EARTH'S FAULTS TYPOLOGY – METHODOLOGICAL APPROACH

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Abstract: *The faults typology is an essential tool for faults identification based on geological, geodynamic and geophysical principles and criteria. The faults are most important element of geodynamics controlling many processes and activities – earth's crust fragmentation, seismotectonics, plate movements, volcanic activity, etc. The methodology for typology is developed considering the geology, geodynamic and geophysical properties of the different types of faults and fault's systems. The typologization is a strong tool to the classification and integral assessment of these very important elements of the Earth's geodynamics.*

ТИПОЛОГИЯ НА РАЗЛОМИТЕ В ЗЕМЯТА – МЕТОДОЛОГИЯ

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Резюме: *Разломите и разломните структури в земната кора са основен елемент на геодинамиката контролиращ редица геоложки процеси – дезинтеграция на границата грунт-въздух (свободна от напрежения), земетръсната активност, движенията на земекорните блокове и континенталните плочи, рудоконтролиращи процеси и явления, вулканична дейност и др. Създаването на обобщена типология с основни понятия и дефиниции, критерии за идентификация, интегрални оценки за структурата и динамиката на разломите, се явява важна стъпка в процеса на изучаване на разломната геодинамика. Разработена е методология за класификация и идентификация на разломи и разломни структури базирана на геоложки, геодинамични и геофизични принципи.*

Introduction

The methodology deals with the definitions and criteria accepter in the international practice, possible methods of identification of active, passive and creep faults, the criteria to connect any fault (segment) and/or fault system with observed earthquakes and other geodynamic phenomena, the ranking of faults, the definition of faults' type, faults branches, faults' systems, faults deviations, faults' elongation and linearization, movements of the faults, depth penetration and development of faults, blocks and lineaments limited by faults, etc. Then the visualization is important to perform. After the establishment of the faults network, the characteristics of any fault, fault segment or fault satellites, the typology is constructed using all available information. The special methodology algorithm is developed and applied on real examples [1].

Definitions

- Blind (buried, crypto) fault – a fault without clear outcrop to the earth's surface
- Active fault – a fault with Neogene (Neocene, Holocene, recent) activity – demonstrates creep and/or seismic and/or geodetic movements

- Sleep fault – with lack of recent activity
- Roughness (new parameter related) – property to the possibility of accumulation of stress in the fault
- Depth – the penetration depth of a fault
- Fault segment – a part of the fault with similar characteristics and possibility to generate a characteristic earthquake
- Rank of the fault – expert assessment of fault importance
- Certain faults – faults proved by geology, geodetic and/or geophysics evidences for existence of a fault.
- Sealed (passive) fault – faults expressed in depth with no any activity
- Supposed faults – presenting indicators to consider the existence of a fault.
- Normal faults – fault with vertical component of displacements of the blocks in extensional stress regime
- Trust faults – fault with vertical component of displacements of the blocks in compressional stress regime
- Strike-slip fault – fault with horizontal displacement
- Echelon – a system of subparallel faults with expressed recent activity
- Listric faults – appear in intensive extensive regime reaching sub-horizontal planes
- Satellite faults – a system of accompanying faults, related to the main fault, usually observed like a fan
- Fault line – the projection of the fault plane on the earth's surface
- Dip – average angle of dip vector
- Rake – average angel rake vector
- Slip – a possible sliding related to a single earthquake (the slip vector represents the direction of motion of the hanging wall relative to the foot wall).
- Seismogenic potential of the fault – potential to generate an earthquake with Mmax.

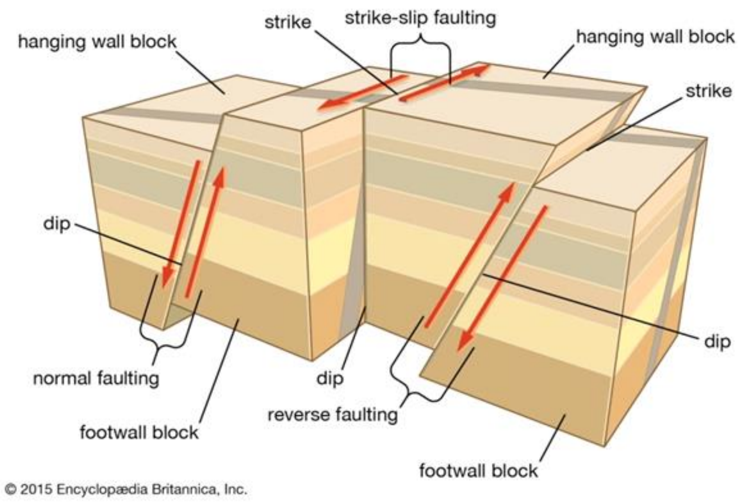

Fig. 1. On the basis of activity and the type of displacements the faults typology is possible

Indicators for identification

- Geology indicators:

Gas seeps and mud volcanoes detected and interpreted by Ranguelov and Dimitrov [1], sedimentation discontinuities and/or granulometric changes, vertical and /or horizontal visible movements at the outcrops, fast transgression/regression evidences, etc. are also used as indicators. Most of these elements could be confirmed by age determination and paleontology fossils.

- Morphology indicators – natural outcrops, man-made diggings and trenches, changes in high resolution DEM (on land or on the sea bottom)

The high resolution bathymetry and faults traces according the bottom deformations, bottom elevations modeled gradients and ancient river beds [1] are important indicators. It is important to mention that the visible deformations on the sea bottom might be produced by tectonic activity or surface gravitational processes as well as by the erosion of ancient river beds. The separation of the different types of bottom faults could be established by the bottom surface DEM, the geophysical prospecting methods, seismic activity and other properties, typical for active faults, segments and fault branches. Frequently the identification is done by a complex study of different disciplines – Geology, geodynamics, geophysics, etc.

- Seismological indicators:

Seismic catalogues, - Historical and Recent seismicity, Macroseismic maps, criteria to join epicenter to fault structures are some of the elements used.

Local week seismicity, earthquake regime (routine seismologic data processing – b-value, aftershocks activity, mechanism of earthquakes, rupture velocity, amplitude field of the seismograms, etc.), strong earthquakes and secondary effects (tsunami deposits, co-seismic cracks and displacements, activated landslides, subsidence and/or seismicities observed, (structural and mineral changes due to the strong seismic forces, etc.), paleo- and archaeoseismological studies and evidences [2].

- Potential fields (anomalies in the gravity, thermal and magnetic natural fields)

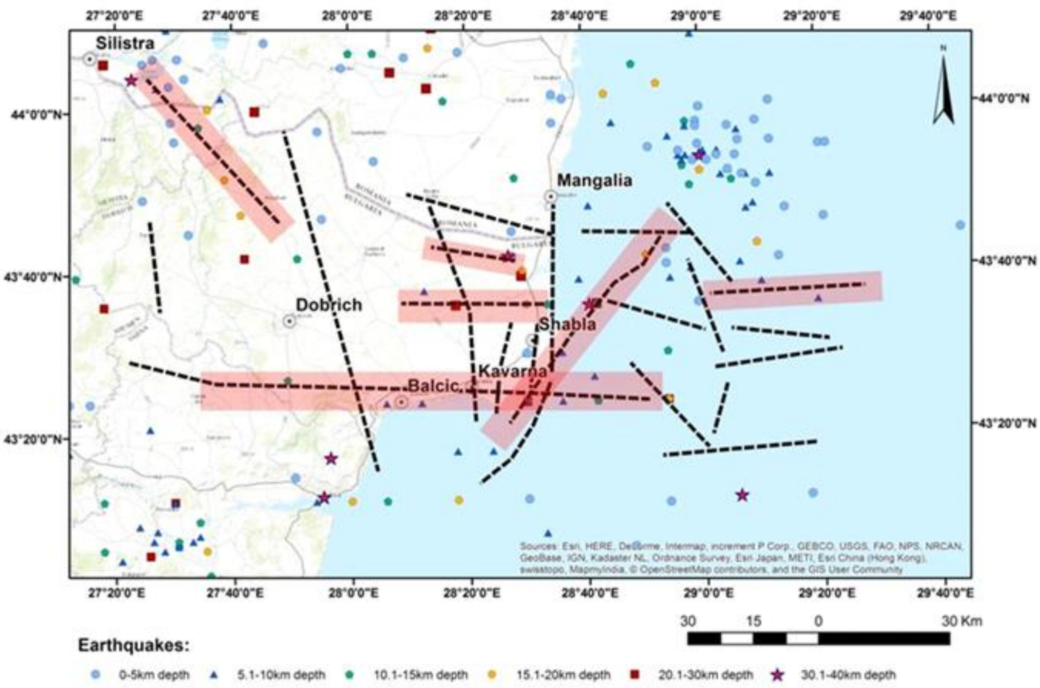

Fig. 2. Faults dislocations according interpretation of potential geophysical fields, together with small magnitude instrumentally recorded earthquakes [3]

- Geophysical measurable indicators:
- Electro tomography profiling and 3D models, seismic exploration and seismostratigraphy
- Geophysics of the deep horizons (earth crust, upper mantle and asthenosphere)
- Blind fault identification using MMS method – earth crust thickness, asthenosphere and high density seismographs network.
- Boreholes– in situ indicators: (one of the best and proved indicators about ancient and recent blind fault displacements)
- Geodetic indicators - movements detected by GNSS, on land measurements, laser interferometry, etc.

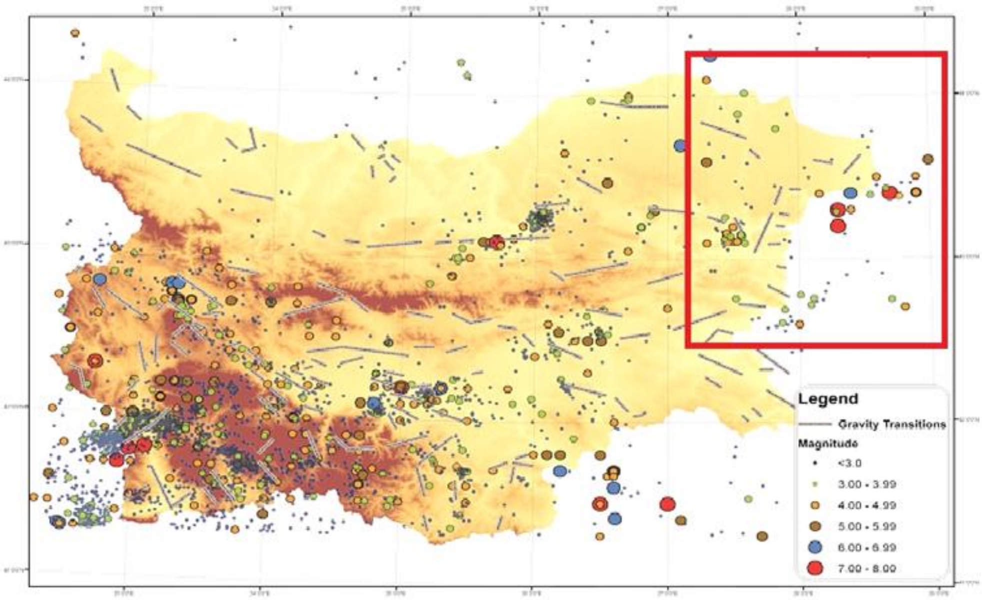

Fig. 3. An example of faults identification by potential geophysical fields and weak and strong earthquakes considerations [4]

The rational geophysical strategy of buried active faults delineation and monitoring is well presented in Budanov et al., [5].

Methodology algorithm

The methodology is developed according to the following algorithm:

- Review and inventory of existing and new data. All known faults are localized due to their expression:
- On the surface - geology and geomorphology methods (surface dislocations, recent movements – GNNS displacements, remote sensing, crack's analysis, co-seismic cracks, etc.)
- Underground faults (geophysical prospecting, seismology evidences, seismic exploration, potential fields, seismic activity, etc.
- Underwater faults (geophysical prospecting, geochemistry, seismic activity, etc.)

Visualization

Using recent graphics tools, all elements of the faults are mapped and visualized. This process has main aim to separate certain and supposed faults.

Comparative analysis

This is obligatory step to compare all types of faults, to clarify the main type of any fault, to identify its properties and to classify it.

Confirmation

Confirmation and/or rejection of fault type and/or structures, based on available information

Integration

Integrating all available data, using all criteria and definitions to confirm and/or reject the attribution of the properties of all discovered and confirmed types of faults, their segments, satellites and echelons.

Compilation of faults' typology table

Using all results of the investigations, the compilation of a new map is the last step of the process to discover and characterize the active faults, the blind faults and the passive faults and to assess their seismogenic potential due to their predefined properties. To discover the blindness, roughness, activity, stress and strain, neotectonic regime, seismogenic potential and possible activation, knowledge of many disciples are in use.

Very important issue is to consider the tectonic context and to produce non contradictory results for the faults typology – Table 1.

Table 1. Typology of the faults in a context of their possible geodynamic activity

Type of fault/ Activity	Active	Passive	Creeping	Roughness
Recent	+/-	+/-	+/-	+/-
Ancient	-	+	-	+/-
Sealed	-	+	-	-
Seismogenic	+	-	-	+
Segment	+/-	+/-	+/-	+/-
Echelon	+/-	+/-	+/-	+/-
Co-seismic	+/-	+/-	+	-
Listric	+	-	+	-
Blind (crypto)	+/-	+/-	-	+/-

Conclusion

On the basis of faults geometry, kinematics and dynamics a typology of different geodynamic features of faults is suggested. The different indicators of identification are considered due to the geodynamic properties and expressions of faults, fault's segments and systems. The typology table suggested could serve as an important tool for the case studies, as well as to the geodynamic context in any selected area. The performance of such a methodology is applied to the North Black Sea Bulgarian coast [1].

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