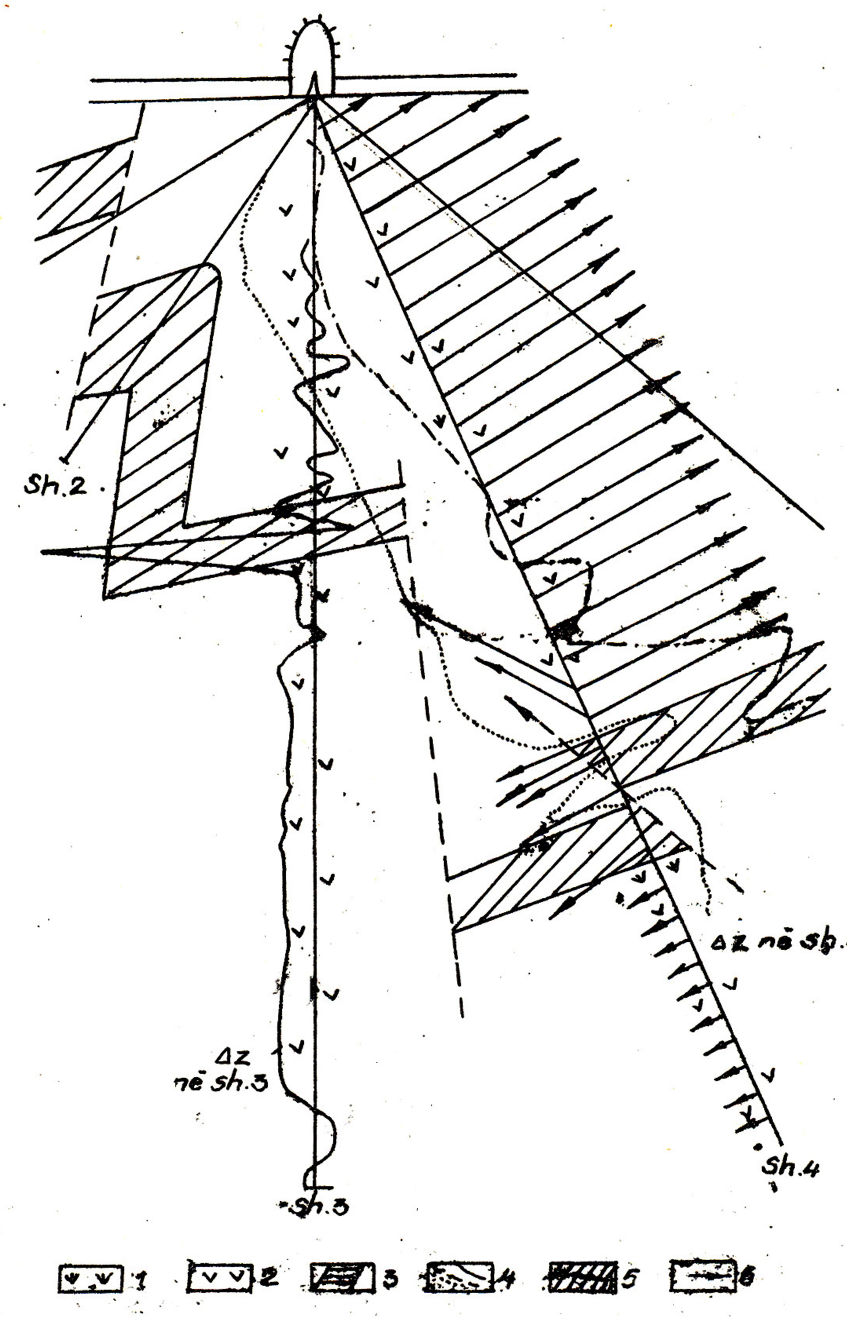

Fig. 4.27.Geomagnetic section according to three component borehole magnetic surveys in Bulqiza chrome deposit (Gjevreku Dh. 1984).

1- Dunite; 2- Hartzbourgite; 3- Ore body; 4- Vertical magnetic component (ΔZ) plot; 5- Total vector of the magnetic field intensity (ΔT).

In borehole S-17, which did not interest any orebody, an anomalous sector of the total magnetic field vector T at a depth of 190-330 m was observed (fig. 4-28). This anomaly was interpreted as being caused by a magnetic chromite ore body between the boreholes S-17 and S-16. The shallow boreholes S-1, S-2, S-3 and S-4 drilled at the end of gallery G-5 intersected the predicted orebody.

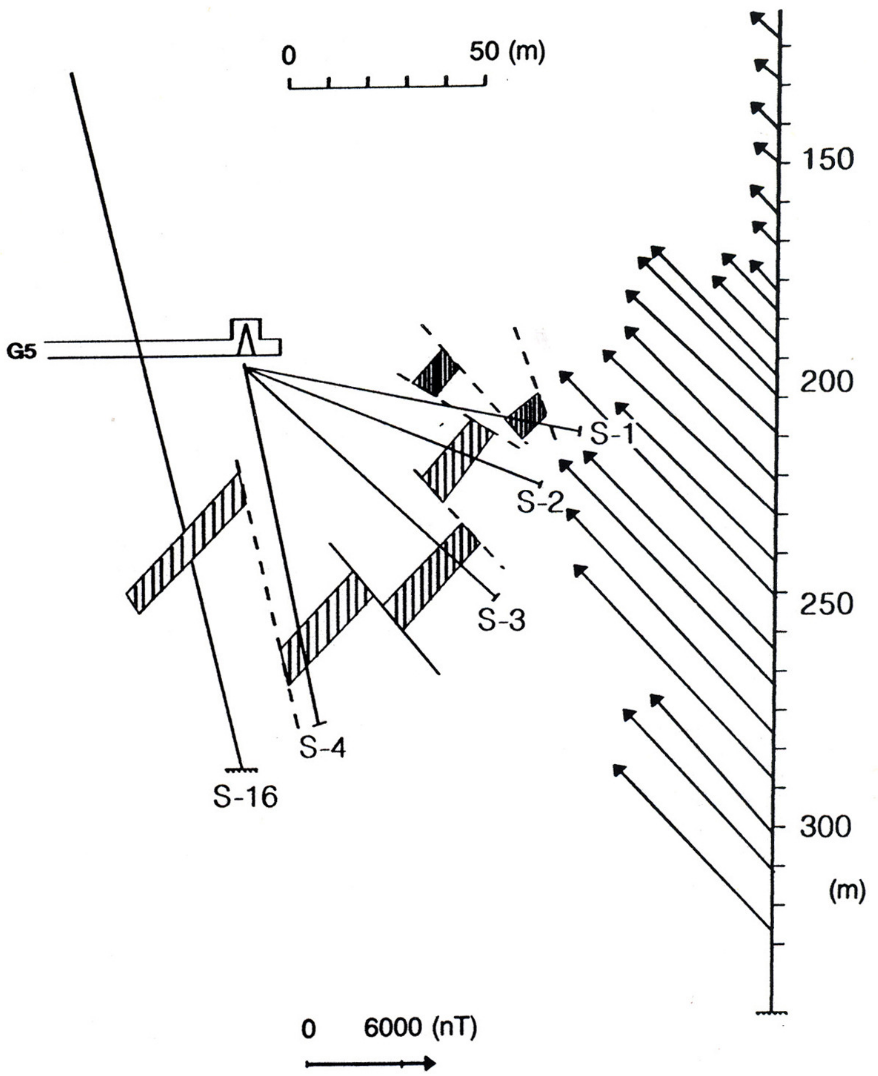

Fig. 4-28. Anomaly of total magnetic field intensity (ΔT), according to the three-components borehole magnetic field surveys for underground exploration of chromite ore (Gjevreku Dh., 1984, Lubonja L. et al. 1995).

The outputs of the radiowave floodlighting and radio wave profiling give good results when the chrome ore is magnetic and has dense up to massive structure (fig. 4.29) The absorption coefficient values of electromagnetic waves of frequency 1 - 10 Hz for this area is b = (0.02-0.04) Neper/m, which is greater than for ultrabasic rocks (b = 0.0012-0.0015 Neper/m).

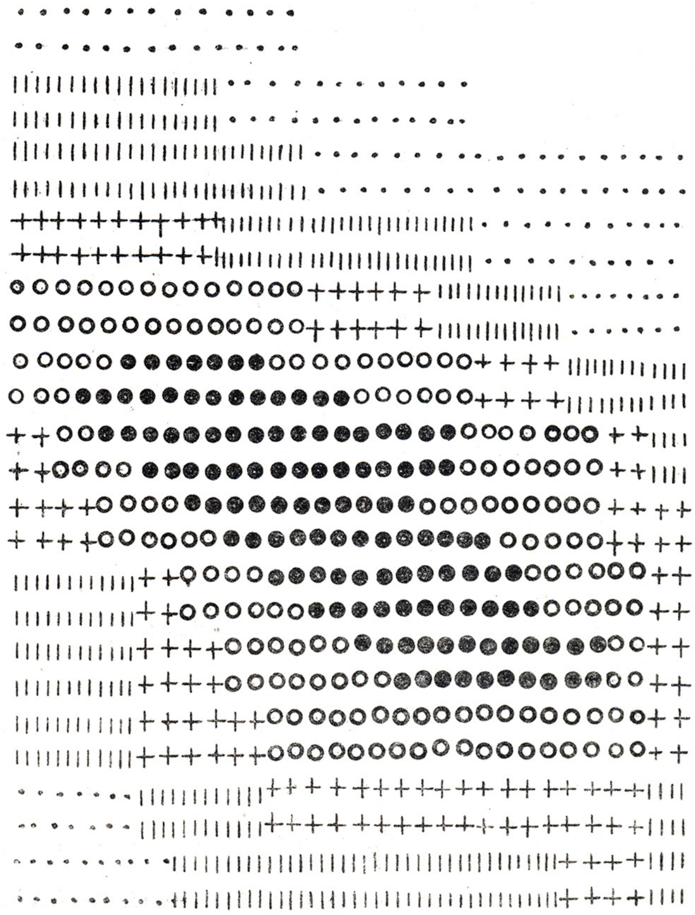

Fig. 4-29. The hologram of radio wave floodlighting borehole to borehole in Shkalla deposit (Mat district) (Gjevreku Dh. 1986).

IP methods can be used for the search of polarised ore bodies around boreholes by using the pole-dipole array N5M5A,B→∞ and N10M100A,B→∞, which can investigate a zone of a radius 7m and 60m, respectively.

The results of underground survey are not affected either by complicated topography, or by alternated rock inclusion nearly to surface. Mine works, metallic equipment and geological heterogeneity have an effect on these results. To avoid these influences, underground surveying is carried out by a special methodology and prior to the interpretation; the results are subjected to different mathematical processing.

b) Well logging

The geophysical methods have been used for geological documentation of the borehole trunk, ore bodies, tectonics faults and rock inclusions of different serpentinization degrees. Ore body thickness, deep layout, Cr_2O_3 content and the ratios Cr_2O_3/FeO, Cr/Al have been determined at a rather high accuracy.

The density is the more stable physical property, which in most cases is used for the selection of ore bodies from the surrounding media. The main method used for documentation of the borehole is the density and selective gamma-gamma logging (fig. 4.30.).

In the borehole log of the diffused gamma radiation (I_{gg}) the ore bodies can be outlined by radiation minimum, because they have higher density values than the surrounding rocks.

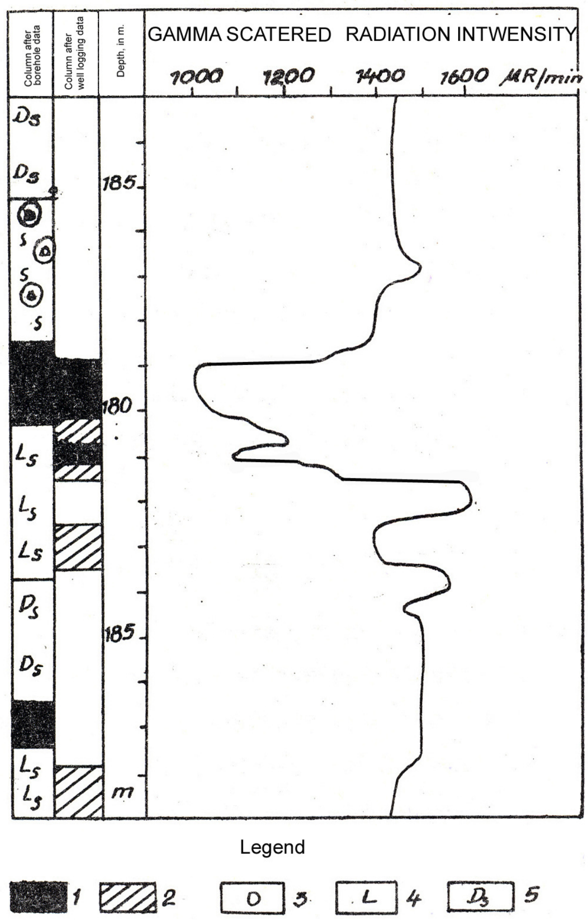

Fig. 4.30. Diffused gamma-gamma radiation log (Iγγ) in Luçiane deposit, Bulqiza massif (after Nakuçi I. well logging).
1- Massive ore body; 2- Ore body with disseminated structure; 3- Dunites; 4- Hartzburgites; 5. Serpentinized dunites.

From this figure can be seen that a detailed description of the borehole geological section and more accurate evaluation, together with partial drill logs, can be made according to well logging data interpretation.

Minimum points have been also observed in fresh, non-serpentinized, rocks individualizations, situated between serpentinized rocks. For discriminating these individualisations, a selective gamma-gamma-ray logging has been used. The intensity of smoothed component of scattered gamma rays, which is determined by heavy element content (as chrome) in the borehole section, is recorded by this logging.

Data on density gamma-ray logging can be used for the assessment of Cr_2O_3 content in the ores, for the computation of the ratios Cr_2O_3/FeO and Cr/Al, because it exist a correlation between the ore density and the Cr_2O_3 content, and between Cr_2O_3 and FeO and Al.

Magnetic and polarisable ore bodies are very well distinguished through magnetic and IP well logging. Serpentinized rock inclusions with secondary magnetite situated between fresh rocks give claire anomalies. These last ones can be used as geophysical indicators to distinguish tectonic sequences from cumulate ones, etc.

Chrome ore bodies can also be discriminated from ultramafic rocks by other parameters such as the effective atomic number 19, cross-section capture 0.054 cm^{-1}, which are greater for hartzburgite and dunite (effective atomic number 12.5 and cross-section 0.0015 cm^{-1}), and characteristic gamma ray spectrum (for high energetic levels 8.5 and 8.9 MeV). Based on these characteristics different kinds of logs, such as the neutron-gamma spectrometric, neutron-neutron, thermal and overthermal neutron logging can successfully be used for geophysical documentation. Ore bodies can be distinguished by higher logging values than those of the surrounding rocks.

As it was mentioned above, it can be seen that, for the geophysical documentation of the borehole in chrome deposit, the basic method to be used should be the radiation logging (density, gamma-gamma, selective gamma-gamma, aluminium neutron-activation, neutron-neutron, thermal neutron and overthermal neutron logging). The magnetic, the IP and conventional resistivity logging can be used as additional methods.

4.3. Geophysical applications for geological mapping

Geophysical methods contributing to geological structural mapping purposes, aimed at successfully solving some regional and local problems. The structure of ultramaphic rocks massifs and their relationship with the surrounding media have been studied. Serpentinized and fresh rocks, tectonic and cumulate sequences have been discriminated by their serpentinization degree. Tectonic faults and deep elements of primary structures such as flow and banded structures, S, L and Q system of primary fissures, the individualisation of fresh and serpentinized rocks were mapped in the ore fields. The conditions of rock formation and their changes in space and time during the geological history have been studied for the mapped regions. During the exploration-developing stage have been studied, at a more detailed scale, the factors controlling the mineralization.

For accomplishing geological-structural mapping tasks, have been used different kinds of geophysical methods such as gravitational, magnetic, micromagnetic mappings; magneto-telluric and electromagnetic soundings; low and high frequency seismic prospecting for big and shallow depths studies, respectively. These works have been accompanied by petrophysical studies

Valuable information about the geology of Bulqiza ultramaphic massif and about other massifs has been received by gravitational mapping at the scale 1:25000 (Kosho P.). In the figure 4.31 is shown a geological geophysical line in Klos-Bulqize-Shpuze (Frasheri A. et al. 1990).

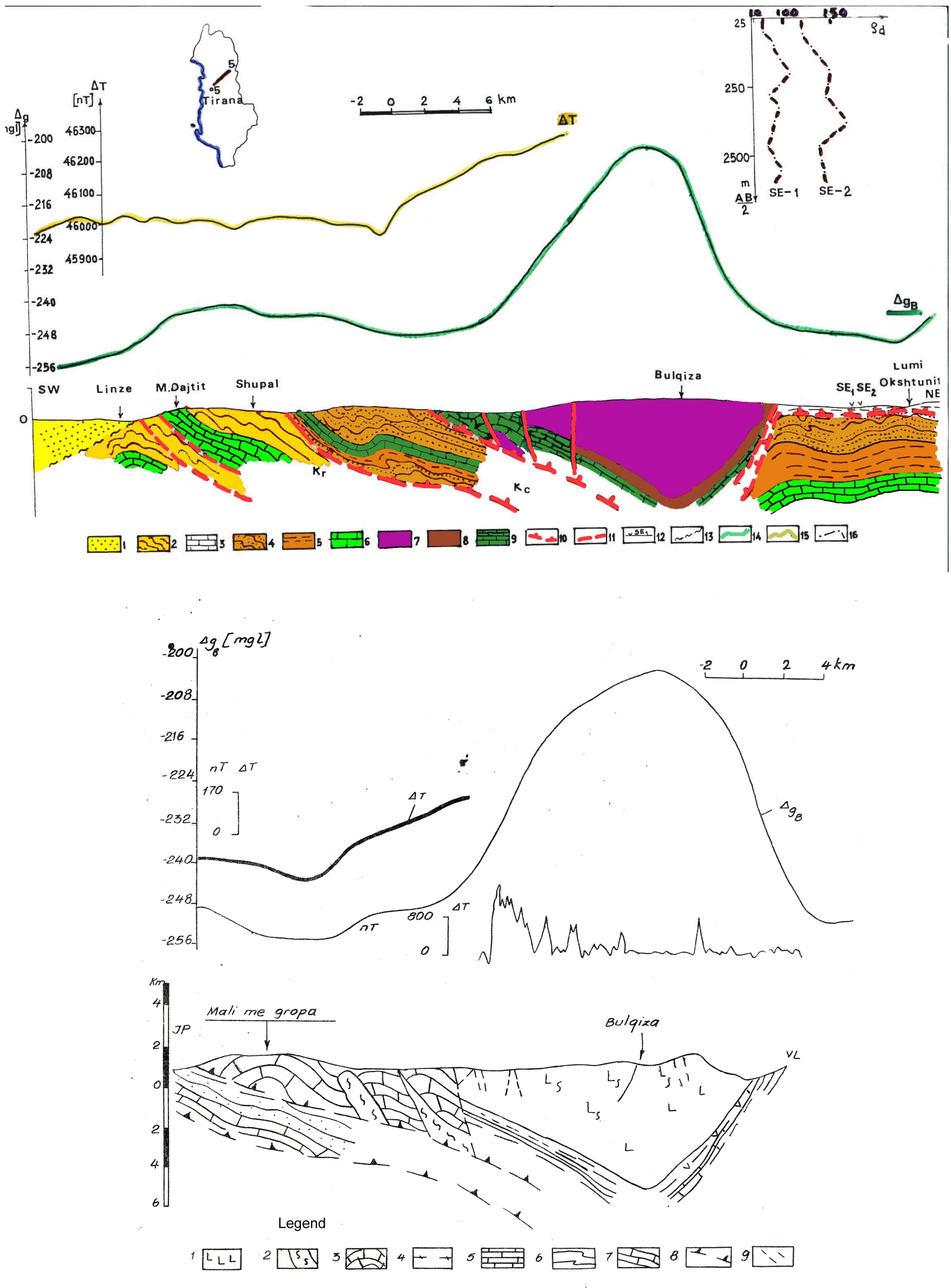

Fig. 4-31. Geological-geophysical line in Klos-Bulqize-Shpuze (Frasheri A. et al. 1990).

1 - Hartzburgites, 2 - Serpentinites, 3 - Triassic limestones, 4 - Volcano-sedimentary series, 5 - Jurassic limestones, 6 - Cr^2 - Pg^3 flysch, 7 - Pg^2 limestones, 8. Cover tectonics, 9 - Disjunctive tectonics.

According to the interpretation of the Bouguer anomaly, the massif has an inverted conic shape. Its thickness is smaller at the edges and increases towards the centre (up to 5.5 km). Based on the distribution of the magnetic field, the serpentinized sector of the ultramaphic rocks and the flanks where re massif is covered by the Neogene molasses sediments (especially the western flanks) have been mapped. The intensity of the magnetic field in these sectors is high due to the content of secondary magnetite. In plane, the anomalies have a mosaic picture, due to heterogeneous distribution of secondary magnetite. In these zones are also found some local minimums.

These characteristics can be used as features for the discrimination of cumulate sequences. Magnetic anomalies of cumulate sequence have high amplitude and high frequency. Anomalies on dunite-hartzburgite tectonic sequences are characterised by smaller amplitudes and lower frequencies, meanwhile the intensity of the magnetic field is smaller than for hartzburgite-tectonite sequences. The correlation of different geophysical parameters, determines different perspective levels of ultramaphic cross sections, which help the search for mineralization.

Micro magnetic survey has given good results in determining the primary textural elements in zones covered by 2-3 m thick soft sediments and in zones where these elements cannot be seen. This is possible because the axis of the magnetic micro anomalies have two directions, one parallel with the fissures systems L, S and flow and banded textures, and the second one which coincides with Q fissure system.

The picture of the distribution of magnetic micro anomalies can be explained by the layout of the secondary magnetite mainly according to flow, banded textures and the fissures system L,S and C (fig. 4.32) and to the direction of the vector of thermoremanent magnetization, which coincide with the direction of primary structural elements.

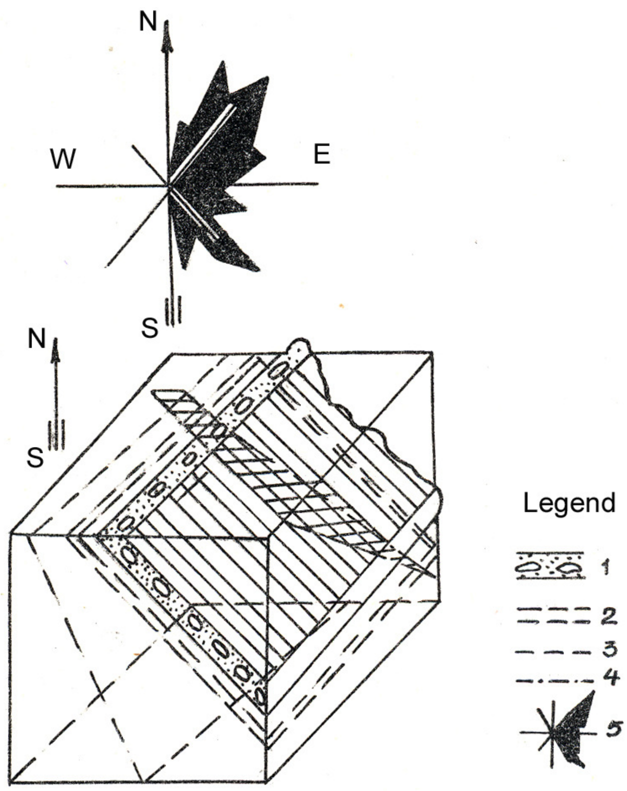

Fig. 4.32. Primary structural elements and the direction of the axis of magnetic micro anomalies. (Frasheri et al. 1969).
1 - Banded texture; 2 - Primary fissure system L, 3 - Primary fissure system S, 4 - Primary fissure system Q, 5 - Rose diagram and vectors of the direction of the magnetic micro anomalies axis.

From the performed magnetic micro surveys, it seems that the axes of magnetic micro anomalies are the same for the dunitic rocks and the hartzburgite. That means that different kinds of rocks of tectonite-hartzburgite-dunite sequence have had the same development during the geological history. Dunites and hartzburgites can only be distinguished by unequal degrees of the serpentinization. The difficulty in distinguishing them is explained by the fact that these rock have physical properties which vary in a wide range and sometimes overlap each other.

Serpentinites, generally, have high contents of secondary magnetite and are magnetic. Therefore the magnetic surveying can be used to study the weathering layer for the search of nickel-silicates.

Geological geophysical studies of chrome ore fields have been carried out simultaneously with regional geological-geophysical mappings and petrophysical studies. These last ones have been used as a supplementary information source about the rock formation conditions, their composition and their changes in space and time. Such data are given in studies about the rock magnetism and its nature.

In the Tropoja ultramaphic massif has been observed an increase of the rock's density values, from the eastern part to the western one (particularly after Kami). That indicates that the rocks in the western part of this massif are less serpentinized than the ones in the eastern part. In the same direction can be distinguished the dunites from the hartzburgites of tectonic sequence. The hartzburgites have higher density values than the dunites. In the western part of the massif, is observed an increase of the content of pyroxenites inside hartzburgites and the degree serpentinization for these two kinds of rocks is different.

4.4 <u>Some important conclusions and recommendations</u>

Based on the results of geophysical investigations for the search of chromite in Albania and in other countries of the world, some conclusions can be made:

Geophysical anomalies are fixed on ore bodies and on rock inclusions. That means, not every anomaly may indicate about the presence of an ore body.
On chrome ores there are not always geophysical anomalies. That means that the lack of anomalies does not necessarily indicate about the absence of ore bodies.

The wide variation of the ore's physical properties and those of the surrounding rocks can explain these, by the small differences between these physical properties, by the shape and the small dimensions of ore bodies compared with their layout depth. Therefore, a geophysical anomaly can indicate only about the possibility of the existence of an ore body.

This anomalous situation is presented in the table 4.1.

The characteristics of the anomalous geophysical picture, in the regions where chrome ore deposits are searched.

Table 4.1

Chromite ore and surrounding rocks	Gravity anomalies	Magnetic anomalies	Induced Polarization anomalies
Massive chromites, magnetic and polarizable	+	+	+
Massive chromites, magnetic, unpolarizable	+	+	-
Disseminates chromites, magnetic and polarizable	-	+	+
Disseminates chromites, nonmagnetic, polarizable	-	-	+
Fresh ultramaphic rocks Individualization	+	-	-
Serpentinized ultramaphic rocks individualization	-	+	+
Serpentinites intersected by gabbro-pegmatite dykes of cumulate sequence	+	+	+
Gabbro pegmatite dykes or frech pyroxenites	+	-	-

In figs. 4-33 and 4-34 are presented a theoretical dependences of gravity anomalies (Bourguer reduction and vertical gradients) by mass/radius and depth of the ore body centres for a model in the sphere shape or horizontal cylinder, to have the possibilities to observed the anomalies, respectively with amplitudes 0,2 and 0,4 mGal, and 20 Oetvesh.

According to these calculations, by gravity surveys is possible to discover chromite bodies in different depth, from tens to hundred meters, if will exist necessary mass of the ore body. For example, the ore body with radius 14,5 m and mass 50.000 tons, is possible to explorer up to 23,5 m depth of location, because the Bouguer anomaly will has an amplitude about 0,2 mGal. The mass about 3.500.000 tons can be explored at 200 m depth of location, by survey such anomaly, 0,2 mGal.

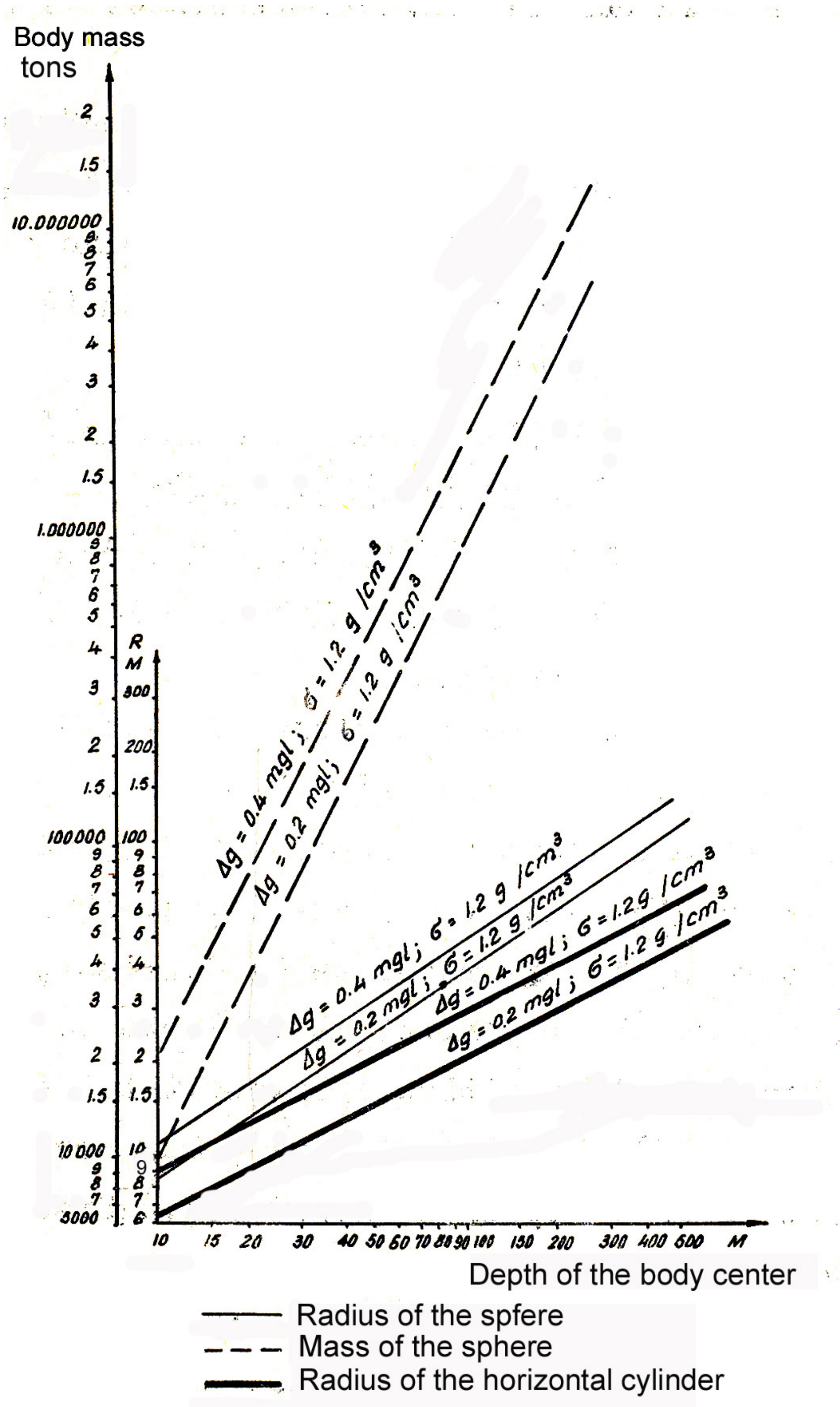

Fig. 4- 33. Theoretical limits of the ore body mass, for constant Depth of location of ore body, which will created an Bouguer anomaly of an amplitude Δg- 0,2 and 0,4 mGal. (Frasheri A. 1968, 1974)

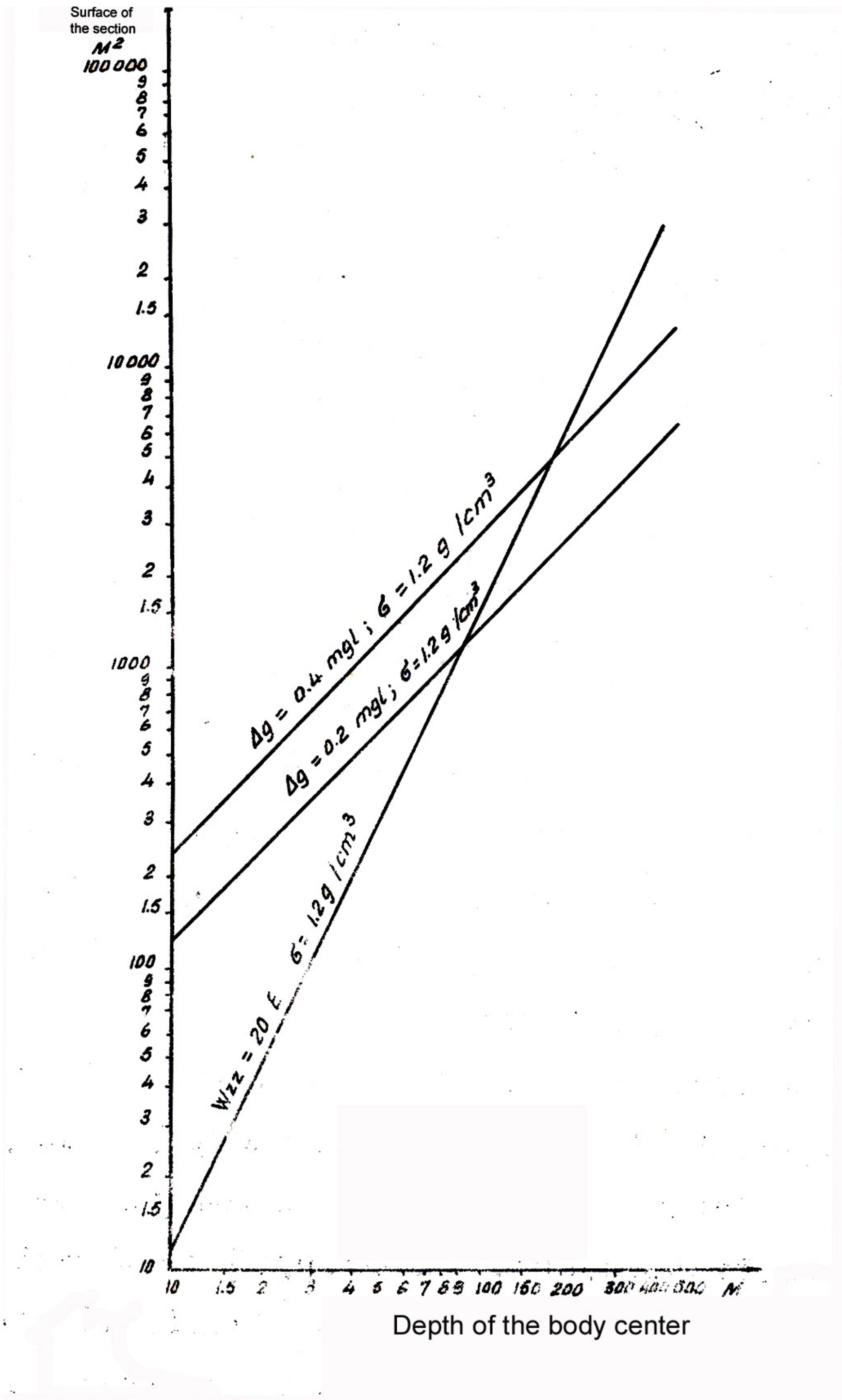

Fig. 4-34. Theoretical limits of the horizontal cylindrical ore body section surface, for constant depth of location of ore body, which will created an Bouguer anomaly of an amplitude Δg- 0,2 and 0,4 mGal and Wzz= 20 Oetvesh. (Frasheri A. 1968, 1974)

These limitations create the need for the implementation of some measures to increase the effectiveness of geophysical search:

Direct search for chrome ore bodies should be carried out simultaneously with the geophysical-structural mappings and petrophysical studies in order to know the factors controlling the mineralisation.

Surface and underground geophysical surveys (gravity, magnetic, geoelectrical ones) should be carried out in complexity. In the interpretation of the results should be considered all other existing geological information. This will make possible the determination of the nature of an anomaly, so that the ones caused by ore bodies can be selected. Better combination of surface with underground surveys leads to the increase of the search depth of the geophysical methods.
Geophysical works can achieve better results when perspective zones are the exploration objects. The work should start from well-known ore bodies and not from small sectors.
Geophysical studies should be carried out in the framework of complex geological studies. Only in this way can better be studied the geology of the ultramaphic massifs, the premises for the search of ore deposits and ore bodies underneath the surface of the Earth.

Since the number of shallow or near- surface ore deposits is decreasing, the implementation of geological methods, at present, is a necessity in order to increase the search depth for chrome deposits.