Ground Conditions in Bucharest Metro

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BUCHAREST METRO SYSTEM - 2021

TECHNICAL DATA:
TUNNELS – over 77 km double track

STATIONS - 63
DEPOTS – 5
59-68 TRAINS (6 CAR)

- Line 1: Northern Half-Ring
- Line 2: North–South Connection
- Line 3: East–West Connection
- Line 4: North–West Extension
- Line 5: Drumul Taberei – Eroilor (Stg 1)

In Construction:

- Line 2: South Extension

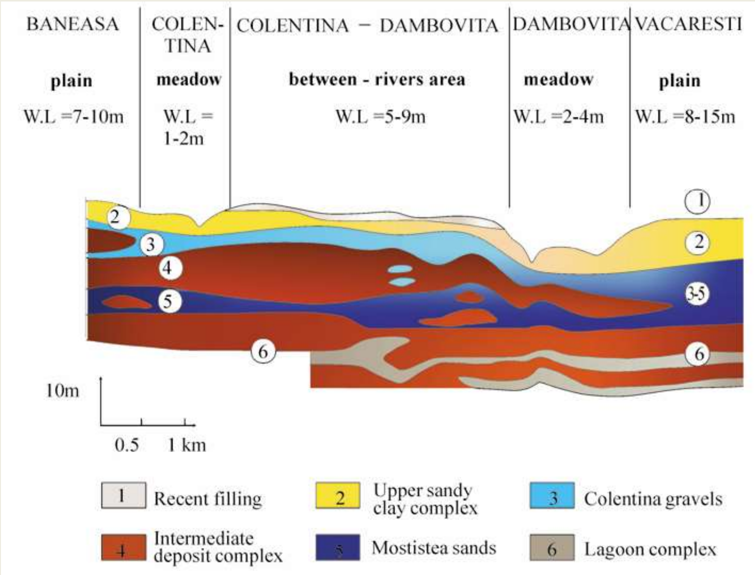
Under Design:

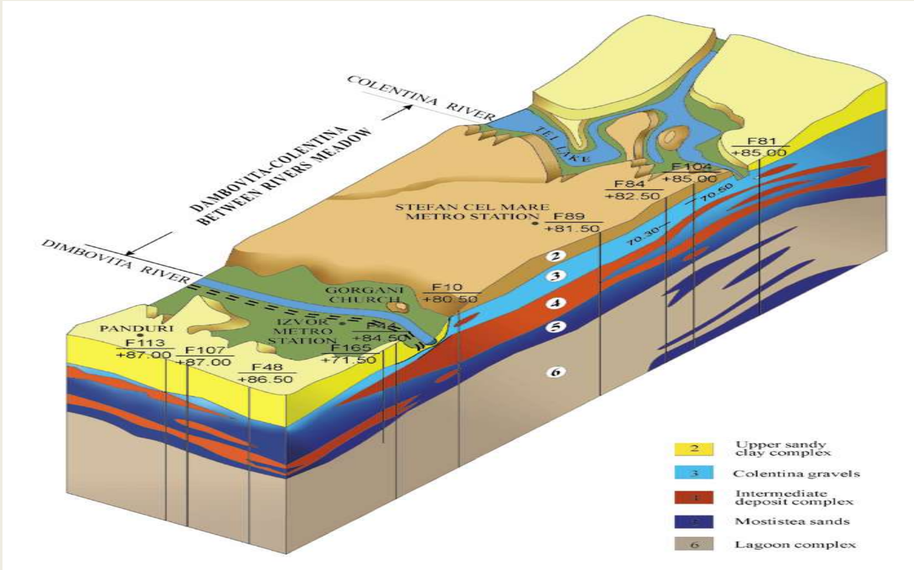
- Line 5: Eroilor – Iancului (Stg 2)

Planned:

- Line 5: Iancului – Pantelimon (Stg 3)
- Line 6: Otopeni Airport Connection
- Line 4: Gara de Nord – Progresul (South Extension)
- Line 7: Bragadiru - Voluntari

GEOTECHNICAL & HYDROGEOLOGICAL CONDITIONS

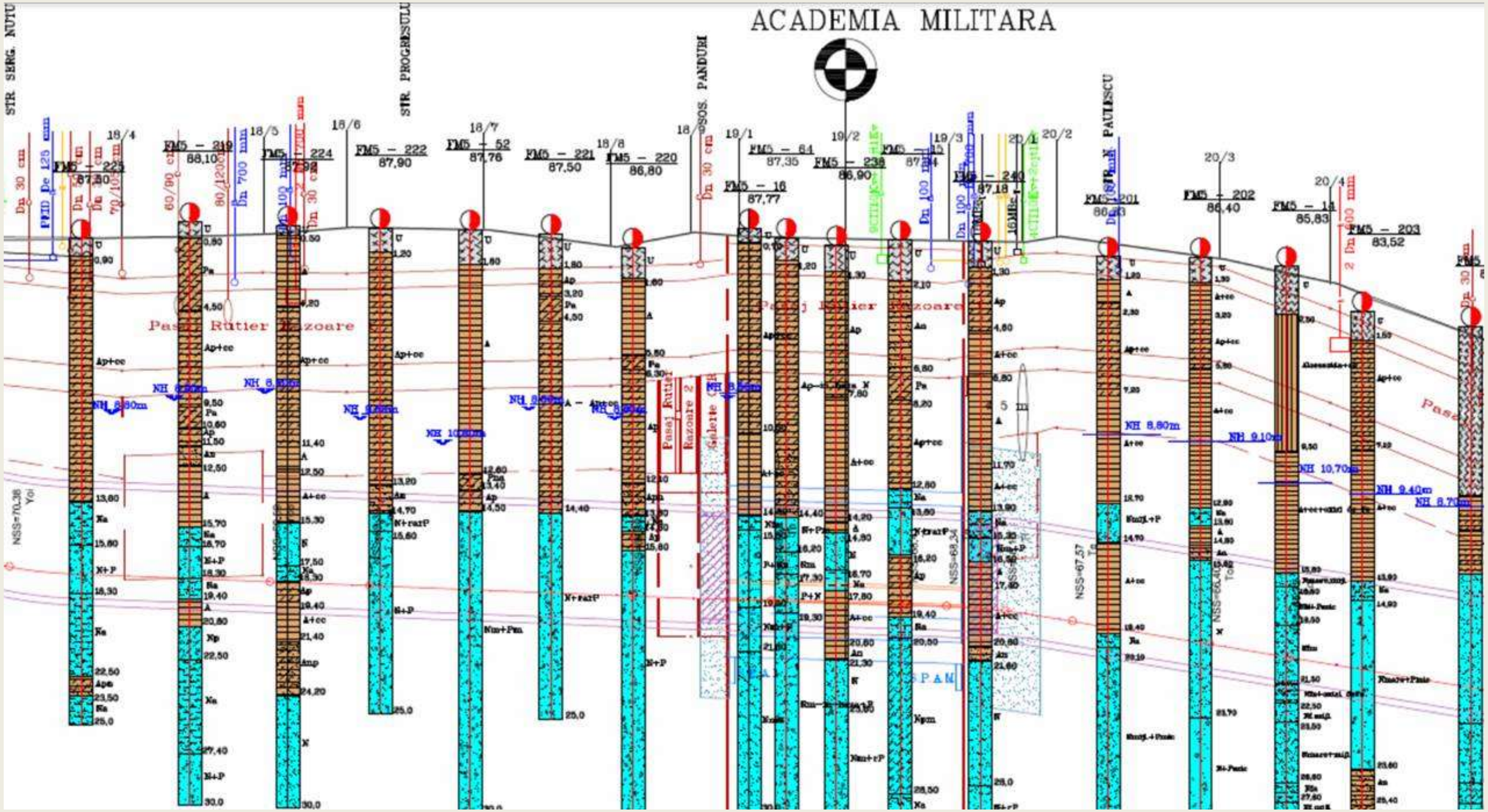




- Type 1 layer – non-uniform and heterogeneous fills, in different consolidation stages.
- Type 2 (upper clay) layer – upper clay complex, encompassing silty clays and sandy clays, with thickness ranging from 2 to 10 m.
- Type 3 (upper sand) layer – sand and gravel complex (Colentina), composed by medium to large sands and small gravels, with thickness ranging from 5 to 9 m.
- Type 4 (lower clay) layer – intermediate clay complex, composed by clays with limestone concretions, and silty clays.
- Type 5 (lower sand) layer – sand complex (Mostistea), composed by medium to fine sands and dusty sands, with great thickness, normally deeper than borehole depths

GEOTECHNICAL and HYDROGEOLOGICAL CONDITIONS

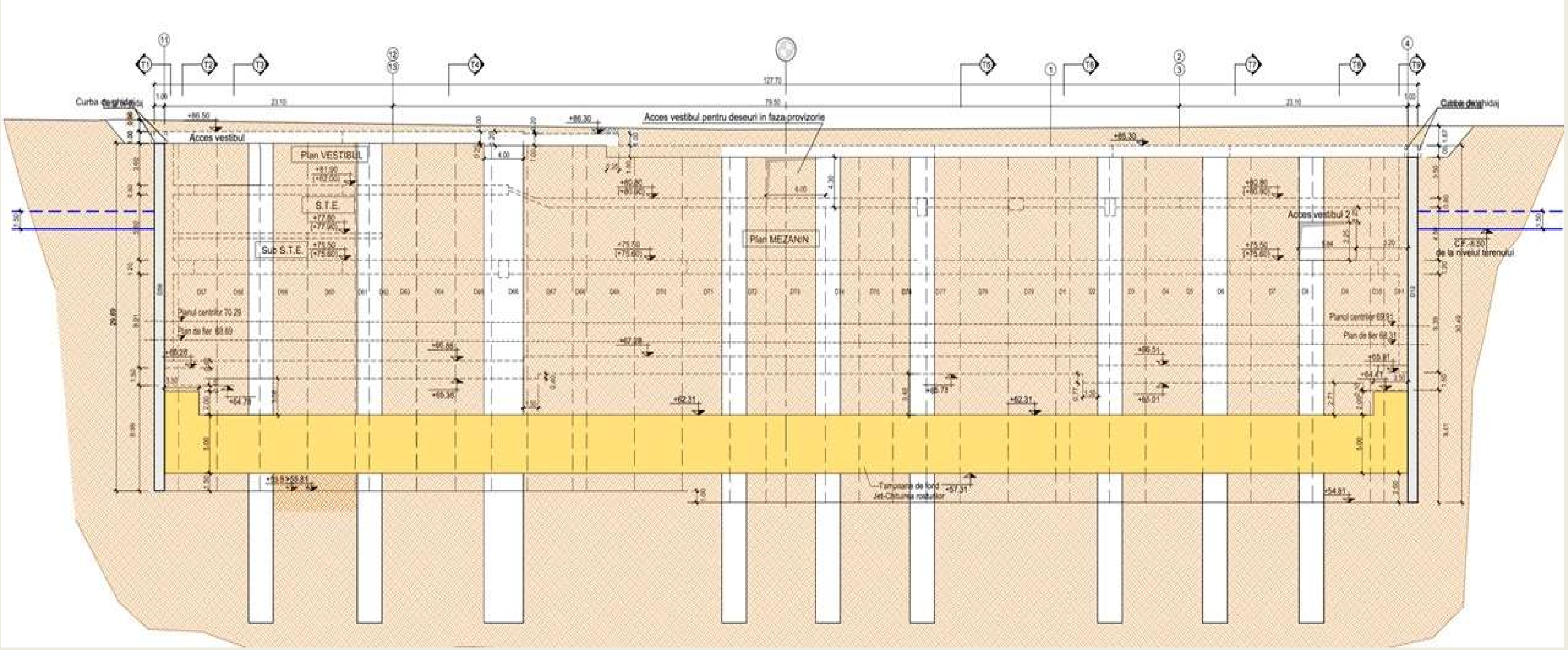
ACADEMIA MILITARA STATION (Line 5)



GEOTECHNICAL and HYDROGEOLOGICAL CONDITIONS

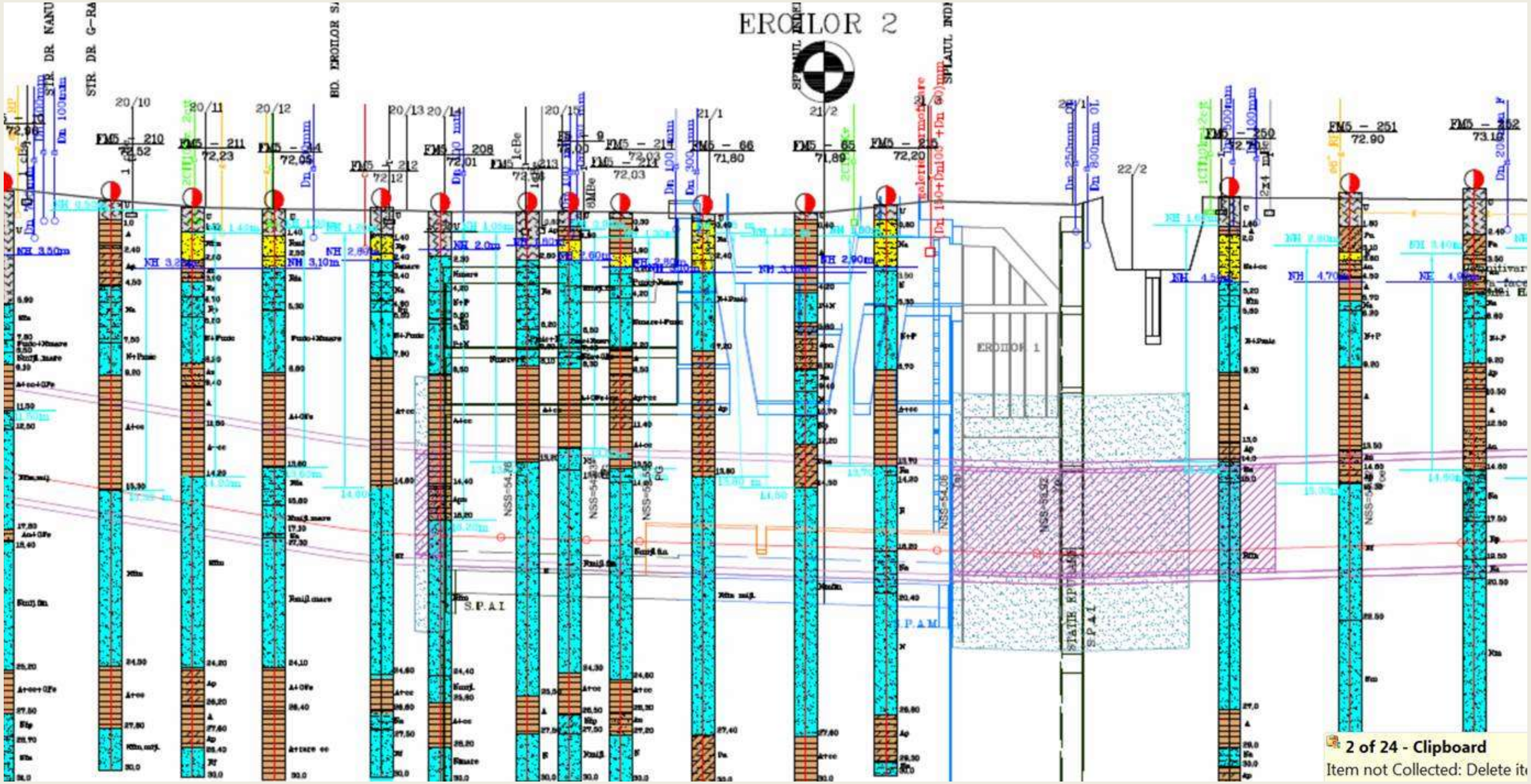
ACADEMIA MILITARA STATION (Line 5)

BOTTOM PAD OF THE JET-GROUTING TREATMENT



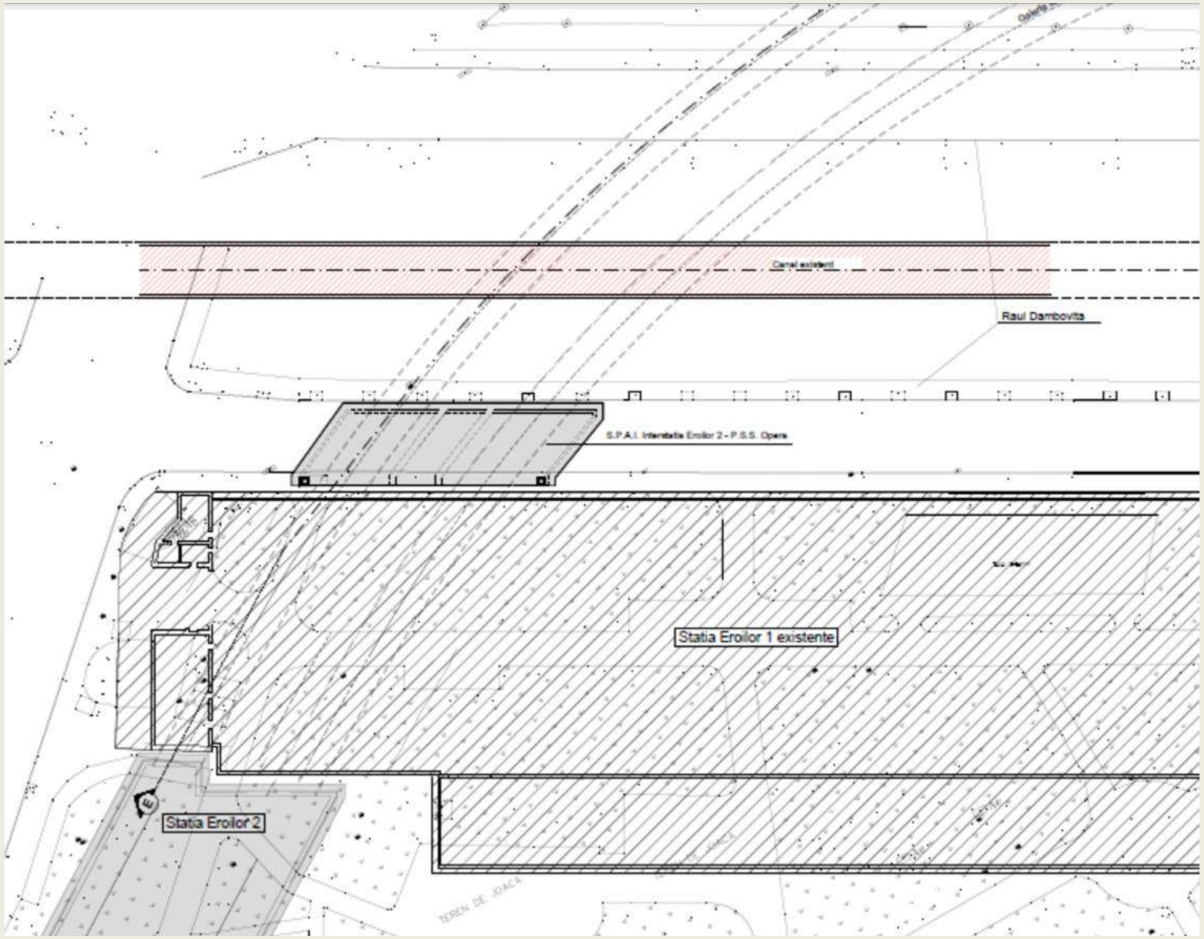
GEOTECHNICAL and HYDROGEOLOGICAL CONDITIONS

EROILOR 2 STATION (Line 5)



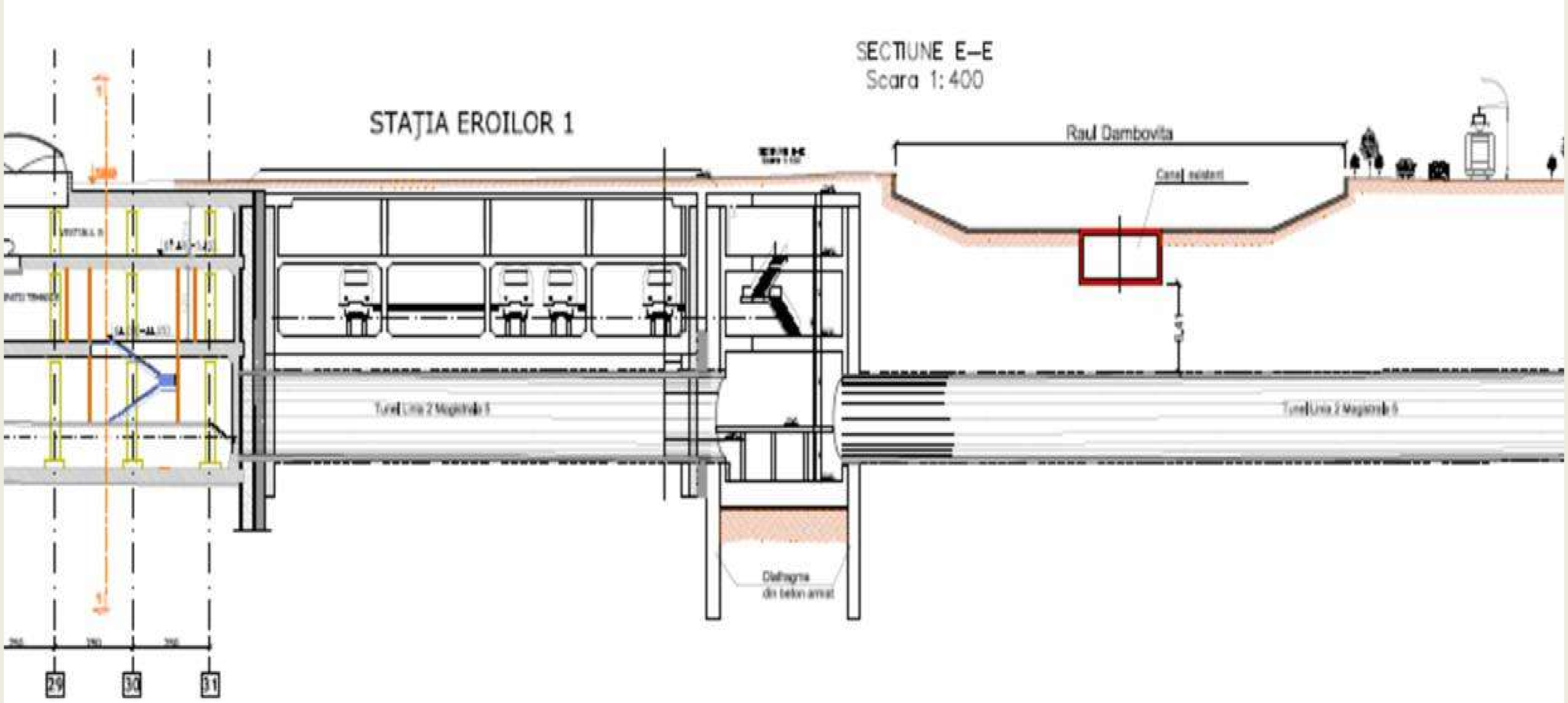
GEOTECHNICAL and HYDROGEOLOGICAL CONDITIONS

EROILOR 2 STATION (Line 5) – PLAN VIEW



GEOTECHNICAL and HYDROGEOLOGICAL CONDITIONS

EROILOR 2 STATION (Line 5) – CROSS SECTION



SEISMIC CONDITIONS

SEISMIC ACTION - Evolution of regulations

The first regulation dates from December 1941, after the severe Vrancea earthquake of November 10, 1940. Based on the Italian norm of 1938, this regulation considered an equal basic seismic force with 5% of the resultant of gravitational forces, evenly distributed on the floors of the building.

„The Conditional Norm for the Design of Civil and Industrial Constructions from Seismic Regions ” - P13-63, entered into force on July 18, 1963, being drawn up in accordance with "Basic Rules for Designing Buildings in Seismic Regions" written in CAER (Mutual Economic Assistance Council created by USSR). At that time, however, they did not exist recordings of seismic movements in locations located in Romania.

On December 31, 1970, the revised edition of normative P13-63 was approved, with the name “Normative for the Design of Civil and Industrial Constructions in seismic regions” - P13-70 (reduction of conventional seismic force with about 20% for reinforced concrete structures).

The effects of the earthquake of March 4, 1977, the conclusions obtained from the observations „in situ”, as well as the registration of the ground acceleration at the INCERC-Bucharest seismic station in during this major Vrancea earthquake, determined the successive elaboration of two new ones regulations: “Norm for the Anti-seismic Design of Social-cultural Housing & Agro-zootechnical and Industrial Constructions” - P100-78 (with experimental application) and the Norm P100-81.

After about 10 years, based on specialized research conducted in the country and on the plan as well as movements recorded in national seismic networks in earthquakes strong magnitude from August 30, 1986 and May 31, 1990, the Regulations P100-91 and P100-92. These seismic design standards have been developed in a modern way, the effects associated with the location of the site and the terrain conditions being included in the map seismic macrozoning and in the zoning map according to the corner period T_c.

SEISMIC CONDITIONS

SEISMIC ACTION - Evolution of regulations

Equivalent Lateral Force Method (P100/2004 - it applies only to structures that can be reduced to two-way plane systems orthogonal and whose total response is not significantly influenced by the upper modes of vibration) - the equivalent seismic forces are obtained by the independent treatment of each its own way of vibration k, characterized by its own period of vibration T_k, its own vector of vibration s_k and equivalent modal mass m_k. Basic seismic force corresponding to the vibration mode r was established as a fraction of the resultant gravitational load issues:

$S_r = c_r G$, where c_r - global seismic coefficient

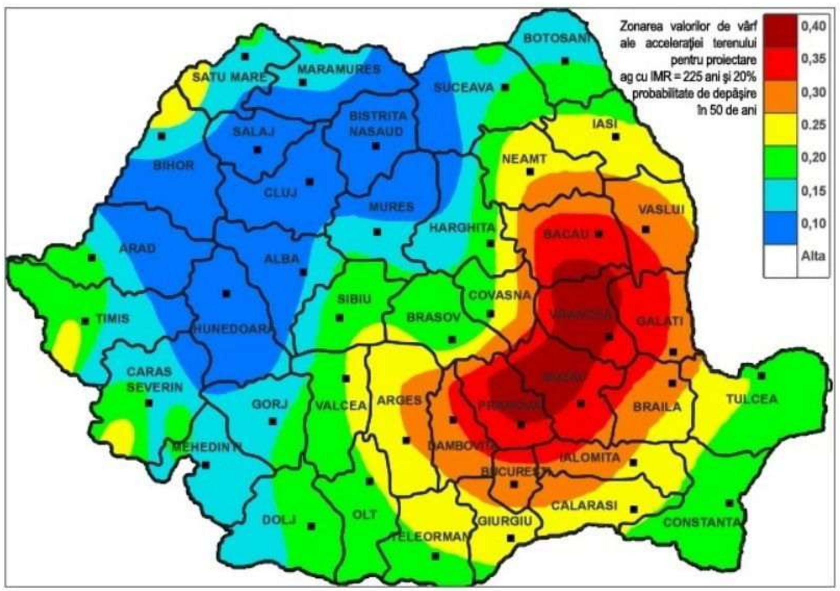
$$c_r = \alpha\, k_s\, \beta_r\, \psi\, \xi_r$$

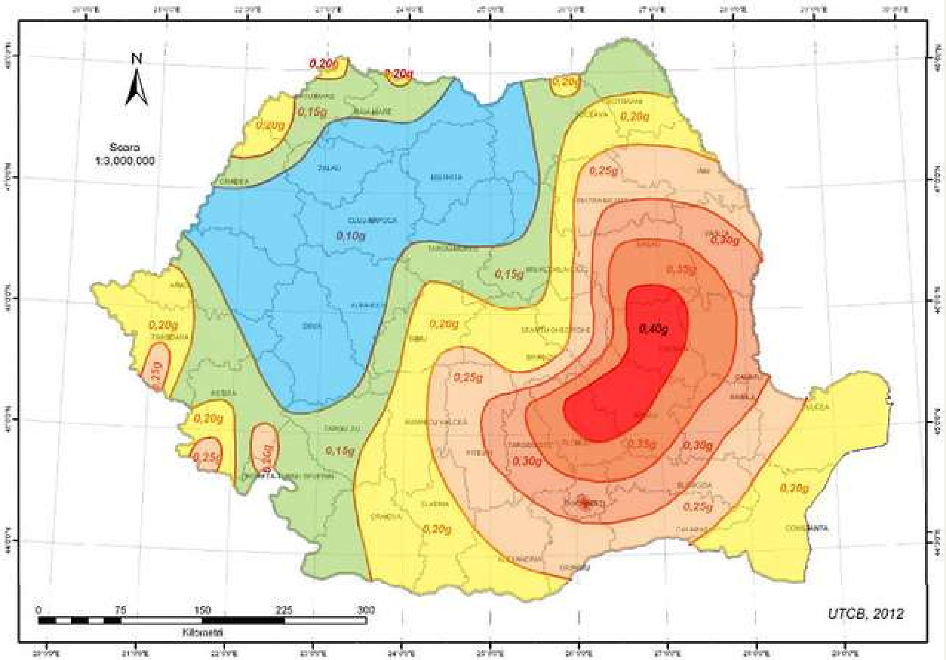
- $\alpha = \gamma_I$ - importance coefficient;
- $k_s = \frac{a_{max}}{g} = \frac{a_g}{g}$ - coefficient depending on the seismic calculation area, which depends on the maximum value of the a_g terrain acceleration, established in the new code for an average recurrence interval of 100 years;
- $\beta_r = \frac{T_r}{a_g}$ - the coefficient of dynamic amplification in its own way r, expressed by the ordinate (corresponding to the proper period T_r) from the normalized elastic response spectrum of absolute accelerations to maximum ground acceleration;
- Ψ - the coefficient of reduction of the effects of the seismic action, taking account of the postelastic deformation capacities of the structures;
- ξ_r - the modal equivalence coefficient.

SEISMIC CONDITIONS

SEISMIC ACTION – today regulations

Response Spectrum Method (P100/2013) - the territory of Romania it is divided into areas of seismic hazard. The level of seismic hazard in each area is considers, simplified, to be constant. The seismic hazard for design is described by the ground peak acceleration value horizontal seismic, a_g determined for a mean recurrence interval (IMR = 225 years, with probability of exceeding 20% in 50 years) reference value, hereinafter referred to as “design ground acceleration”. Seismic motion at a point on the surface of the ground is represented by elastic response spectra for absolute accelerations.

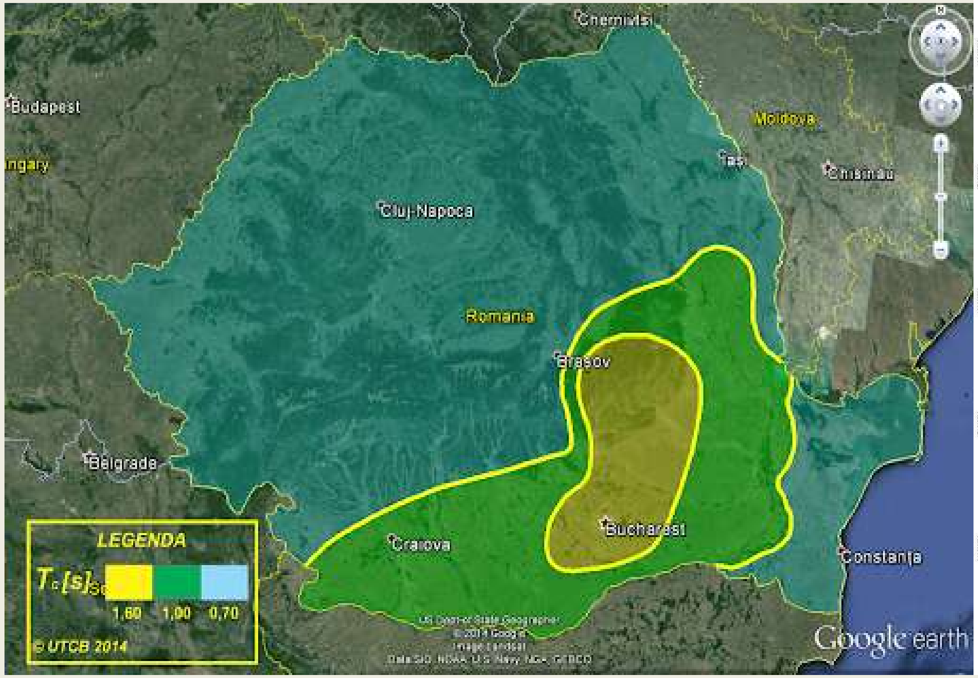


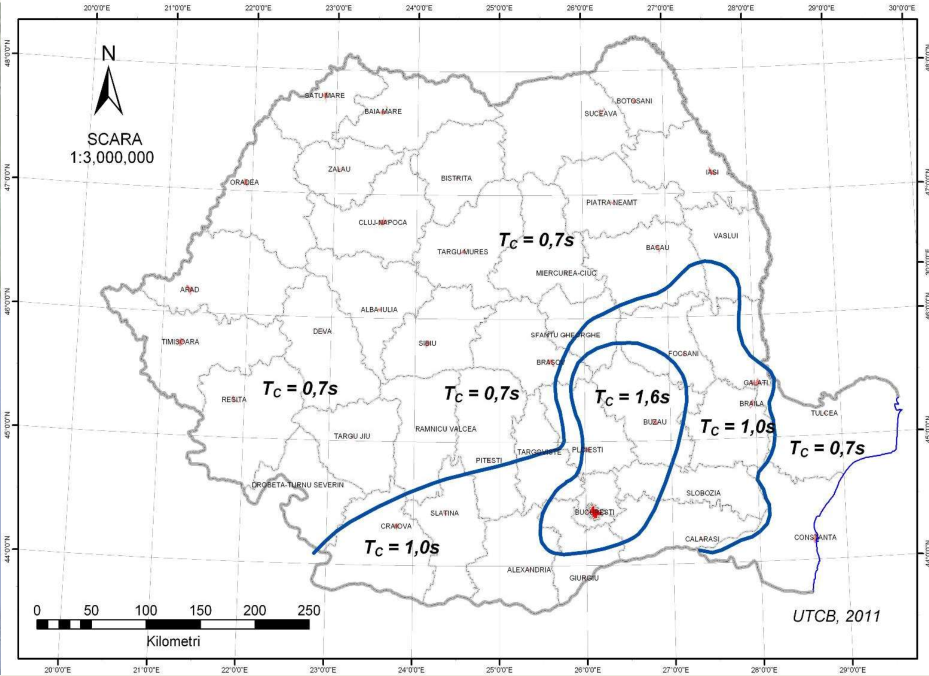


SEISMIC CONDITIONS

SEISMIC ACTION – today regulations

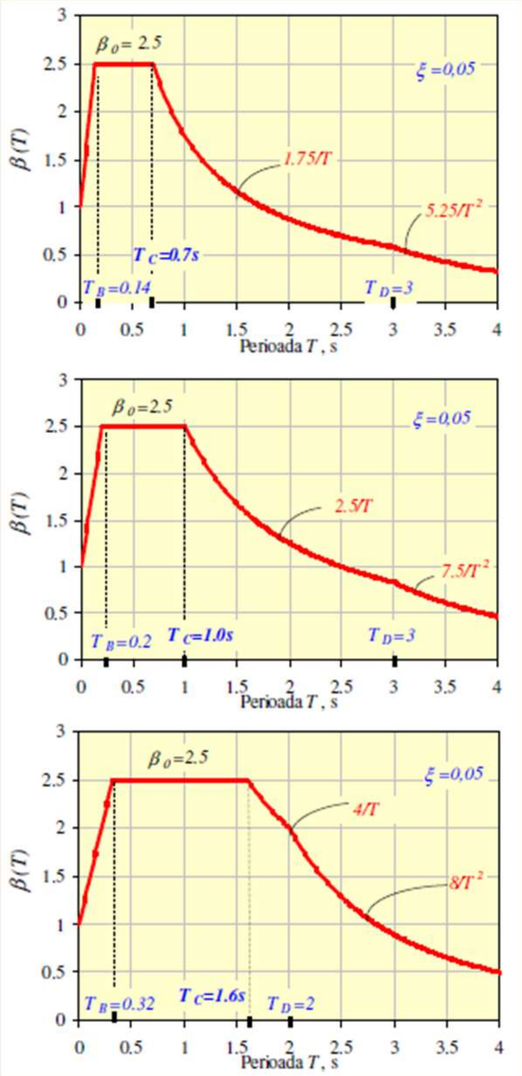
Response Spectrum Method (P100/2013) - the control (corner) period T_c of the response spectrum represents the boundary between the area (level) of maximum values in the spectrum of absolute accelerations and the area (level) of maximum values in the relative velocity spectrum. In fact, the T_c corner period of the design spectrum is the time required to achieve a complete oscillation of seismic waves specific to an area and characterizes its seismic conditions (expressed in seconds). Local field conditions are described simplified by the values of the control period (corner) T_c of the response spectrum for the area of the considered location. These values synthetically characterizes the frequency composition of seismic movements.





SEISMIC CONDITIONS

SEISMIC ACTION – today regulations



Response Spectrum Method (P100/2013) - local field conditions are described simplified by the values of the control period (corner) T_c of the response spectrum for the area of the considered location. These values synthetically characterizes the frequency composition of seismic movements.

Normalized elastic response spectra of absolute accelerations for the fraction from critical depreciation ξ = 5%, for seismic and ground conditions in Romania, β(T), for each T_c corner period.

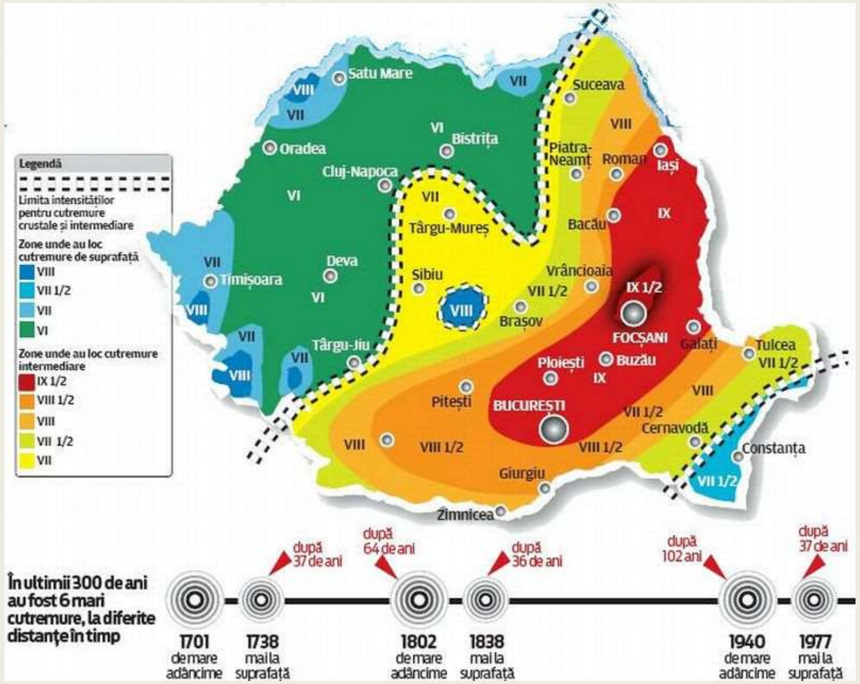
β(T) - the normalized elastic response spectrum of absolute accelerations.

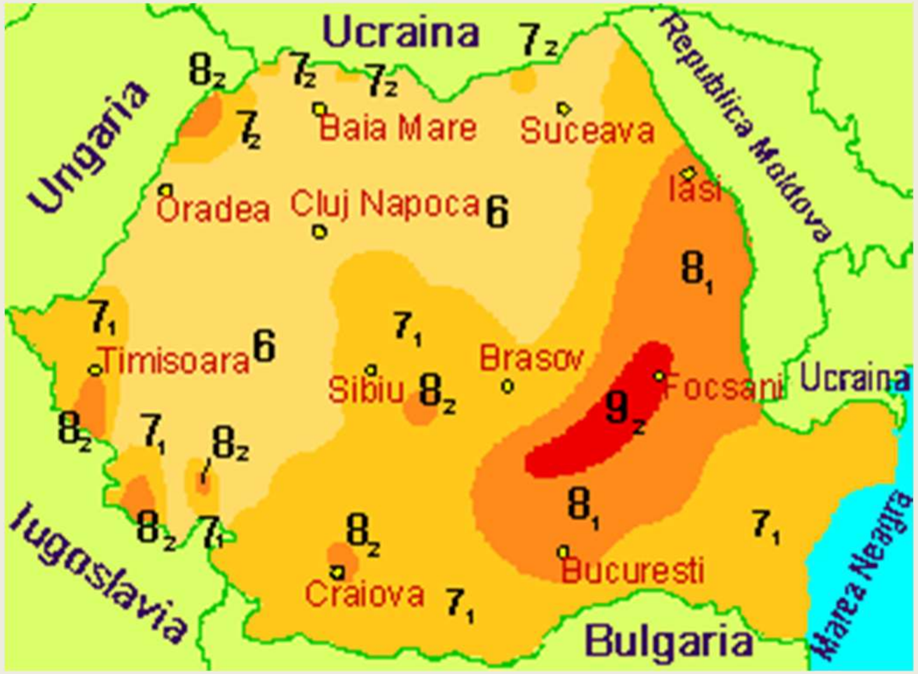
For Bucharest, in case of using the method for the structural calculation equivalent static lateral forces, for constructions and structures whose own period of vibration in the fundamental mode T_1 is in the range of (1.4s ÷ 1.6) s, the value of the factor of maximum dynamic amplification β_o multiplies by 1.2.

β_o - the factor of maximum dynamic amplification of the horizontal acceleration of the terrain by a system with a degree of dynamic freedom, whose value is β_o = 2.5.

SEISMIC CONDITIONS

SEISMIC ACTION – zoning maps





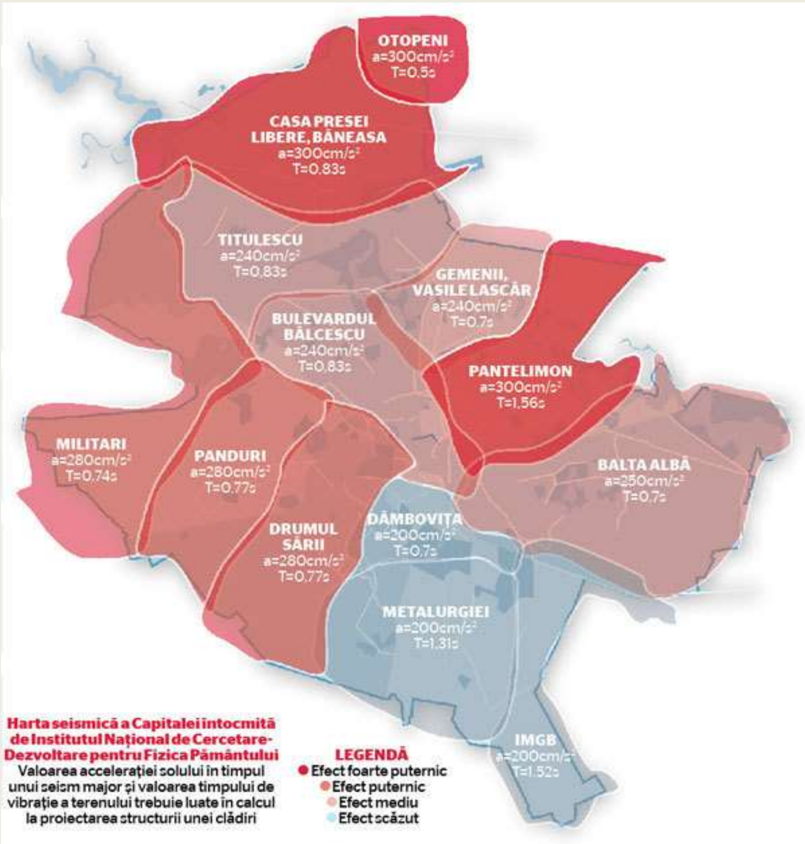
In Vrancea there are two types of earthquakes: crustal ones - shallow (less than 60 km depth), relatively low energy and quite small magnitudes – max. 5.2 degrees on the Richter scale and subcrustal, intermediate, deep (between 60 and 220 km depth) - the latter are very dangerous, reach large magnitudes (about 7.8 ÷ 8.0 degrees Richter) and are felt over very large areas, causing large and very large damage.

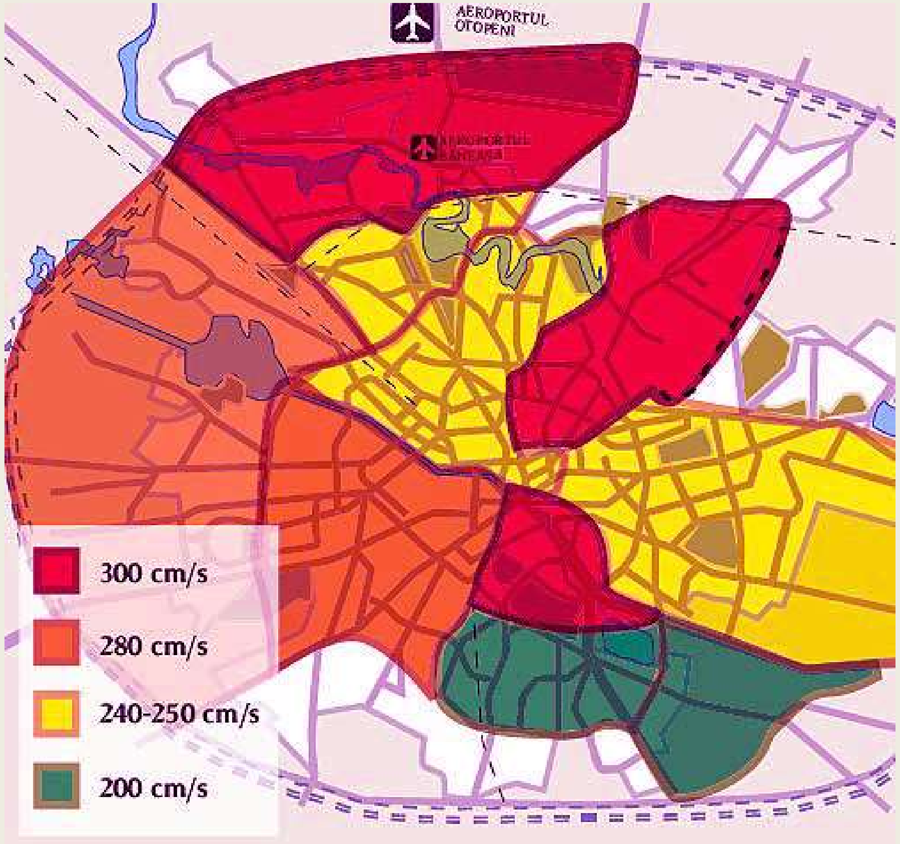
In the other seismic areas of the country there are shallow earthquakes (between 5-35 km), with smaller magnitudes than the earthquakes in Vrancea.

Earthquakes in areas such as Banat, Crisana, Maramures, Fagaras or Dobrogea (the list can be extended) have local effects, limited in extent.

SEISMIC CONDITIONS

SEISMIC ACTION – Bucharest zoning maps





SEISMIC CONDITIONS

SEISMIC ACTION – Bucharest earthquakes

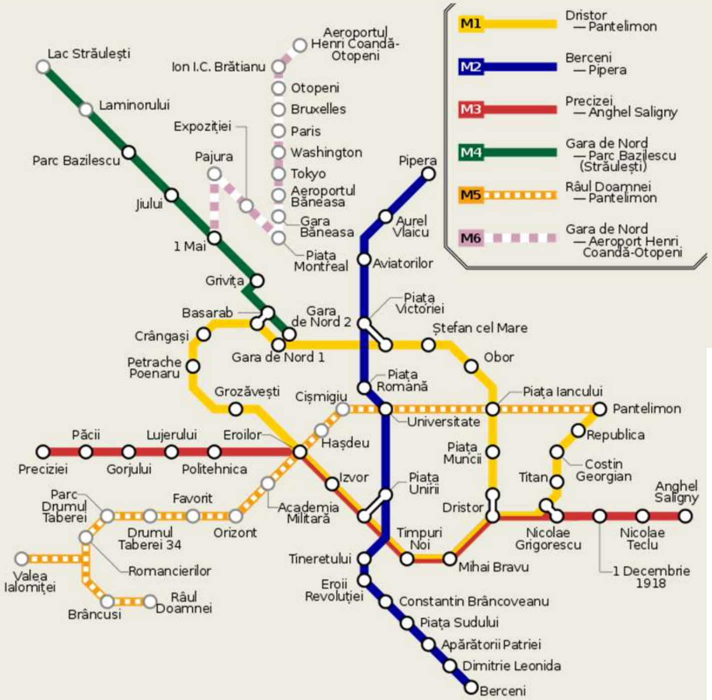
3.39 a.m., November, 10, 1940 – 7.4 Richter scale; 133 km depth; 45 s duration
Carlton Building (47 m height) colapsed

SEISMIC CONDITIONS

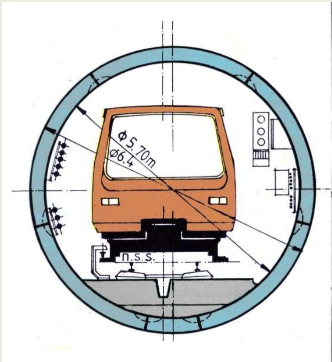
SEISMIC ACTION – Bucharest earthquakes

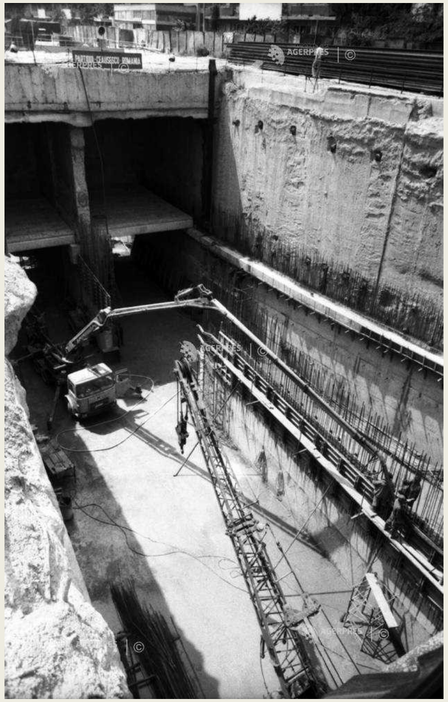
9.22 p.m., March, 4, 1977 – 7.4 Richter scale; 147 km depth; 56 s duration
32 buildings collapse; more than 1570 victims

BUCHAREST METRO HISTORY



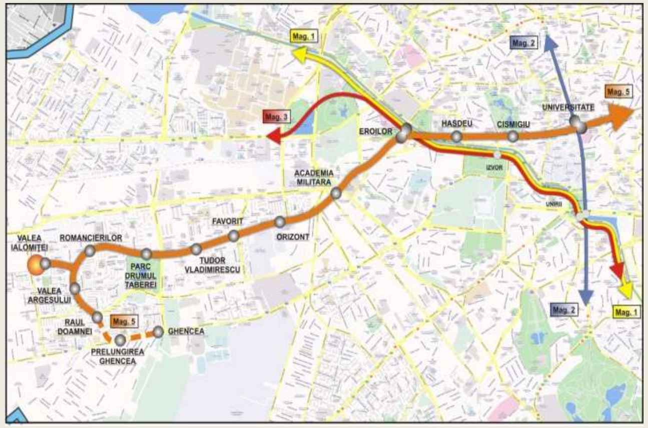
February, 1975 – start of designing
March, 1977 – start of construction
November, 16, 1979 – first section of M1 put into operation (Semanatoarea – Timpuri Noi)





BUCHAREST METRO HISTORY

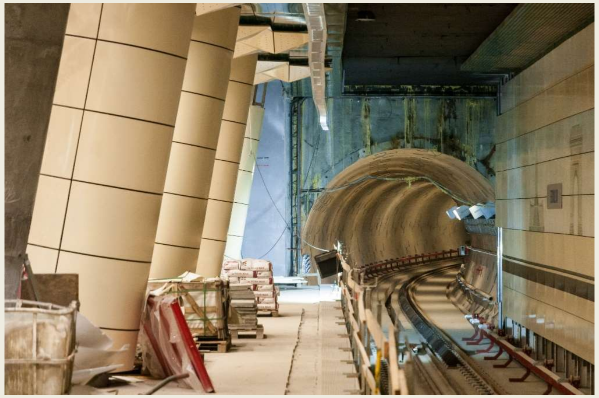
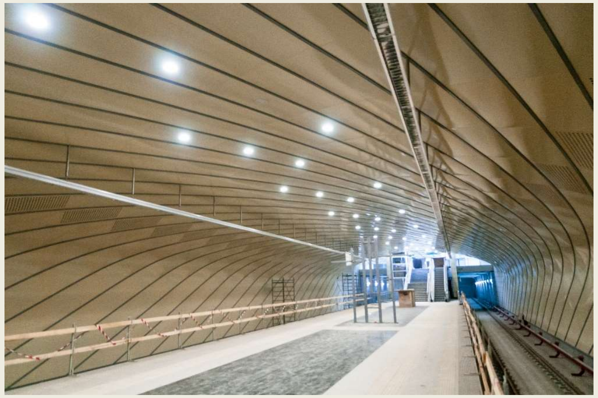
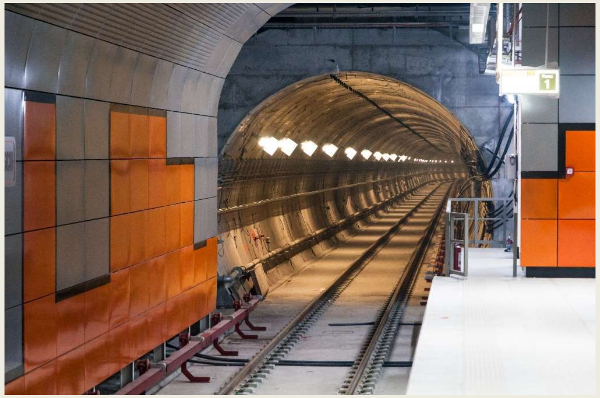
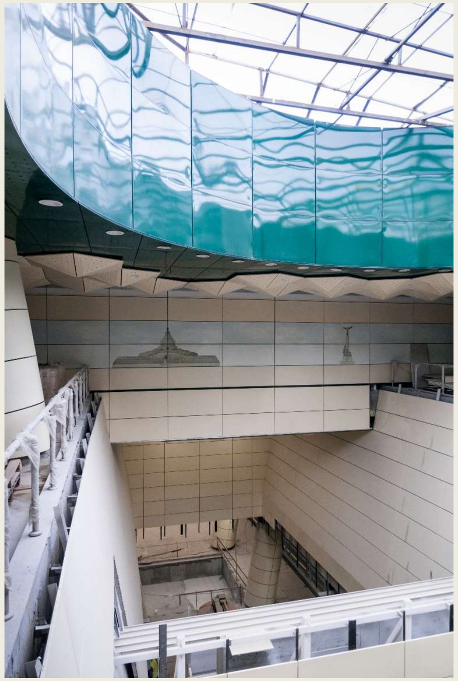
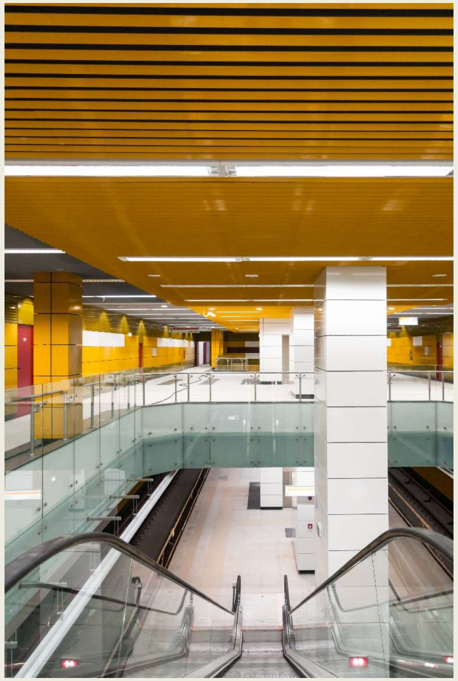
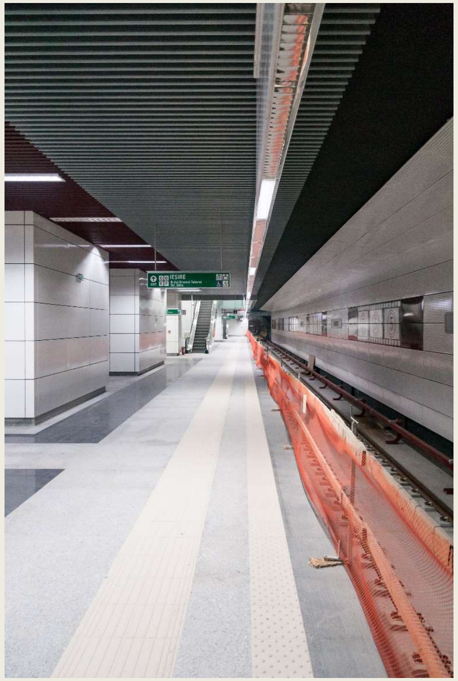
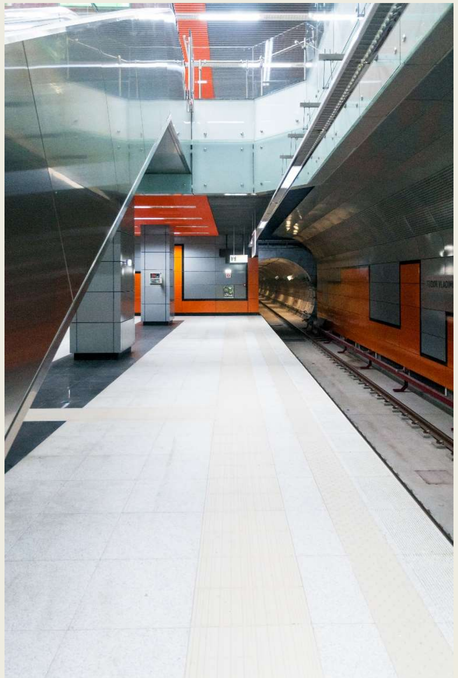
NEW METRO LINE 5 – 2012-2020



Length: 9.29 km; Stations: 13; Stations length: 2.52 km; Depots: 1.

TBM Tunnels length: 11.55 km; Cut-and-Cover Tunnels length: 0.81 km.

BUCHAREST METRO HISTORY
NEW METRO LINE 5 – 2012-2020

THANK YOU FOR YOUR ATTENTION !