Šuplja stijena Historic Zn, Pb, Cu (+Ag, Au) Mine, Montenegro, Water Outburst Experience

Presentation prepared by:

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Chief mine geologist, and
President of the Board of Directors of Gradir Montenegro d.o.o.
INTRODUCTION:

- The Šuplja stijena mine ore has average 3,5% (Zn+Pb) and large ore reserves available for low cost open pit production and ore reserves for more than 30 years of production.
- New topmost technology – “MetsoMinerals” new Pre-Concentration and Flotation will guarantee the best ore beneficiation results.
- Top quality Zn and Pb concentrates production. No penalties for Fe, As, Bi, Sb, Hg, Cd; credits for Ag and Au.
- Favourable market condition and equipment enable profitable production.
- Full production will start in June 2010.
- Big exploration potential gives opportunity to double the mining and beneficiation capacities in near future.
Introduction

• New open pit “Suplja stijena” is located in the area of historic underground mining (1953-1987), and surface mining (1997-2000) of Zn+Pb(Ag, Au) ore, which is hosted in hydrothermally altered andesite.

• Recent open pit mining target is the remaining part of a massive sulphide ore veins and disseminated – veinlet impregnation (stockwerk) sulphide mineralisation between the mainly mined out ore vein-type ore bodies.

• New dense media liquid pre-concentration and new up to date flotation were designed and produced by reknowned “MetsoMinerals Ltd.”. We plan to install them till the end of January 2010.
Project main goals

- The yearly planned open pit production is 1.000.000 t of ore. Ore will be pre-concentrated by Dense Media Separation.

- Flotation will process 350.000 t of pre-concentrate per year.

- The yearly planned quantity of metal from the produced concentrate is more than: 17.000 t of Zn, 5000 t of Pb, 3,4 t of Ag, 200 kg of Au.

- Removal of 1.000.000t/year hanging wall limestone burden is needed.

- High quality stone aggregate and lime will be produced. With the stone aggregate and lime production mining of the hanging wall gangue limestone is planned to be payed.

- Mineral pyrite concentrate is going to be used for neutralisation of high pH value waters from alumina production in Kombinat Aluminija Podgorica.

- Environmentally sustainable production of the environment will be ensured with the use of hanging wall burden limestone as a buffer for acid mine drainage waters (no extra costs needed).
Geographic position of Montenegro

- Part of the Middle Europe.
- Central position in the Balkan peninsula.
- Neighbour states are Croatia, Bosnia and Herzegovina, Serbia, Kosova, Albania.
- Positioned at the coast of the Adriatic Sea (part of the Mediterranean).
- Most important trade communication door is port Bar.
- From the mine to the port of Bar on the Adriatic Sea there is 300 km of bitumen road for a heavy truck transport.
- 75 km of bitumen road for a truck transport to the closest railway station.
Geographic position: State of Montenegro is located at the coast of the Adriatic Sea (Mediterranean), East of Apenine peninsula and Italy, NW of Albania, SW of Serbia, and SE of Bosnia and Herzegovina.
Geographic position: Open pit Suplja stijena is located in the NW of the Montenegro state (original meaning of the name is “Black Mountain”).
Geographic position: Open pit is located in Montenegro at the border with Bosnia and Herzegovina. About 10km to the NE of the ore field is the border with the state of Serbia.
Geographic coordinates of the open pit “Šuplja stijena”: 43°22′47,04″N; 19°02′47,04″E; elevation from 1180m up to 1470m above sea level.
To the closest town Plevlja (with more than 21,000 inhabitants) there is 35 km’s of asphalt road for a heavy truck transports up to 25 tonnes of load. Brown coal open pit (mining tradition is strong, job market developed) and Thermal Electric Power Plant is located near the town Plevlja.
Closest Railway Station is in the Town Prijepolje (Serbia) at the Distance of 70\text{ kms} Bitumen Road. Prijepolje is Connected with the Port Bar on Adriatic Sea (Mediterranean).
Map of the mining lease - concession field and schematic position of partly explored orebodies.

Drawn on the topographic map, ratio of the original is 1:25,000.
History of underground and surface mining

• Vein type of mineralisation found on the surface in 1948.
• Exploration till 1952 proved reserves for the start of underground mine operation and installation of Flotation for 250,000t of ore per year.
• Positioning of the Flotation 9.6kms from the mine to the town Gradac was a problematic decision due to high transport costs. Steel rope cable transport from the mine was installed in 1953. For its maintenance and operation 280 workers were employed. Operated till 1987.
• Up to 580 miners employed in the underground mine.
• Flotational gangue depony (tailings) was located in the meander of the river Čehotina (tunnel deviation of the river was needed).

Mine was a part of RMHK Trepča (Mining, Metalurgy and Chemical Kombinate Trepča (Stan Trg mining area) in Kosova (also part of ex Tito’s Yugoslavia).

Massive sphalerite and galena ore vein type of mineralisation was mainly mined out. Security pillars and thinner veins still sit there.

Mine was closed in 1987 due to low metal prices at the time and a lack of reserves of the vein type of ore.
History of the surface mining

- Open pit started in 1997. Lower grade disseminated - vein impregnation (stockwerk) mineralisation between the already mined out ore vein system was the mining target.

- Truck transport - 14kms of bitumen road to the Old flotation in Gradac from 1997-2000 was too expensive. Steel rope system was not useful anymore at that time.

- Open pit was closed in 2000 due to the war (NATO strikes of the smelter in Trepča, Kosova) and international trade blockade of ex-Yugoslavia (international metal market was not accessible anymore).

Open pit as it was abandoned in the year 2000. Photo taken in early spring 2008.
From 1948 to 1991:

- 54404m of adits,
- 7711m of inclines, and
- 83031m of drill cores.

Around 95% of exploration works were done in the area of the existing mining lease field of Šuplja stijena.

Extremely valuable database!
Historic production statistics

- **UNDERGROUND PRODUCTION 1953. – 1987.**

<table>
<thead>
<tr>
<th>ORE (tonnes)</th>
<th>Pb (%)</th>
<th>Zn (%)</th>
<th>Pb (t)</th>
<th>Zn (t)</th>
<th>Pb (t)</th>
<th>Zn (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUM</td>
<td>3.950222</td>
<td>1.72</td>
<td>4.73</td>
<td>76687</td>
<td>299890</td>
<td>67927</td>
</tr>
</tbody>
</table>

- **OPEN PIT PRODUCTION 1996. – 2000.**

<table>
<thead>
<tr>
<th>ORE (tonnes)</th>
<th>Pb (%)</th>
<th>Zn (%)</th>
<th>Pb (t)</th>
<th>Zn (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>283016</td>
<td>0.72</td>
<td>1.42</td>
<td>1975</td>
<td>4352</td>
</tr>
</tbody>
</table>
Old Flotation and Flotational Gangue Depony – tailings is located in town Gradac along river Cehotina 9,6kms from the mine.
9.6 km of steel rope cable transport from the mine was built in 1953. 280 workers were employed for the maintenance of it. Operated till 1987.
Old Flotation had capacity of 250,000 t of ore/year. In the Flotation gangue depony there is around 3,750,000 t of milled rock (-100µm size) deposited.
At the time of high market price of the Zn and Pb metals reworking of the tailings depony has great economic potential as there the rock is already milled (no costs for mining, crushing, and just minor expenses for some more milling).
Town of Gradac and Flotation Gangue Depony in the Former Meander of the River Cehotina.
Depony is constantly flooded by the local creek. This conserved the primary mineralogy of ore minerals and will enable their reworking. GradirMontenegro Ltd. owns the depony.
Remaining already milled rock contain more than 0,7% of Pb+Zn. It is already profitable to rework it. Studies on pre-concentration on site are in progress.
Montenegro state is obliged to finance the dam construction for prevention a river erosion of the tailings depony.
Old flotation in the town Gradac. It was decided not to use it due to high transport costs and old worn out equipment.
Old Flotation in the town Gradac.
Flotational cells in the Old Flotation (1953-2000) in the town of Gradac can not be used anymore.
Geology of the ore field “Šuplja stijena”

- Geotectonic genetic environment – Middle Triassic aborted riftling (“Montenegro” tectonic trough was active in Anisian and Ladinian – Middle Triassic).
- **Volcanic succession** originated by multiphase bimodal efussive volcanism (basalt – riolite).
- Later **dioritic intrusions** gave hydrothermal ore fluids.
- Structurally controlled postvolcanic massive sulphide **vein type and veinlet impregnation** – disseminated (stockwerk) Zn, Pb (Ag) mineralisation.
- Host rock andesite is hydrothermaly altered: chloritised, sericitised, silicified, and pyritised.
Compiled Regional Geological Map, Ratio 1:50,000.

**GELOŠKA KARTA LJUBIŠNJE 1 : 50 000**

**LEGENDA:**
- 4J: krecnjaci, laporoviti sa proslejcima i muglama rožnaca
- 3J: pečari, alvevoluti, konglomerati, rožnaci, laporci i laporoviti krecnjaci
- 2J: krecnjaci, retko pečari, konglomerati, škrljci
- 1J: pečari, škrljci, laporci, rožnaci konglomerati laporoviti krecnjaci
- 4: terigene stone, krecnjaci, rožnaci
- 2: slojeviti i masivi krecnjaci
- 1: andeziti, andesitobazaliti, andezitodelečiti, bazaliti i tufovi
- 1b: krecnjaci, pečari, škrljci, alvevoluti i rožnaci
- 1a: subvulkanске intruzije facije utisnutog vulkanita: kvarcidioliti, kvarcidiolititski i dioritski porfiriti, graniti, porfiriti, eruptivne breče
- NEJ: serpentini dijabazi
- a: stratografski kontakti
- b: utvrđeni
- c: predpostavljeni
- a: kontakt utisnutog magmatita
- b: rased i rasedne zone: sigurni, predpostavljeni ili fotografski ustanovljeni
- c: rudne žice (moćnosti van razmere)
- d: jamski radovi, napušteni
- e: eksploatacijna ležista Pb i Zn
- f: rudne pojave
Rock types and position of the regional tectonic structures in the area of Ljubišnja, Supla stjena ore field. Position of the Suplja stijena mine – 1.

LEGEND:
1. Neogene clastics
2. Jurassic limestone&chert
3. Limestones $T_2-T_3$
4. Efussive rocks $T_2^2$
5. Volcanic+sedimentary rocks $T_2^1+T_2^2$
6. Axis of the Ljubišnja anticline
7. Diskordant contact
8. Normal contact
9. Main faults
10. Other faults
11. Ore deposits and ore minerals occurrences

NAMED FAULTS:
3 – Debelopotočki
6 – Ribnički
12 – Ravnogorski,
22 – Riječki
5 – Mjedenički
26 – Viševinski,
25 – Granitni,
28 – Konjopoljski,
Detailed Geological Map 1:10,000 for 100km² of mineralised volcanic rocks - andesite.

Positions of historic underground works, geological and geochemical data are documented in detail on plans of all 9 horizons also onto the maps with the ratio 1:250.
General Lithology of the mining lease concession field with the defined position of vein type Zn and Pb ore bodies.

Four ore deposits:
- Šuplja stijena
- Eastern Structure (Istočna struktura)
- Old Mine (Stara jama)
- Western Structure (Zapadna struktura)
- Durdeve vode
- Paljevine
- Ribnik

Legend:
- Red lines: ore vein systems
- Blue lines: faults.
- Hanging wall – limestone.
- Host rock - andesite.
Suplja stijena type of the ore mineralisation

• Two types of ore bodies:

1. Ore Veins

2. Disseminated - Veinlet Impregnation (Stockwerk)

• General orientation of ore veins is NE-SW.
• General dip of ore veins 20 – 90° towards NW. Most of them have dip of around 60°.
• Length of veins is from 50 to 100m, max. up to 300m. Thickness 0,2 to 3m (max. 9m). Only weak post ore tectonic displacement.
• Eastern structure ore body - several veins also in NW-SE direction.
• Disseminated - veinlet impregnation (stockwerk) mineralisation is located between the main ore vein system.
• Contacts of massive sulphide ore veins with the host rock is mostly sharp.

• In some parts of the mine soft chlorite clay envelopes on the contact of ore veins with the host rock were the cause of geomechanical instability for the underground mining and left in situ. Their thickness varies from few cm to 20cm (max. 50cm). They are still available for open pit mining.

• Contact of ore veins with the andesite host rock is often transitional with the set of thin tectonic fractures and joins filled with disseminated - veinlet impregnation (stockwerk) type of mineralisation. It is controlled by the tectonic fragmentation of the host rock - andesites.
Suplja stijena ore minerals

• Most common ore minerals:
  1 - pyrite, 2 - sphalerite, 3 - galena, 4 - chalcopyrite.

• Economic importance:
  1 - sphalerite, 2 - galena, 3 - chalcopyrite.

• Pyrite form 6,3-8,5% of the ore. It is important for the sulphuric acid production. We plan to use it for neutralisation of NaOH rich fluids of the Podgorica aluminium industry.

• Ore is very flotable! Flotational recovery is very high.
Most important minerals in the polished ore sections

Sphalerite (ZnS) - gray, galena (PbS) - white, chalcopyrite (CuFeS$_2$) – intensive yellow, and pyrite (FeS$_2$) bright yellow, gangue minerals: quartz and calcite are dark gray.

Length of the observed polished ore on photo is around 3 mm.
Šuplja stijena
Zn, Pb, Cu (Ag, Au) orebody

• Historically divided into three parts (from east towards west):
  
  – **Eastern Structure** (vein type of mineralisation, only partly mined out, disseminated ore type precisely defined to be mined out);
  
  – **Old mine** (vein type of mineralisation, mostly mined out, security pillars, and veins below 20cms thick still there, richest part of disseminated ore type in the central zone of the vein system – metal content was not systematically sampled);
  
  – **Western Structure** (almost all vein type of mineralisation is still there, clay envelopes (geomechanical unstability) didn’t allow underground mining, old adits accessible and exploration data available, continuation of exploration drilling possible).
Geological cross section:

Translation of the legend:

Beded and banded limestones, partly sedimentary limestone breccia

Andesitic lavas

Andesitic-basaltic lavas

Limestones, hydrothermally altered, limestones, sandstones, breccia, shale, siltstone, andesite, andesite-basalts

Vein type orebodies and parallet veinlet ore impregnation
Spatial model of the mineralised ore blocks 20x20x10 m for the Eastern orebody.
Genetic interpretation of the Suplja stijena type ore deposits

- Source of magmatic ore fluids are postvolcanic intrusions of diorite.

- Open fractures within 200 to 500 metres thick andesite rocks succession were filled with Zn, Pb, Cu ore minerals in Ladinian (Middle Triassic).

- Hydrothermal vein and disseminated (stockwerk) mineralisation has been formed in the broad temperature interval. Most of ore minerals were deposited in the mesothermal temperature range from around 225°C to 300°C.
Demonstration of the geometric construction for C1 ore category borders (indicated ore reserves). To the C1 ore category belongs an area up to 35m from the source data. Constructed for the adit horizon 300 with respect to the geometry of sampling and ore bearing lithology.
Ore reserves estimation study

Demonstration of the ore category borders construction for the 10 metres open pit level etage in cross section – an area up to 20m for B category (measured) and an area from 20-35m from the source data for horizons 100 and 200.
Demonstration of results for B ore category (measured) borders construction – an area up to 20m from the source data for the mining etage 1260 – 1270 between horizons 300 and 400 of the “Eastern Structure”.
Example of the Map done for the Ore Estimation Study: Arial view of the source data for “Eastern structure”: position of drillholes and chanell samples, and all positions of adits and inclines which are also 3D vectorised.
Source data (metal content) from drillcores and chanell samples. B (proved) and C1 (indicated) ore category borders. Ore block metal (20x20m) content estimations on every 10m slice of the open pit. Final open pit contour proposed.
Graphic presentation of the estimated metal content for 10 metres horizontal slices of ore blocks sized 20x20m. B (proved) and C1 (indicated) ore category borders defined. Final contour of Eastern ore body open pit for level 1200m proposed.
Estimated disseminated ore type Resources within the mining lease – concession contract field.

<table>
<thead>
<tr>
<th>Ore deposit</th>
<th>Kateg.</th>
<th>Quantity</th>
<th>Content</th>
<th>of metal</th>
<th>%</th>
<th>Quantity</th>
<th>Of metal</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore body</td>
<td></td>
<td>(t)</td>
<td>Pb (%)</td>
<td>Zn (%)</td>
<td>Cu (%)</td>
<td>Pb (%)</td>
<td>Zn (%)</td>
<td>Cu (%)</td>
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<tr>
<td>Eastern Structure</td>
<td>Inferred</td>
<td>20.000000</td>
<td>0,40</td>
<td>1,50</td>
<td>0,03</td>
<td>8000</td>
<td>32000</td>
<td>600</td>
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<tr>
<td>Old Mine</td>
<td>Indicated</td>
<td>1.800000</td>
<td>0,65</td>
<td>1,65</td>
<td>0,03</td>
<td>1170</td>
<td>32040</td>
<td>540</td>
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<tr>
<td></td>
<td>Inferred</td>
<td>12.500000</td>
<td>0,60</td>
<td>1,50</td>
<td>0,03</td>
<td>75000</td>
<td>187500</td>
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<td>Western Structure</td>
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<td>1,75</td>
<td>0,03</td>
<td>28000</td>
<td>70000</td>
<td>1200</td>
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<td>Ribnik</td>
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<td>800000</td>
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<td>1,95</td>
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<td>7200</td>
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<td>320</td>
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<td>Paljevine</td>
<td>Inferred</td>
<td>1.700000</td>
<td>0,30</td>
<td>1,00</td>
<td>0,40</td>
<td>5100</td>
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<td>Summary</td>
<td>Indicated</td>
<td>1.800000</td>
<td>0,65</td>
<td>1,65</td>
<td>0,03</td>
<td>1170</td>
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<td>540</td>
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<tr>
<td></td>
<td>Indicated + Inferred</td>
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<td>1,61</td>
<td>0,03</td>
<td>138440</td>
<td>448140</td>
<td>9093</td>
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</tbody>
</table>
Open pit design

The Starting data:

Etage height : 10 m

General slope angle: 38° (in andesite)  
50° (in limestone)
Profit calculation for 61 variations of the Open pit design.
Eastern Structure Orebody Open pit
8,500,000 t of Zn+Pb(Ag) ore

The planned final form of the “Eastern Structure” ore body.

Ariel view of the optimal open pit design.
Environmental issues

- Modern process of flotation without the use of cyanide.
- Up to date flotation gangue depony.
- Acid mine drainage from old adits and flotation gangue – tailings depony will be treated – neutralised with the limestone aggregate and precipitated mud with heavy toxic metals separately deposited.
- Use of ISO standards for the control of toxic heavy metals contamination is obligatory, and we do not expect any problems.
Main exploration targets from 1948-1987 were massive sulphide ore veins (for underground mining).

Since 1987 exploration target are disseminated vein impregnated (stockwerk) type mineral deposits (for open pit mining) due to low mining costs.

Experiences of the Chief geologist on the field of Mineral deposit studies and detailed study of the regional lithological succession of the ore field gave an idea and opportunity to future exploration for a metasomatic and/or skarn type massive sulphide ore deposits within the Anisian limestone just below the andesite succession in extension of the vein type mineralisation and already mined out vein ore type system of Suplja stijena. Future investment needed for exploration of this type ore bodies is around 5.000.000 EUR.
Most Important Future Exploration Targets will be Metasomatic and/or Skarn Type Ore Deposits
Main factors of the success:

- The proved usefulness of DMS - Dense Media Separation - heavy liquid Pre-Concentration process for Šuplja stijena disseminated stockwerk type of mineralisation allow **cheap and efficient pre-beneficiation**.
- Modern open pit mining with **low costs** and several ore bodies allows **flexibility** for production of ores with lower metal content and **fast respond** to the metal price.
- **Best metal recovery** will be achieved with up-to-date “MetsoMinerals” Pre-concentration and ore Flotation plants.
- **High quality concentrate with no “nasties”**, and **Ag credits** (in Pb concentrate) + **Au credits** (in Zn concentrate).
- **Great exploration potential** within the mining lease field and in the area of Šuplja stijena ore field around.
- Extensive geological archive of the previous exploration.
• World metal market price

• The cut-off grade of the Šuplja stijena ore (Zn+Pb) is 0,75% at recent prices.

• The planned expected metal content for the first three years of production is 3,5% (Zn+Pb).

• The world metal price which is the limit for profitable production is 1500US$/ tonne of Zn or Pb metal.
Zinc price - last year
Lead price - last year
Silver price - last year

1 Year Silver Price in USD/oz

High: 18.82 Low: 9.30 ▲ 8.51 82.49%

Last Close: 18.82

goldprice.org
Big importance of the growing demand for metals from China and India.

Recovery of the economic growth of the Western World will give rise for their demand for metals, too.

Sustainable production of cars include the use of zinc galvanised steel sheets.

Electric scutters and solar panels electricity production need lead batteries for storage.
Techical Details and Visual Presentation of the Open Pit “Suplja stijena”

• The planned positions of new technological units.
• Comparison of the open pit status as left in 2000, and on 29th of November 2009.
Situation as left in the year 2000 to early spring 2008.
Situation as left in the year 2000 to early spring 2008.
Recent situation above “Old Mine” west of the planned “Eastern Structure” open pit.
Planned Position of New Technological Units from Early Spring 2009.
Position of New Technological Units

- Head Office
- Pre-Concentration Platform
- Primary and secondary crusher
- Flotational gangue - tailings depony
- Mills
- Flotation
- Open pit
Open pit position:
Open pit position:
Early spring 2008 status:
Status of limestone hanging wall moving works
Status: left – limestone depony, right – andesite gangue depony.
Crushing and Heavy Liquid
Pre-Concentration Platform Detail Plan

SITUACIONI PLAN

PODACI O SNIMANJU

SITUACIONI PLAN

PLATO ERDBRÜCKUNGSPRÄPARATION

ISOK 40600 m³ kub. čvrste mase
NASIP 4380 m³ kub. rastresite mase
IDEJNO REŠENJE
radni prostor

CRUSHING AND HEAVY LIQUID
PRE-CONCENTRATION PLATFORM DETAIL PLAN
Crushers, Siever and Pre-concentration Platform, April 2008.
Crushers, Siever and Pre-concentration Platform, in April 2009.
General Technology Plan: Crushing, Sieving, Pre-Concentration, Milling, and Flotation.
• Primary and Secondary Crushing and Sieving
• Primary and Secondary Crushing and Sieving
• Primary and Secondary Crushing and Sieving
Sieving
Crushers, Siever and Pre-concentration Platform, recent situation.
Crushers, Siever and Pre-concentration Platform, recent situation.
Four Mills by the Flotation
Recent situation
Recent situation
Planned Position of the New Flotation Below the Open Pit, March 2008.
Planned Position of the New Flotation, March 2008
Planned Position of the New Flotation, April 2008.
Planned Position of the New Flotation, June 2008.
Planned position of the new Flotation, August 2008.
Planned position of the new Flotation, August 2008.
Planned position of the new Flotation September 2008
Planned Position of the New Flotation, April 2009
Planned Position of the New Flotation, recent situation
Planned Position of the New Flotation, recent situation
Plan of the New Flotation – Project and All Equipment Done by Metso Minerals
Flotational gangue – tailings depony
Flotational Gangue – Tailings Depony
Head Office Position – May 2008
Old Settlement for Miners - Šula