The effect of the inherited Miocene extensional geometries during the inversion of the Sarajevo Basin, Bosnia & Herzegovina

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Abstract

The effect of inherited basin structure and rheological stratification of a basin fill on the deformation created by inversion is a topic which has not received a lot of attention. Therefore we studied the Sarajevo-Zenica basin, a late Oligocene – Miocene endemic intramontane basin, situated in the Dinarides mountains of Bosnia and Herzegovina. To establish how inherited basin properties, structural and rheological, exerted control on the inversion deformation. We carried out structural and lithological mapping to examine the basins pre-inversion evolution and analyse its effect on the inversion. Two deformation events affected the basin before inversion. It was initiated as a foredeep basin during late Oligocene - Miocene during a phase of compression, and opened further during a phase of extension associated with the opening of the Pannonian basin in the Early – Middle Miocene. The basin was inverted obliquely to its NW-SE structural trend, in the Late Miocene by a N-S oriented compression, which is generated by the convergence of the Adriatic plate into the Dinarides. Inversion created a large E-W striking thrust through the centre of the basin which connects to a detachment in the Bosnian Flysch. Folds striking E-W to NW-SE were formed. Due to the oblique angle of inversion the thrust sheet moved over oblique ramps inherited from the NW-SE trending normal fault blocks created during extension. Tear faults were formed to accommodate for the hanging wall slipping over these oblique ramps. Lateral movement along these tear faults rotated some E-W striking structures in the hanging wall to a N-S orientation. The deposition of coarse competent lithologies along the SW basin margin which transition into finer incompetent lithologies towards the NE basin margin created a rheological stratification of the basin. Where the basin fill was more competent the inherited structure exerted a stronger control in the inversion deformation, while inversion deformation in areas with incompetent lithologies was much less controlled by the inherited structures.

Introduction

Geological properties inherited from earlier geological events can greatly affect successive deformation phases. After a basin is formed due to extension and is subsequently inverted, the inherited normal faults can control the geometry and location of the inversion structures (i.e. reverse faults, folds)(McClay et al., 1989; Butler, 1989). Structures are not the only inherited geological properties, the rheological contrasts created by lithological distribution also play a key role. Such contrasts create weak and strong zones which will respond differently to deformation (Butler et al., 2006).

Positive inversion has primarily been studied in the case of passive margins that are incorporated into a fold-and-thrust belt. This research demonstrated that the existing extensional architecture affects the type of inversion deformation. Inherited normal faults can be reactivated by inversion or truncated by newly formed thrusts (Scisciani et al., 2009). On the other hand, there are instances where existing extensional architecture is overwritten by the compressional structures and it therefore exerted very little to no control on the inversion deformation (Bonini et al, 2012). The style and distribution of inversion deformation also varies according to the amount of contraction. In case of minor inversion, often high-angle thrust faults will develop. Yet when major inversion takes place, low-angle thrusts develop, cutting through the inherited extensional structure (McClay et al., 1992).

Besides the control of pre-existing deformation structures, the rheological stratification of the basin also controls the inversion deformation. The style of folding is controlled by the mechanical anisotropy, which is governed by the thicknesses of competent vs incompetent layers. A stratigraphic unit with strong lamination or repeated competent-incompetent layers and ample low resistance to slip bedding planes has a high mechanical anisotropy (Fossen, 2016). Deformation of such a unit results in angular box folds with inclined axial planes. Inversely thick competent beds and high slip resistant bedding planes form a low mechanical anisotropic unit. In which case deformation would result in rounded buckle folds with vertical axial planes (Sepehr et al., 2006). The rheological stratification also affects faulting, e.g. a ramp-flat-ramp geometry of thrust faults is created by incompetent layers forming the detachment levels and competent layers forming steeper ramps (Fossen, 2016). In turn the rheological stratification is also affected by the structures, e.g. normal faults which off-set the position of the competent and incompetent layers and thereby create a rheology contrast, which influences ramp locality (figure 1)(Rowan & Linares, 2000; Butler et al., 2006; Missenard et al., 2007).

Here we will study the Sarajevo-Zenica basin situated in the Dinarides, stretching northwest of Sarajevo, Bosnia & Herzegovina. A relatively small endemic lacustrine asymmetric intramontane basin, its formation started in the late Oligocene/early Miocene (Hrvatović, 2006). After which it got filled with alluvial, fluvial and lacustrine sediments until the Pliocene. Which resulted in a heterogeneous basin fill and a complex rheological stratification.

Positive inversion in these type of geological settings is still poorly understood. Due to the formation of the basin inside an orogen at a late stage of its evolution, a complex architecture is inherited due to all the previous deformation events. The basin recorded a late Oligocene compressional and a Miocene extensional deformation phase that could have affected the inversion. Besides these inherited structures the nappe structure of the Dinarides could have affected the inversion phase as well. Which makes the process of inversion more complex, making this the ideal place to improve our understanding on which factors control these processes.

We study this mechanism by mapping the deformation and lithology of the basin and studying the vergence and asymmetry of the structures, and placing them in a chronological framework. Through this we can study the control the inherited graben structure has exerted on the inversion deformation, and how the inherited structures were altered by the inversion phase. Scrutinizing the position of the inversion structures compared to the lithological distribution will demonstrate how rheological contrasts influenced the inversion architecture.
Creating a synopsis on how the different geological properties created during earlier deformation events controlled the deformation during inversion. Such a model is novel and will improve our understanding of similar Miocene Dinaridic basins and others outside the Dinarides with a complex pre-inversion history.

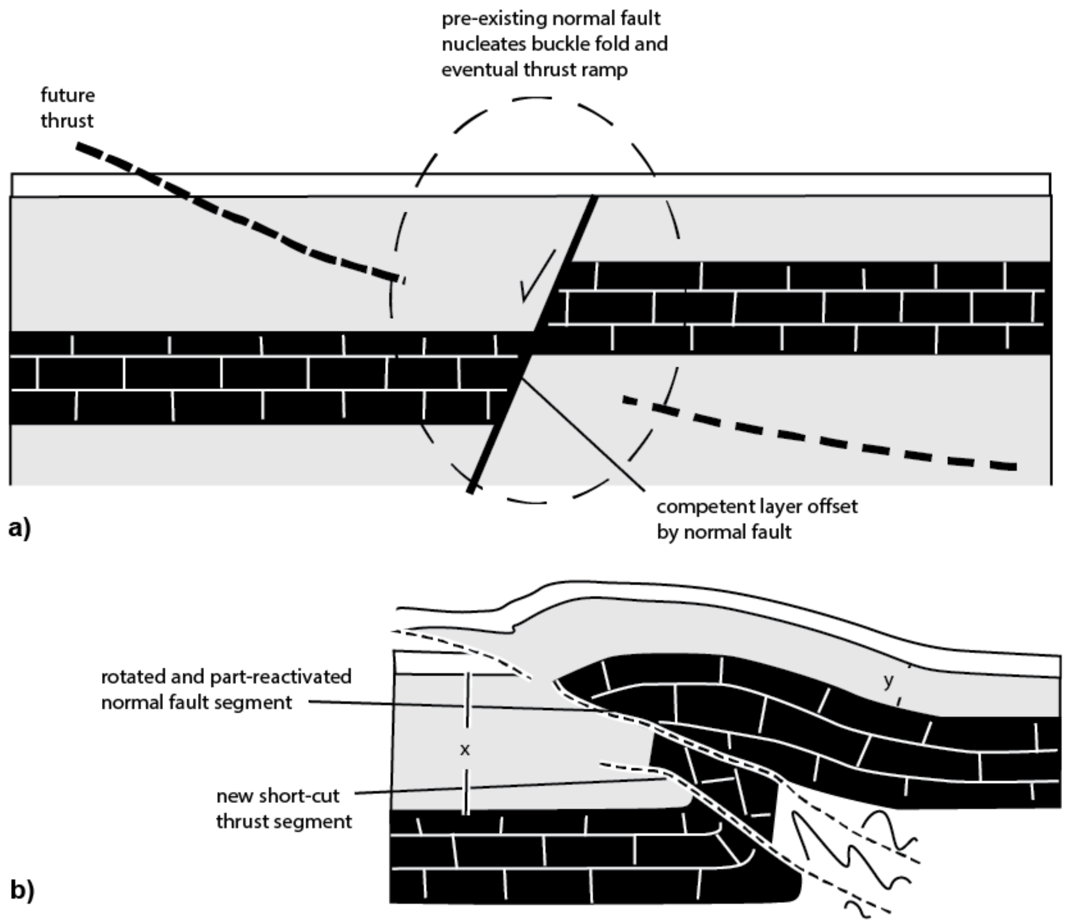


*Figure 1: **a)** A normal fault displaces a competent bed (brick fill), and incompetent beds (grey), creating a rheology contrast along its fault plane. Creating a ramp for a future thrust to develop when the package is inverted. **b)** Inversion occurs and a thrust fault is formed through the original normal fault zone, ramping over the competent lithology (brick fill)(from Butler et al., 2006).*

Geological context and tectonic setting

The Dinarides form part of the Alpine-Himalayan orogenic system, they continue into the Southern Alps to the NW and into the Hellinids to the SE (figure 2). The evolution of the Dinarides started during the break up of Pangea and rifting in the Middle Permian, coincidental magmatism affected the Variscan basement. Later during the Middle-Late Triassic/Early Jurassic the Neotethys ocean started to open up, the sea-floor spreading continued until Late Jurassic/Early Cretaceous times (Schmid et al., 2008). Around that time the convergence between Adria and Europe (Tisza and Dacia units) triggered subduction and SW directed obduction of Dinaric parts of the Neotethys ophiolites onto the NE margin of the Adriatic microplate and thereby the closure of the Neotethys commenced (Pamic et al., 1998; Tari & Pamic., 1998; Ustaszewski et al., 2010). Subsequently collision took place between the Adriatic and European units during the Late Cretaceous/Eocene. Out of sequence thrusting uplifted the Dinarides mountain chain, which altered the quite simple geometry created by the obduction (Schmid et al., 2008). Resulting in the present day NW-SE trending nappe stack, with a transport direction towards the SW (Pamic et al., 1998; Pamic et al., 2002).

After the main orogenic phase in the Eocene a system of intra-montane basins formed within Dinarides, referred to as the Dinarides Lake System (DLS). At the beginning of the Miocene, roll-back of the Carpathian slab created a back-arc basin, namely the Pannonian basin, on the NE margin of the Dinarides (Horvath et al., 2015). The opening of the Pannonian basin was likely associated with the opening of the DLS basins (i.e. Sarajevo-Zenica)(de Leeuw et al., 2012). Yet the exact geodynamics behind the opening of the DLS basins remains unclear. Several different mechanisms have been postulated, such as the creation of transtensional depressions by strike-slip faulting on the Peri-Adriatic fault that were deepened due to the subsequent Pannonian extension (Hrvatović, 2006). Alternatively a piggy-back basin model is suggested, where the basin formed as a wedge-top basin (Korbar, 2009). Ilic & Neubauer 2005, propose pure extension in two phases, an Early Miocene NE-SW extensional phase and a middle Miocene orogen parallel NW-SE extensional phase.

The Sarajevo-Zenica basin is the largest of the Tertiary intramontane basins in the Dinarides. It is an endemic basin between the East Bosnian - Durmitor and Pre-Karst units of the Dinarides mountain chain (figure 2,3), which opened in the Late Oligocene/Miocene (Hrvatović, 2006). The basin opened along an inherited detachment in the Bosnian flysch. It is bordered by the Bosnian flysch at the NE basin margin and the Mid-Bosnian mountains along the SW margin, consisting of a Paleozoic metamorphic complex and Mesozoic cover.

The opening of the intramontane basins like the Sarajevo-Zenica basin is part of the post-orogenic Dinaric evolution (de Leeuw et al., 2012). Timing of basin iniation has been done by magnetostratigraphic studies of the basin fill. Basin formation started in the Late Oligocene with a second phase during the Early/Middle Miocene (18Ma to ~13Ma), which is correlated to the main phase of extension in the Pannonian basin (de Leeuw et al., 2012). The created accommodation space during the pre-rift phase of the basin was filled with lacustrine sediments during Oligocene/Lower Miocene times by an alternation of conglomerates, sandstones, limestones, marlstones and coal layers. The second extensional phase took place during the Miocene and created more accommodation space which was filled with thick conglomerates interbedded with sandstone, limestone and marlstones. After extension halted, a package of marlstones, limestones, sandstones, clay, coal, and fine-grained conglomerates were deposited (figure 4).

Following this stage of extension, the basin fill was inverted, from late Miocene/early Pontian times (~7.5 Ma) until present by a N-S directed shortening phase (Matenco et al., 2012; Matenco et al., 2016; Ilic et al, 2005; Ustaszewski et al., 2014; Ustaszewski et al., 2010; Hrvatović, 2006; Tari & Pamic, 1998; Tomljenović & Csontos, 2001). These ongoing compressional stresses are caused by the continued convergence of the Adriatic plate into the Alps and Dinarides. The effects of this compressional stress regime are visible all the way from edges of the Adriatic plate, the Adriatic coastline, to as far as the Pannonian basin. At the location where the Adriatic plate and the Dinarides converge the stress regime is pure compression, while towards the Pannonian basin interior the stress regime changes to a strike-slip stress field (Bada et al., 2007). The area of the Sarajevo-Zenica basin was subjected to a N-S compressional regime, which developed the inversion deformation structures and their interplay with inherited basin structure we will study.

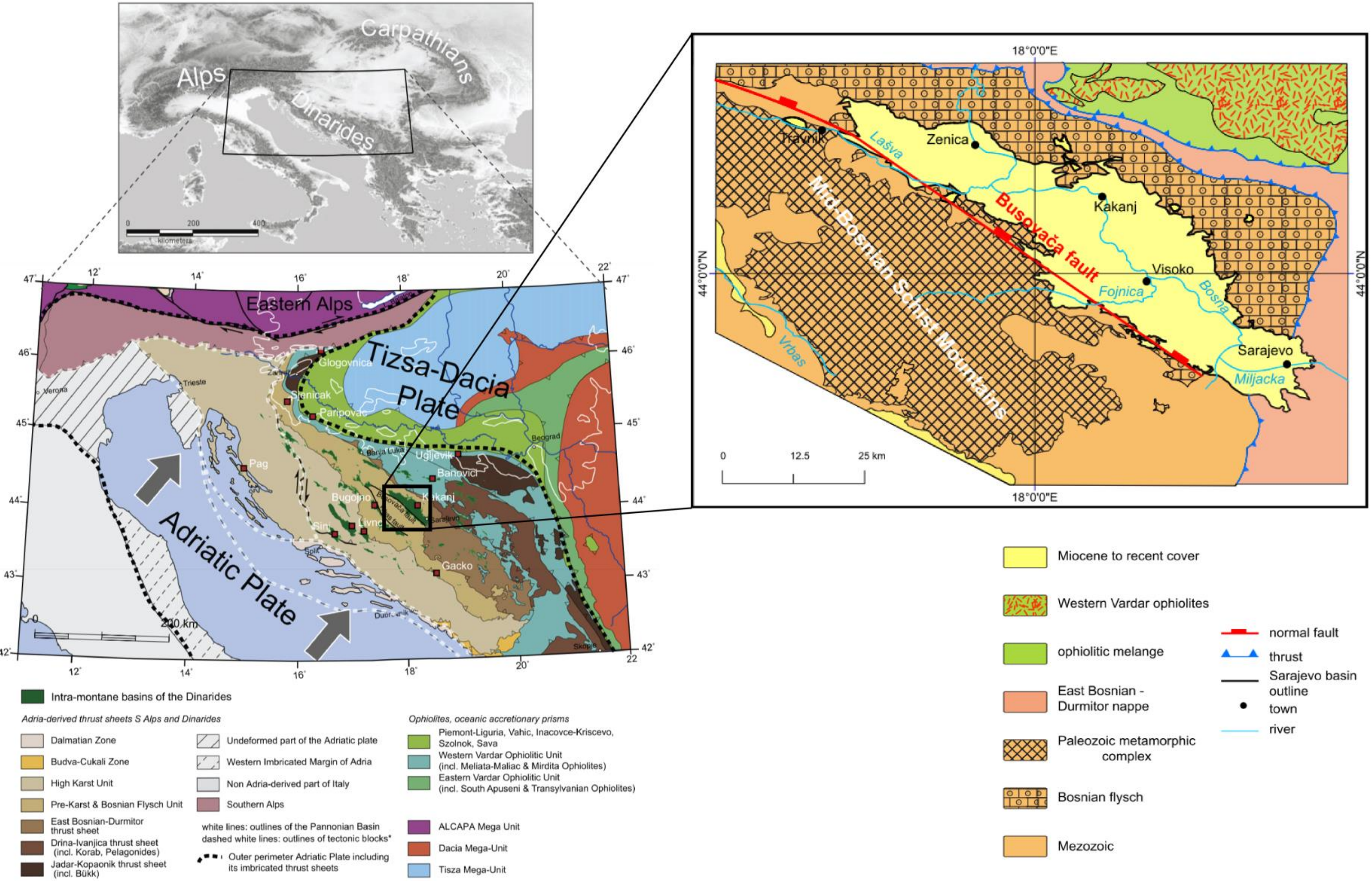


Figure 2: Geological map of the Dinarides and the position of the Sarajevo-Zenica basin within this system (adapted from Andric et al., 2017; de Leeuw et al., 2012).

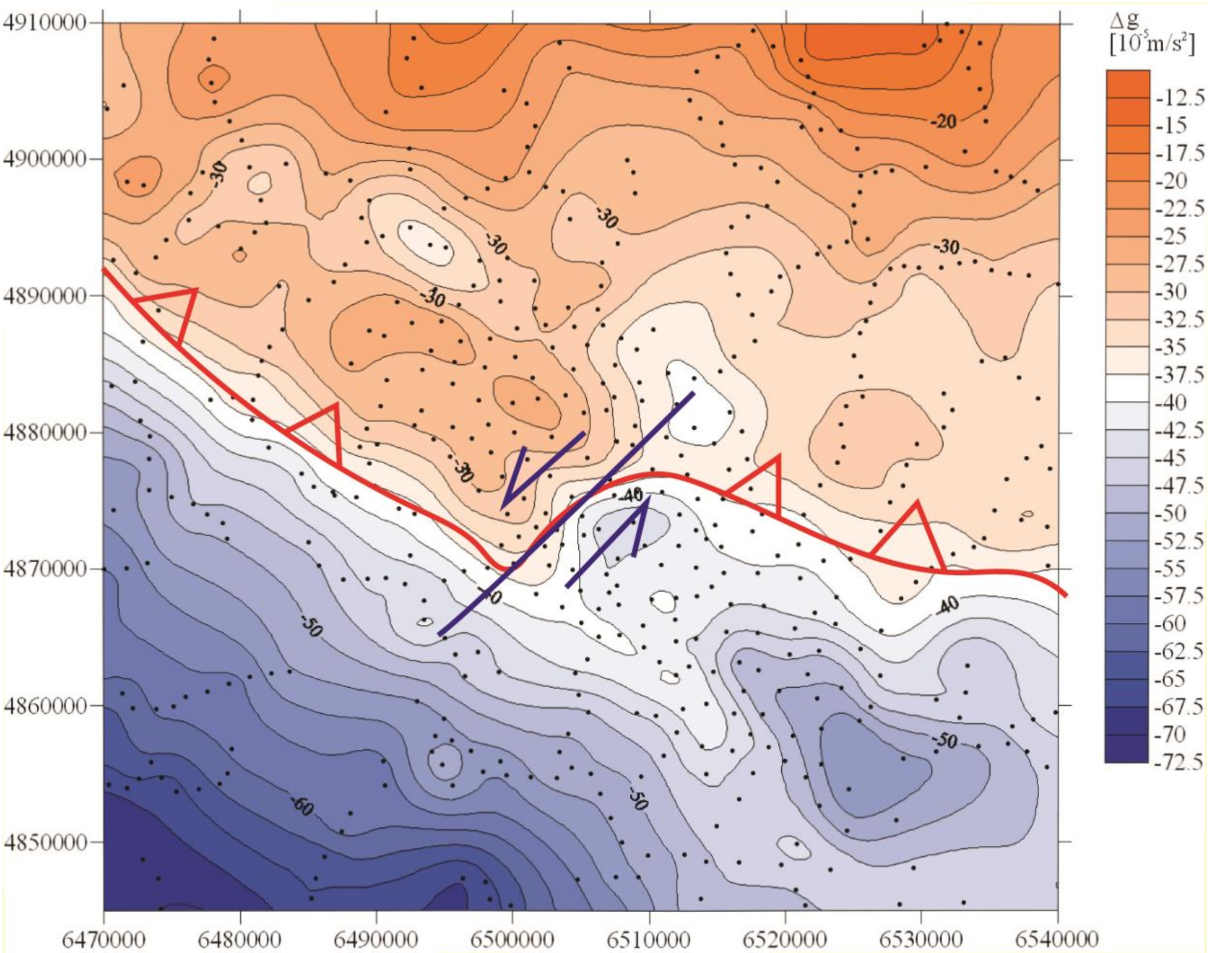


Figure 3: Gravity map showing a basement contact between East Bosnian-Durmitor and Pre-Karst unit op top of which the Sarajevo-Zenica basin is located (Geophysical database of Department of Geophysics, University of Belgrade, Faculty of Mining and Geology, Belgrade).

Basin stratigraphy

Basin development initiated during the Oligocene-Early Miocene along the contact between the East Bosnian-Durmitor and Pre-Karst units (figure 2,3). A package of ±800m sediments were deposited during this time, along the present NE basin margin, unconformably over the Bosnian Flysch basement rock. Beginning with a sequence of continental alluvial clastics, followed by carbonates deposited in a lacustrine environment as accommodation space increased. Limestones alternating with thick coal packages and alluvial sediments were deposited around the lake shore. On top of this the Red series was deposited, which consists of red alluvial clastics that are covered with a package of porous bituminous limestones and travertine in the NE of the basin.

On top of this a ±1500m thick Lower-Middle Miocene aged sediment package was deposited, which was deposited after 17Ma (de Leeuw et al., 2012). The onset of this sedimentary cycle is marked by a transgression, creating a swamp environment where clays, marlstones, sandstones interbedded with coal layers were deposited. Which are covered by shallow water lacustrine limestones.
On top of this a laterally variable sequence was deposited. Starting with thinly bedded marls and siltstones which are gradually and laterally replaced by sandstones and conglomerates, creating a coarsening upwards pattern. Laterally this sedimentary sequences changes from the up to 1000m

thick conglomerates of the Lasva series in the NW extent of the Miocene basin fill, to a hundred metres thick sandstone and marl alternation in the SE of the basin (Milojević, 1964). Material for this sedimentary cycle was derived from the basin margins made up by the Mid-Bosnian Schist mountains in the SW and Bosnian Flysch in the NE (Jovanović et al., 1971).

These sediments are subsequently covered by a new sedimentary cycle during the late Miocene. Which deposited the ±650m thick Koševo series consisting of marls, limestones, argillaceous sandstones, clays and coals. Indicating a gradual drowning of a swamp environment forming a perennial lake (Milojević, 1964). The Koševo series were then covered by the 200m thick Orlac conglomerates.

The youngest basin fill consists of a Pliocene alluvial series consisting of clay, sand and pebbles. Created a general trend of younger sediments towards the SW basin margin. Except for some of the Upper Miocene-Pliocene sediments which are deposited in depressions created by folds in the N, W, and S of the basin.

The arrangement of especially the Lower-Middle Miocene lithologies, that vary laterally from thick conglomerates and sandstones along the SW basin margin transitioning to sandstone and marl alternations towards the NE margin, creates a basin scale rheological stratification. The incompetent thinly bedded turbiditic alternations will preferentially act as décollement layers during deformation. The thick bedded conglomerates and sandstones will act as buttresses and faults tend to ramp up to a higher stratigraphic level until they reach another effective décollement level creating a ramp-flat ramp geometry (Cloke et al., 1997).

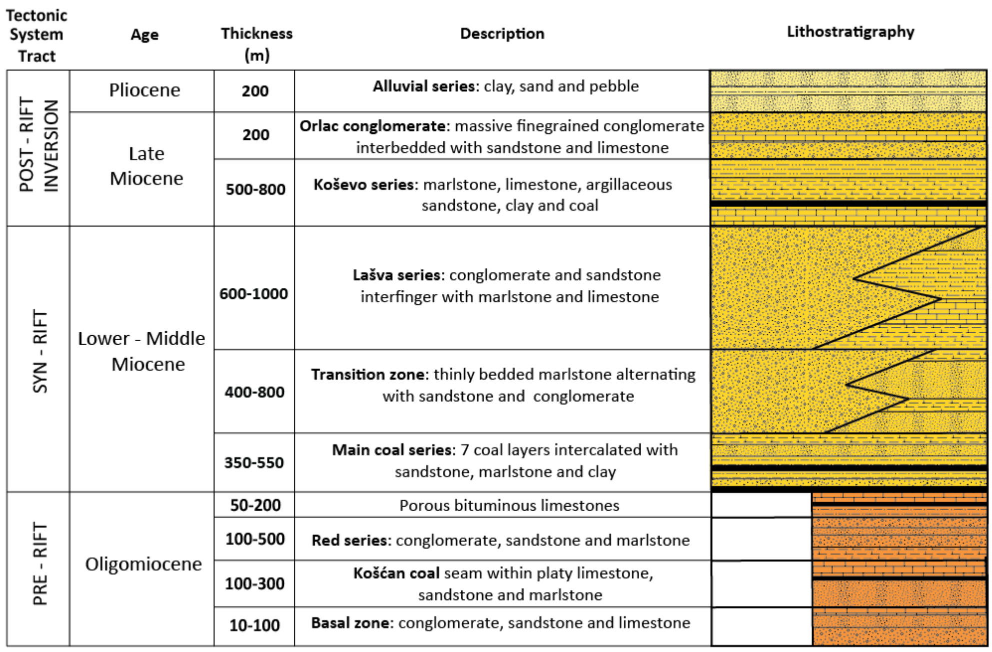


Figure 4: Stratigraphic column of Sarajevo-Zenica basin (adapted from Andric et al., 2015)

Methods

A field study of the Sarajevo-Zenica basin was conducted to study the effect of its inherited structure and lithology on the kinematics of the later inversion phase. The geological features (i.e. bedding, faults (and kinematic indicators e.g., slickensides, drag folds, and Riedel shears, cleavage and folds) were mapped. The timing of deformation was derived from the stratigraphy affected by the deformation, especially where we found syn-kinematic sediments, and cross-cutting of structures.

Folds of various scales, ranging in wavelength and amplitude from centimeters to hundreds of meters were observed. With interlimb angles ranging from gentle to isoclinal.
Second-order parasitic folds provided information on the geometry of the first order larger scale fold associated with it. Parasitic folds of shorter wavelength form around the longer wavelength first-order folds due to different layer-thicknesses and mechanical strengths of individual layers in the folded package (Frehner et al., 2006).
Assymetric folds were often found directly associated to faulting. Where faults were not visible, fault-propagation folds and fault-bend folds were used to interpret the presence of buried faults and ramp-flat-ramp geometries. Chevron folds were used as indicators of the proximity of detachments. Large scale folds were inferred by mapping beddings planes and cleavage across large distances where they were not visible on outcrop scale.

Axial planes and hinges of the folds were calculated to study the vergence using Stereonet 9 by Richard Allmendinger (Allmendinger, R. W. (2013). Fault orientations were plotted using FaultKin and Wintensor (Allmendinger et al., 2012, Delvaux et al., 2003). The folds are grouped into three areas covering the basin named after towns and rivers in these areas (see figure 6 for localities).

Intersection lineations are calculated where we measured cleavage and bedding planes (figure 10A). The line of intersection between bedding and cleavage has an azimuth and plunge defined by the compression and/or folding that created the cleavage giving us an extra indicator of the stresses apart from folding and faulting. Perpendicular to the intersection lineation lies direction of maximum shortening that created the intersection lineations. Which was useful in places where good outcrops were missing as this type of observation requires a comparatively smaller outcrop.

Results

Field observations are presented in chronological order, separated into three basin deformation stages that were identified. Basin formation was initiated by a phase of compression (D1), and was subsequently opened further by extensional phase (D2). Ultimately a compressional phase inverted the basin (D3).

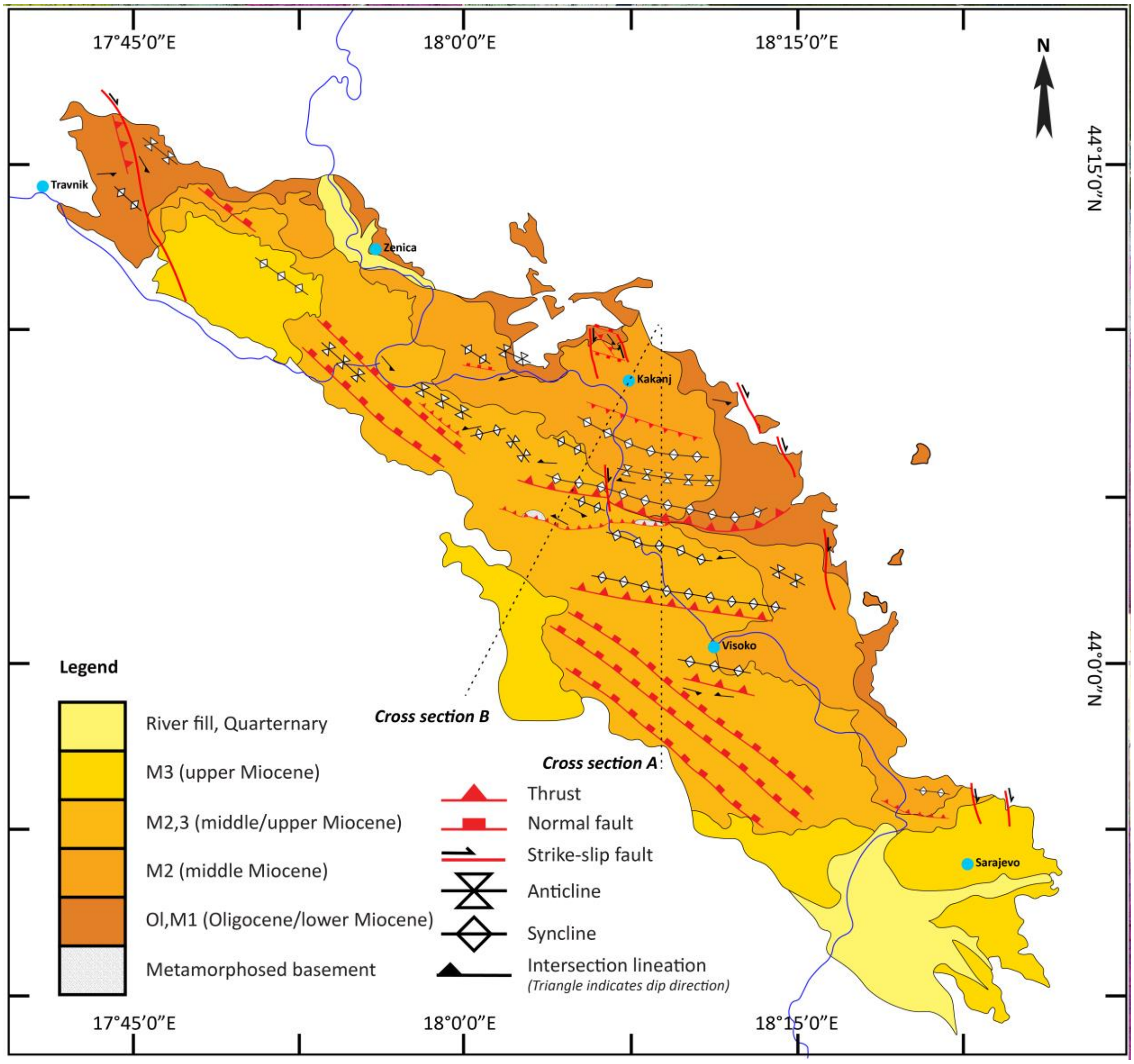


Figure 5: Structural map of Sarajevo-Zenica basin.

All structural and lithological observations were mapped, resulting in figure 5. The map shows how normal faults concentrate along the SW margin of the basin, striking NW-SE, and how reverse faults and folding strike E-W in the centre of the basin. Towards the NW extent of the basin folds and faults strike NW-SE. Notice the blocks of metamorphosed basement that crop out just south of the main thrust zone.

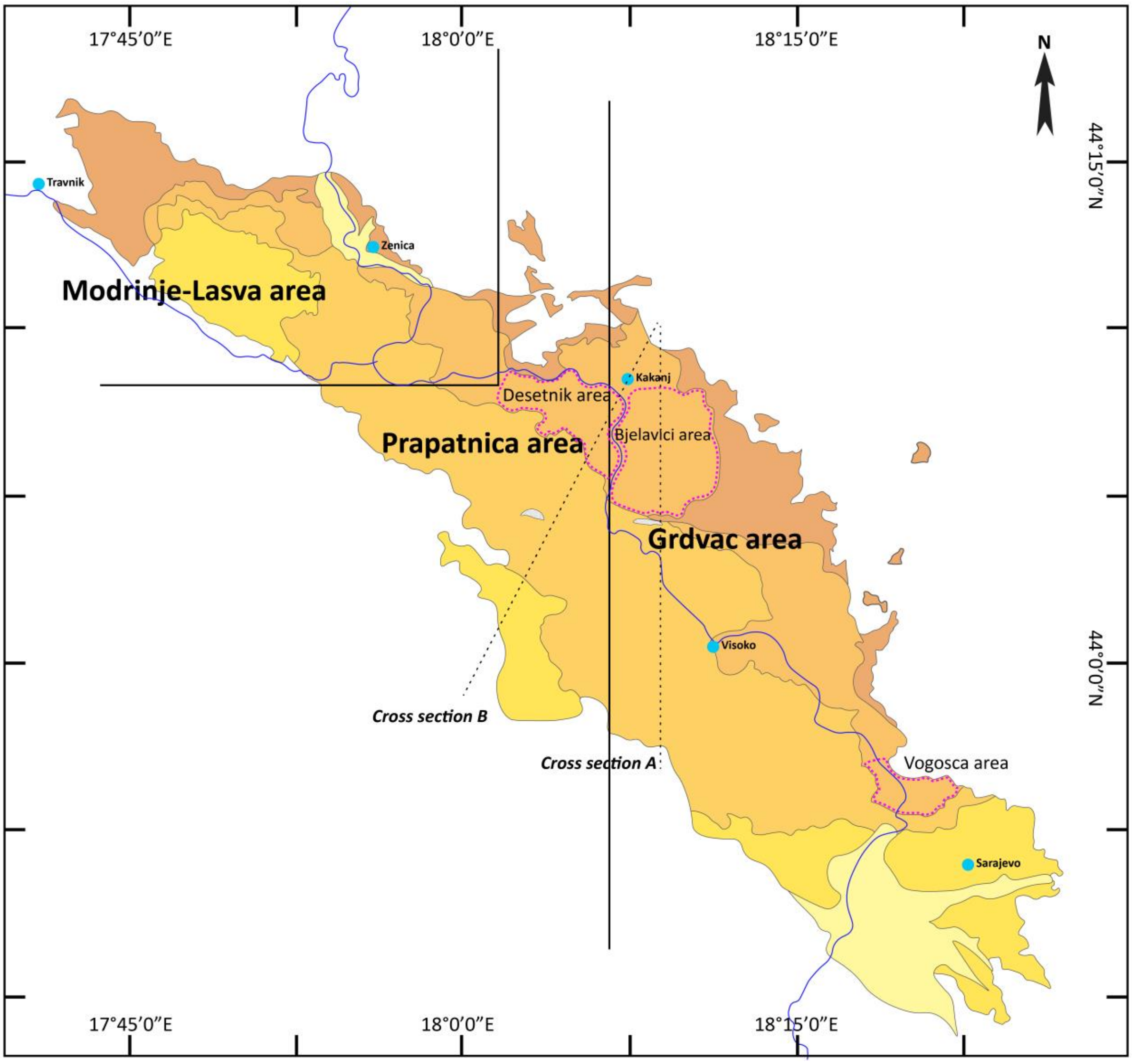


Figure 6: Locality map shows a separation of the basin into different areas to categorize the heterogeneous response to inversion deformation (for legend see figure 5).

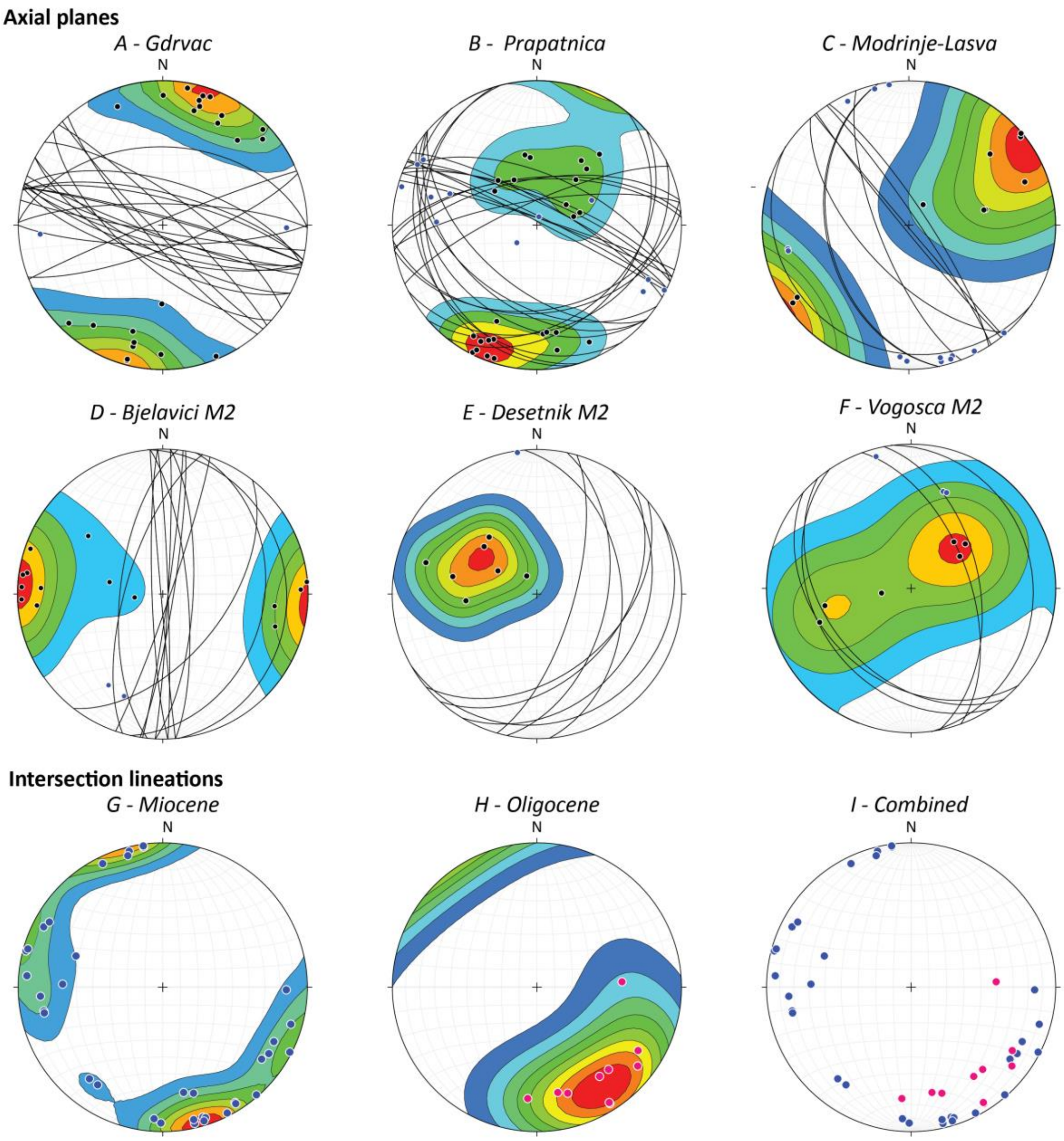


Figure 7: The axial planes and their poles plotted, the coloured contours plotted indicate the highest concentration of poles and thus indicate the average maximum shortening direction observed in different areas of the basin (see figure 6 for localities). ***A,B,C,D,E,F*** *Stereoplots of the axial planes and their poles (black dots).* ***G,*** *Stereoplot of Miocene intersection lineations. Coloured contours indicate grouping of intersection lineations, perpendicular to this lies the maximum shortening direction* ***H,*** *Stereoplot of Oligocene intersection lineations (magenta dots).* ***I,*** *Stereoplot of Miocene and Oligocene intersection lineations combined.*

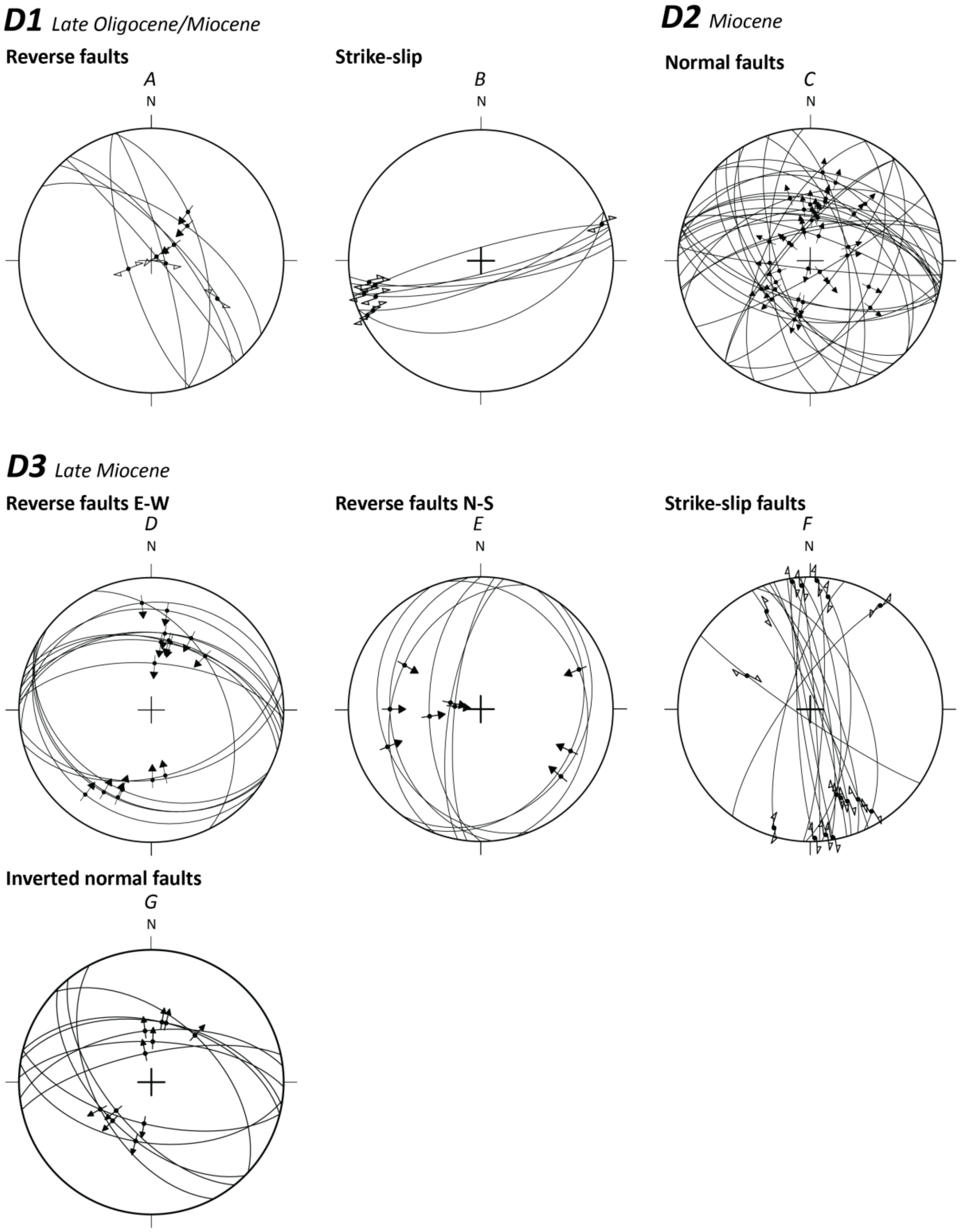


Figure 8: ***A,*** *Stereoplot of D1 Late Oligocene - Early Miocene reverse faults.* ***B,*** *Stereoplot of D1 Late Oligocene - Early Miocene strike-slip faults.* ***C,*** *Stereoplot of D2 Miocene normal faults.* ***D,*** *Stereoplot of D3 Late Miocene E-W reverse faults.* ***E,*** *Stereoplot of D3 Late Miocene N-S reverse faults.* ***F,*** *Stereoplot of D3 Late Miocene strike-slip faults.* ***G,*** *Stereoplot of D3 Late Miocene inverted normal faults.*

D1 : Late Oligocene - Early Miocene compression

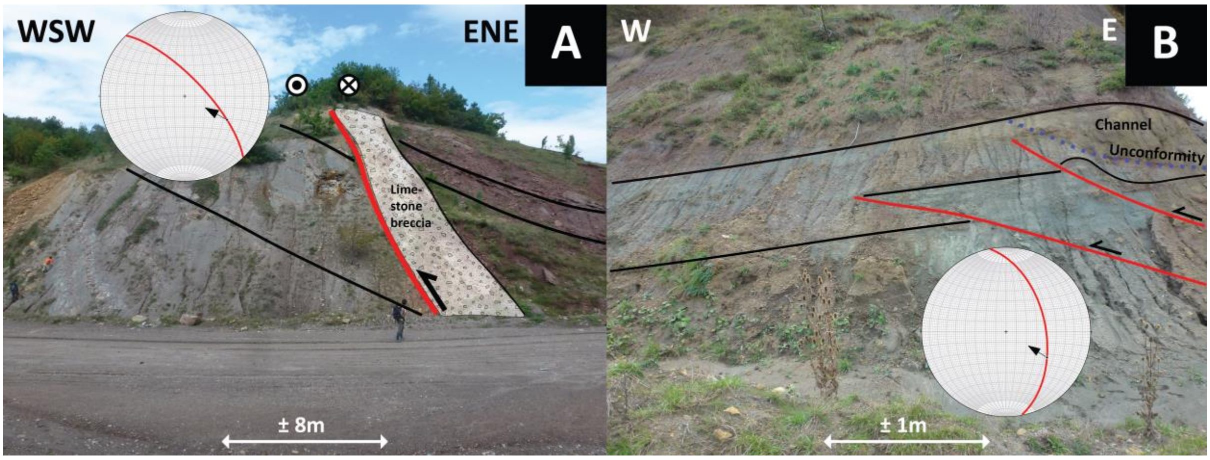


Figure 9: ***A,*** *A thrust with sinistral component (direction top WSW) placing syn-kinematic red-beds on top of lacustrine limestones which are strongly brecciated in the fault zone (age Oligocene/lower Miocene).* ***B,*** *Two thrusts (orientation bottom one) piggyback style, displacing Oligocene/lower Miocene silty marlstones with some sandier intervals (which show dragfolding), covered by more siltstone, marls and fluvial sandstone/conglomerate channels.*

Contractional structures affecting strata of different ages were observed, thrusts were predominantly found in the Miocene aged parts of the basin, however these are not associated with D1. The Late Oligocene - Early Miocene age sediments were affected by an earlier compressional phase (figure 9A,B). Figure 9A shows a high-angle thrust with sinistral component (top WNW) in Oligocene strata with a syn-kinematic wedge of red beds onlapping on to the fault, thinning in the hanging wall of the thrust. Indicating compressional deformation during the early stages of basin formation. Other reverse structures are buried by Oligocene/lower Miocene sediments, further indicating compression at the start of basin development (figure 9B).

The orientation of reverse faults affecting the Oligocene strata is roughly NW-SE, mostly top SW direction of transport (figure 8A). Various have a strong strike-slip component, likely induced by the younger inversion phase.

Dextral strike-slip faults striking WSW-ENE are found cutting Late Oligocene - Early Miocene strata (figure 8B). They differ from a group of N-S striking strike-slip faults associated with D3 (figure 8F). Furthermore they can not be explained as antithetic and synthetic strike-slip faults created by the same deformation phase, as both groups are dextral. Therefore these are interpreted as Oligocene age strike-slip faults that formed due to the compressive regime during the early stages of basin formation. These could have formed as tear faults in response to the NE-SW shortening phase that created the NW-SE striking reverse faults.

The intersection lineations derived from the axial surface cleavage in these oldest basin sediments on average plunges towards the SE, dipping at angles of 5-30° (figure 7H). Further substantiating a NE-SW oriented compressional phase at the time of basin opening. The dip of the intersection lineations could indicate that they were rotated from horizontal during the deformation phases that followed.

Normal faulting is also observed within the Late Oligocene - Early Miocene sediments, yet these are not flanked by syn-kinematic sediments or buried by the oldest basin sediments. Thus these are interpreted to have formed during the later D2 deformation event.

D2: Early - Middle Miocene extension

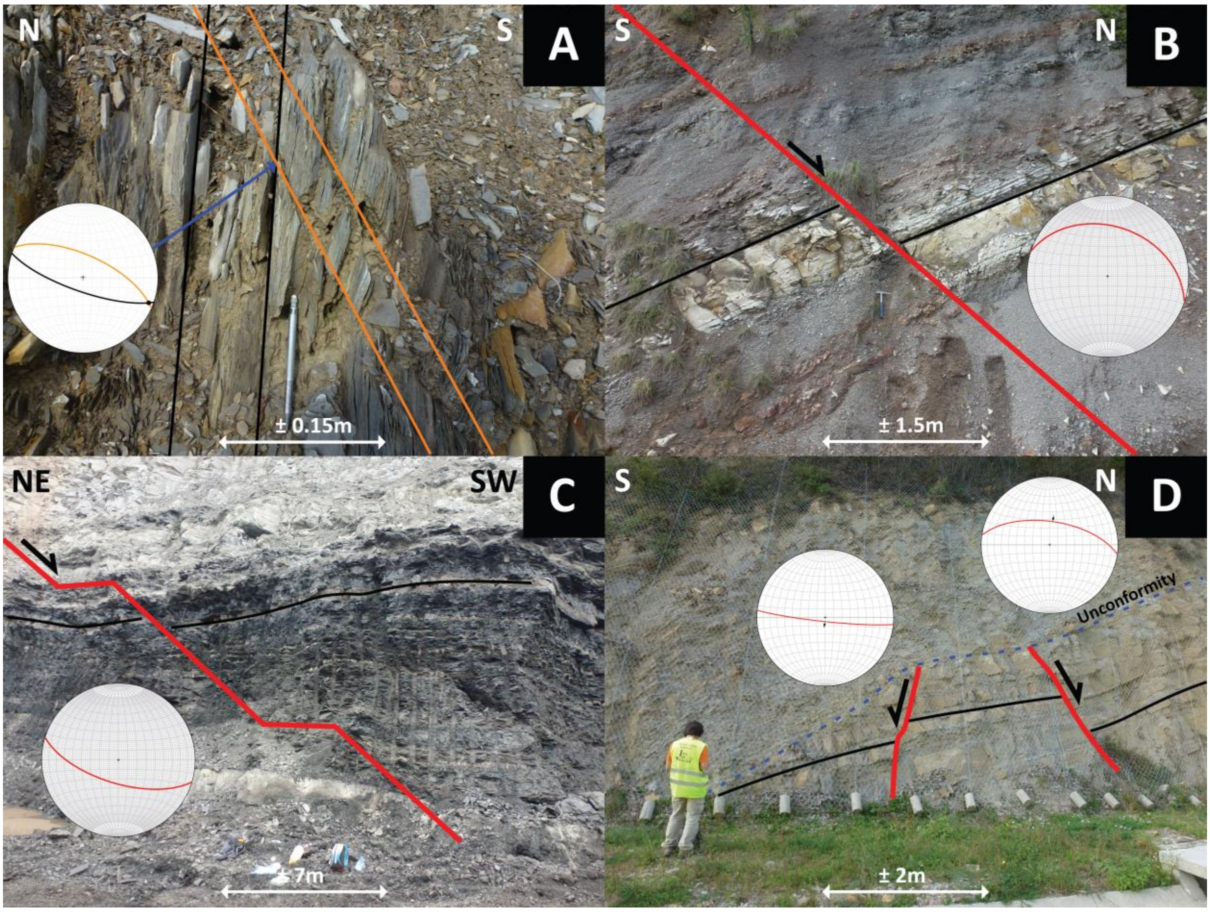


*Figure 10: **A**, The cleavage (orange) intersecting the bedding (black), the line of intersection gives the intersection lineation. **B,** A "domino-style" normal fault, displacing Oligocene limestone and silt/marl beds, offset ±0.8m. **C,** Stepped normal fault through lower Miocene coal beds, offset ±1m. **D,** Two syn-depositional normal faults displacing middle Miocene sediments, offset ±0.3m.*

Normal faults are found cross-cutting basin fill of all ages, some large listric normal faults with >10m offsets and syn-kinematic sediment wedges, others with much smaller centimeter scale offsets and no clear syn-kinematic character (figure 10B,C,D). Faults with large offsets are mostly observed in the NW (south of Zenica) and SE (west of Sarajevo) extent of middle Miocene sediments.The ones with smaller offsets are found throughout the basin.
The extension creating the normal faults occurred syn-depositional, some normal faults are cut by erosional unconformities while other propagate through it (figure 10D).
Across many of the fault planes strata of different thicknesses and competence are juxtaposed across the faultplane (i.e. the limestones and silt/marlstone in figure 10B).

The normal fault plane in some instances shows a ramp-flat-ramp geometry (figure 10C). Dipping horizontally in incompetent strata such as marlstone and running at higher angles through more competent lithologies.
Generally the normal faults strike WNW-ESE, NW-SE, and some NE-SW (figure 8C). The latter NE-SW fault group generally truncate the Late Oligocene - Early Miocene sediments.
Not all normal faults fit the standard 60° dip after backtilting, this could result from the dip changing along a listric faultplane or possibly negative reactivation of older low angle reverse faults.

D3: Late Miocene compression/inversion

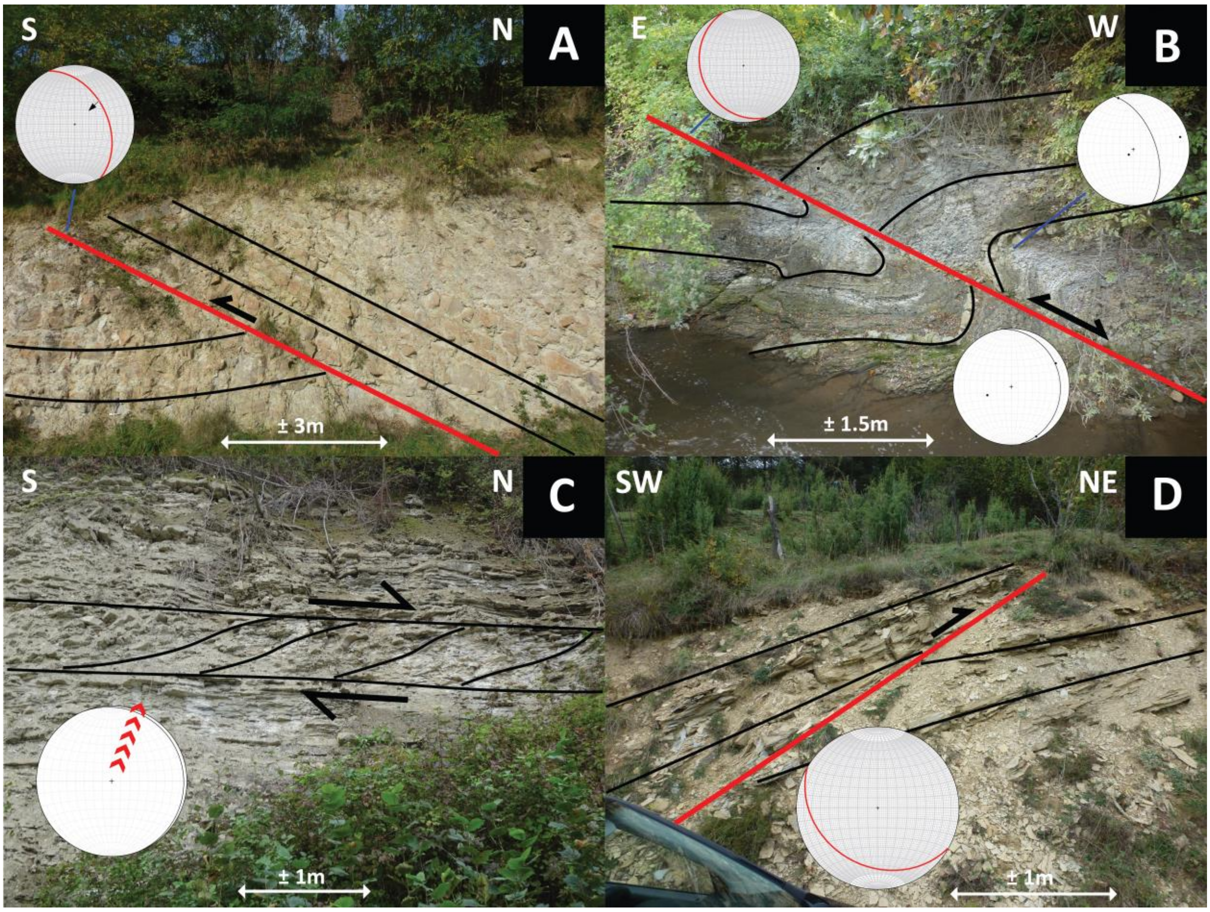


*Figure 11: **A,** A thrust (transport top SE) cutting through Late Oligocene - Early Miocene limestones, conglomerates and sandstones. Part of the large thrust zone in the centre of the basin. **B,** An inverted growth fault, normal displacement of bottom beds but reverse offset of top beds and reverse dragfolding, displacing M2 marlstone interbedded with sandstones. **C,** A layer parallel shearzone, a duplex structure, roof and floor thrust, and S-shaped horses through marlstone interbedded with sandstone (transport top NNE). **D,** A small reverse fault (transport top NE) cutting through M2 turbiditic sandstones and marls.*

Reverse faults found displacing Miocene lithologies do not show evidence of syn-kinematic deposition of sediments, which we do observe at reverse faults formed during the earlier D1 stage. Low angle reverse faults with offsets ranging from centimeters to meters are common (figure 11A,D), with transport top NNE and SW.
Décollements allowing large layer-parallel offsets are found in the incompetent turbiditic alternations of silts, marls and sandstones (figure 11C), this example showing top NNE transport. Where the lithologies are more competent the faults tend to ramp up (figure 11A,D).
Reverse faults created by the D3 phase strike roughly E-W in the centre of the basin (Grdvac, Prapatnica areas), and in the NW extent of the basin (Modrinje-Lasva area) their strike rotates towards NW-SE, closer to the trend of the normal faults (figure 8D). The NE vergence of folding in the Modrinje-Lasva area can be directly linked to the reverse structures with a top-NE direction of transport. Direction of transport ranges from top N, top S, top SW, top NE (see figure 8D), with a predominance of transport towards the S. Perhaps indicating a group of reverse faults influenced more by the NW-SE structural grain of the basin and a group that was affected less by it.

Normal faults created during D2 are also inverted by the inversion phase in the Modrinje-Lasva and Vogosca areas away from the central thrust (figure 11B). These can be identified by normal offset of the lower beds but reverse offset of the upper beds, and sometimes reverse drag folding of the layers. They are not completely inverted, as they still display a normal offset. These inverted normal faults (figure 8G) all roughly strike WNW-NW/ESE-SE. Associated dragfolds are NE and SW-vergent due the NW-SE strike of the normal fault inverted (figure 7F).

A large reverse fault cuts through the middle of the basin, we observed superposition of older strata over younger, and dragfolding (figure 12). The Late Oligocene - Early Miocene hanging wall limestones are thrusted on top of middle Miocene turbidites in the footwall, forming a footwall drag fold (figure 12B) with a SSW vergence. Direction of transport on the fault is top-S/SSW
Fault breccia with a shaly matrix is present between the hanging wall and footwall, forming an upto 200m wide zone in places along the fault strike. The fault breccia contains Oligocene/Miocene rocks as well a metamorphosed basement rocks. The superposition of Oligocene-Early Miocene rocks onto Middle Miocene turbidites represents a vertical omission of minimally 500m upto 1250m of stratigraphy.
South of the main thrust outcrops of Triassic metamorphosed limestone basement rocks are found on top of the M2,3 basin fill. Therefore, the main thrust must run as deep as the basement rocks to have brought these to the surface. The inherited orogenic contact visible of the gravity map lies below this large reverse fault zone in the basin sediments (figure 3), indicating its reactivation during the inversion deformation.

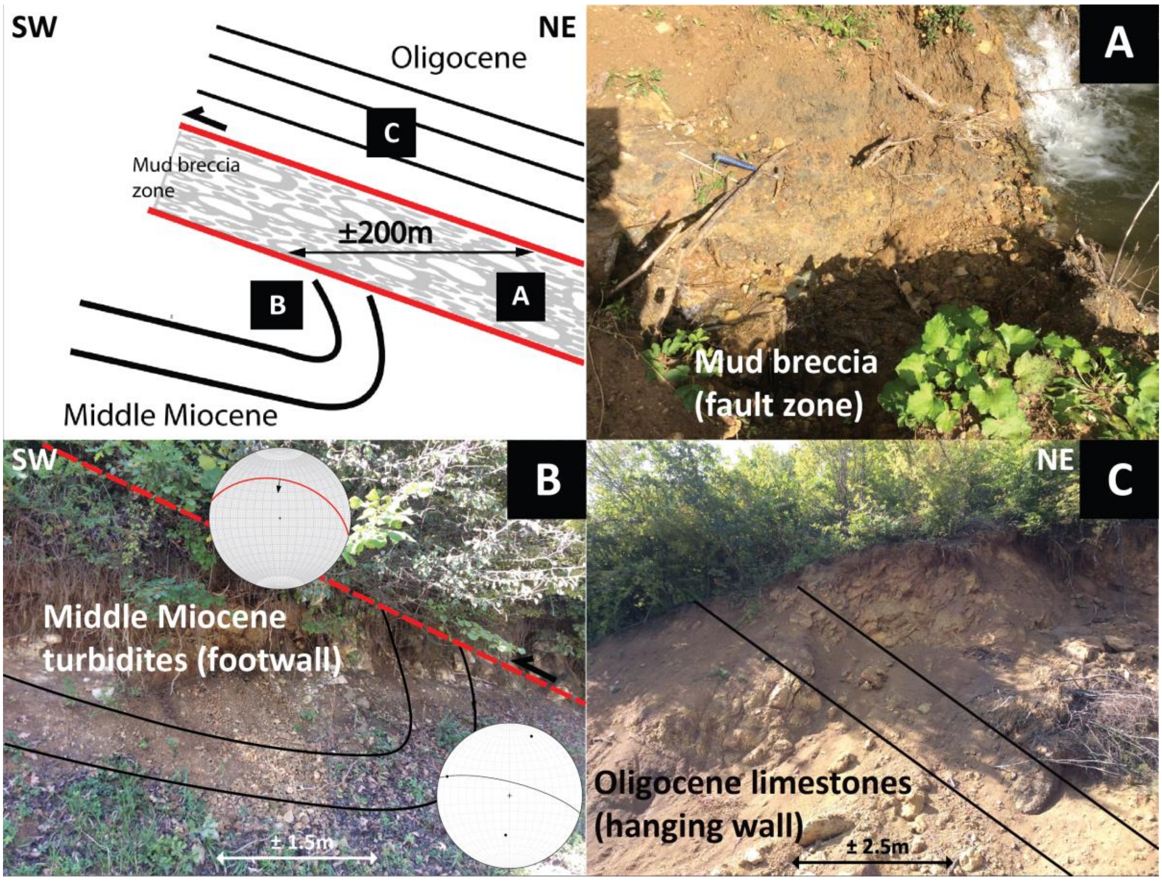


*Figure 12: The clearest outcrop of the large thrust fault striking roughly E-W through the middle of the basin. Oligocene limestones **C** are superposed onto middle Miocene **B** turbidites in the footwall, with a large zone of mud breccia **A** inbetween.*

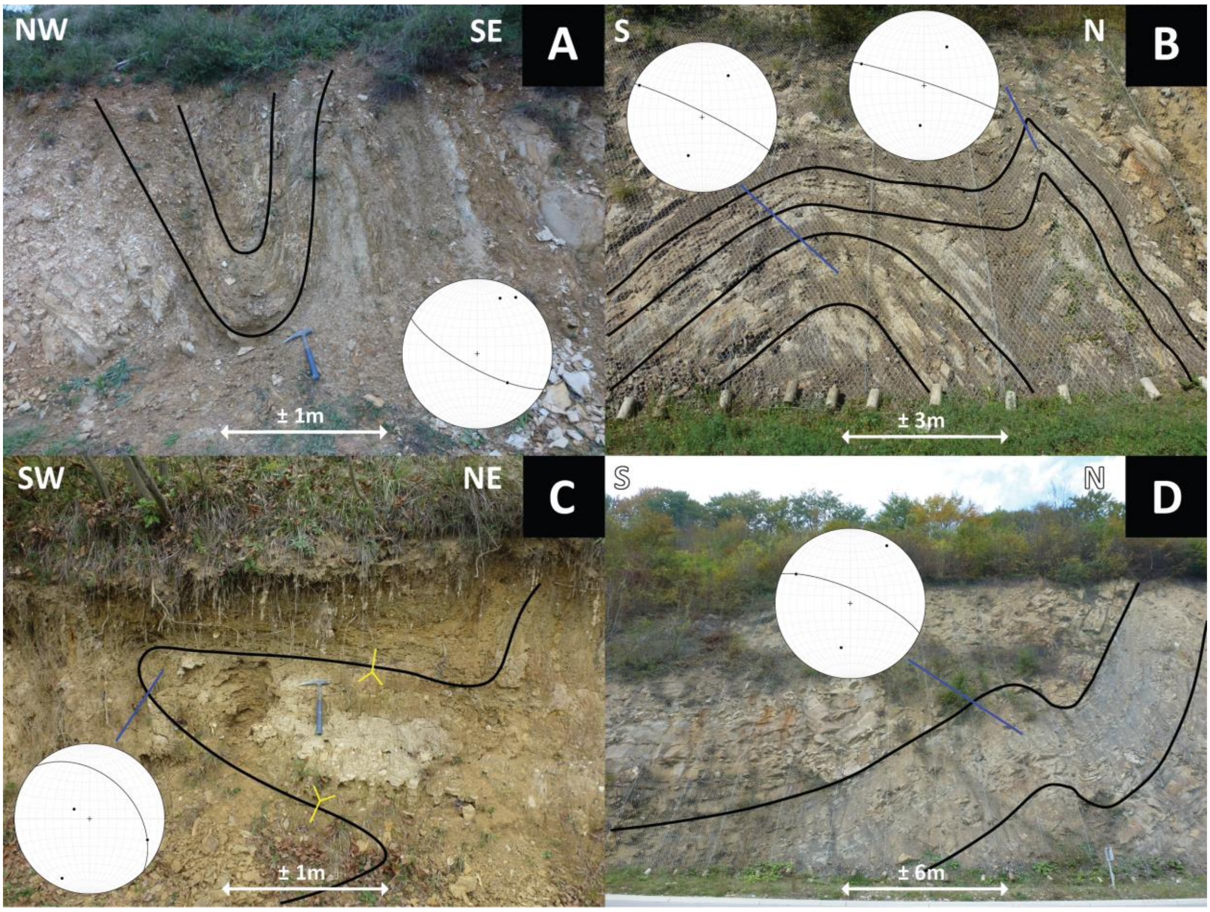


Figure 13: ***A,*** *A tight to isoclinal syncline with a slight vergence to the NE.* ***B,*** *An open slightly assymetrical anticline with an almost symmetrical chevron fold which formed in the younger layers in the right (N) limb of the fold.* ***C,*** *A strongly assymetrical S-shape tight fold. (Yellow Y indicates younging direction)* ***D,*** *A Z-shape parasitic fold. (Stereoplots: line= axial plane, dots= poles to bedding, and hinge when on axial plane)*

Folding has affected most of the basin sediments, especially the middle Miocene (M2;M2,3) deposits in the central part of the basin. Long wavelenght (up to 1km) open folds affect the more competent lithologies such as the Lasva conglomerates. Much tighter folds are found in the incompetent turbiditic lithologies, where thin sandstone layers and marls alternate (figure 13A). Chevron folds indicate the proximity of detachments located below them (figure 13B)

Assymetric folds are also common, concentrated around the area north and south of the large reverse fault striking roughly E-W in the middle of the basin (figure 13C). Parasitic folds are mainly found in the incompetent marls and sandstones. Fault-propagation folding is visible along the whole strike of the main E-W striking thrust in the centre of the basin (figure 13D).

The folding in the Grdvac area (S of Kakanj, E of the river, including Visoko area) strikes WNW-ESE, are N and S vergent (figure 7A). The closer they are to reverse faults the more asymmetrical they become. The axial planes of the folds indicate they are not extremely asymmetric as most are sub-vertical (see figure 7A). Approximately as many fold are slightly N and S vergent.
The folding in the Prapatnica area (area SW of Kakanj), is oriented WNW-ESE and rotates towards NW-SE when they are more proximal to the basin margin. These folds are assymetrical and N-vergent as their axial planes dip much shallower (figure 7B). The N-vergence of folding contradicts the dominant S-vergent reverse faults.

Moving away from the central thrust zone we find open symmetrically folded conglomerates in the Modrinje-Lasva area (from Zenica straight to the south, and west of this line), which is distinctly different compared to the central areas, the axial planes strike NW-SE similar to the orientation of normal faults in this area (figure 7C). There are some strongly assymetrical folds in finer-grained lithologies close the reverse faults, but also gentle open folds in thick bedded competent conglomerates & sandstones. Vergence of the folding is NE (figure 7C).

The intersection lineations in Miocene strata indicates two directions of compression, roughly N-S and E-W (7G). The N-S compression is linked to the D3 inversion phase, but evidence for a E-W oriented phase was not found elsewhere in the basin. These N-S striking intersection lineations are located in the Desetnik and Bjelavici localities in the hanging wall of the large thrust, therefore we assume these lineations are rotated lineations due to local variability of structures (figure 15).

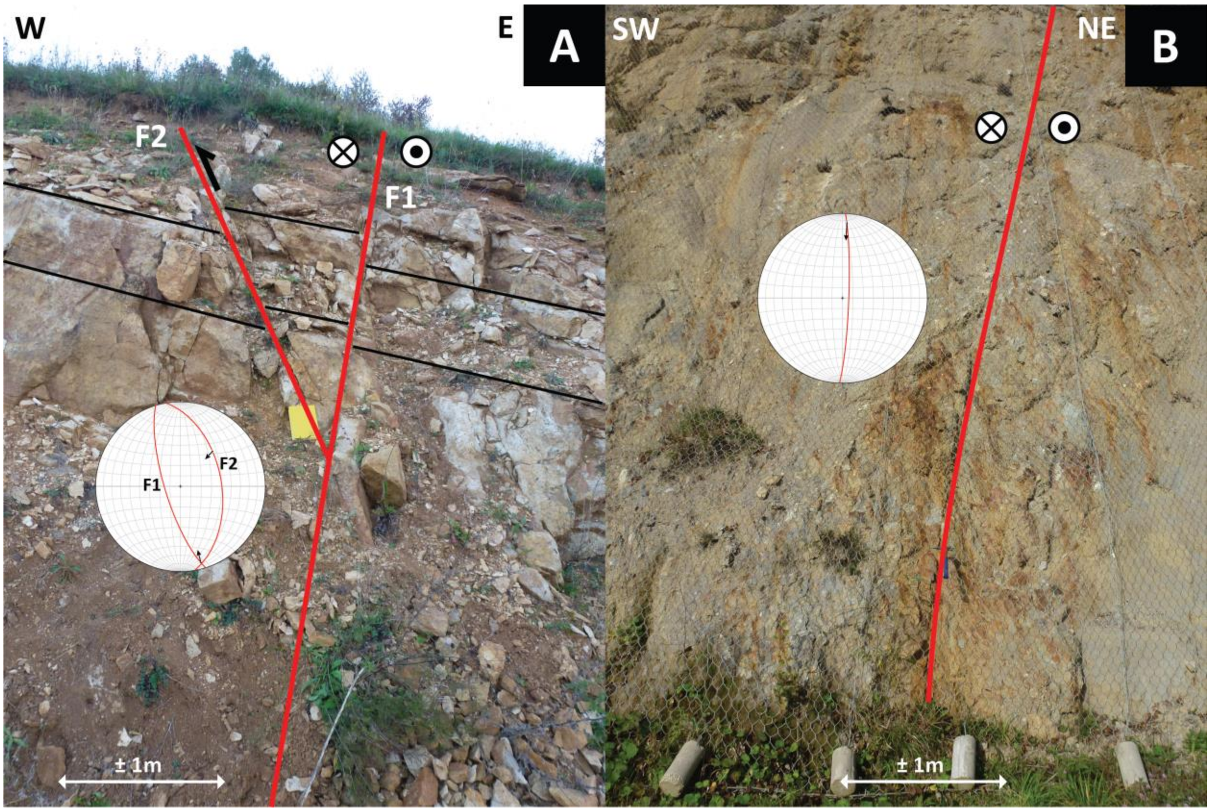


Figure 14: ***A,*** *A dextral strike-slip fault with a positive flower structure cutting through Late Oligocene - Early Miocene (Ol,M1) lacustrine limestones.* ***B,*** *A dextral strike-slip fault displacing middle Miocene (M2) conglomerates and sandstones.*

Strike-slip faults are found throughout the basin (figure 14). Most show dextral displacement, some create a positive flower structure (figure 14A). Closer to the large thrust in the centre of the basin, several dextral tear faults have been formed (figure 14B). Which accommodate for the differential movement of segments making up the thrust sheet. These strike-slip faults show a more predominant N-S orientation and are mostly dextral, with a few striking NW-SE & NE-SW (figure 8F).

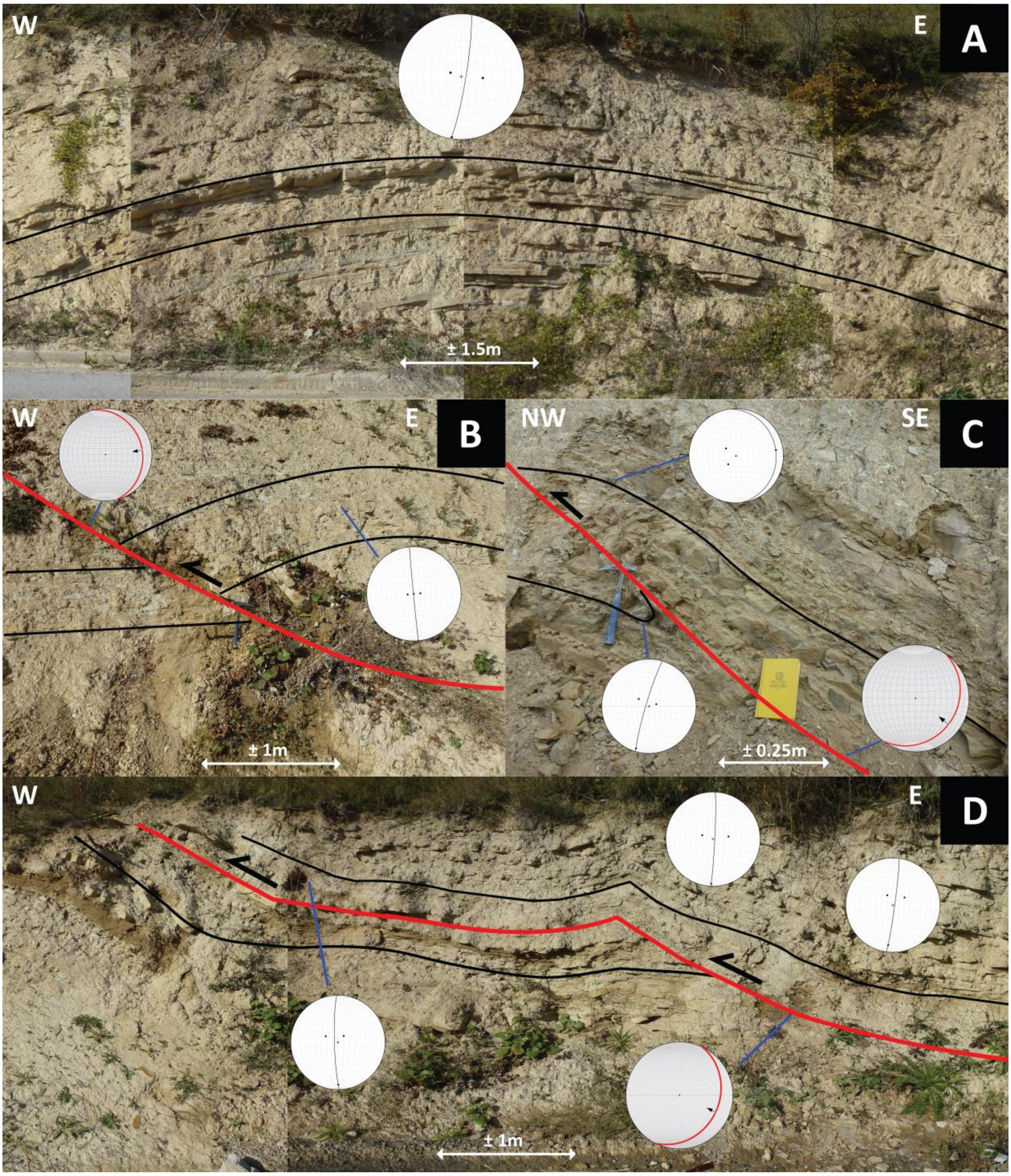


Figure 15: ***A,*** *Gentle fold of M2 turbitic bed.* ***B,*** *Low angle reserve fault and symmetric hangingwall drag fold in M2 lithology.* ***C,*** *Low angle reverse fault and foot/hangingwall dragfolds cutting M2.* ***D,*** *Ramp-flat-ramp reverse fault cutting M2 lithology.*

Apart from the dominant group of ~E-W striking inversion deformation structures a group of relatively minor N-S striking folds and faults was also observed, suggesting an E-W oriented shortening event, however no other expressions of such an event are observed outside the Desetnik and Bjelavici areas in the hanging wall of the thrust (figure 7D,E & 8E). Due to this localized nature of the anamalous inversion structures we propose another explanation for them than an E-W oriented compressional phase. The tear faults created in the hanging wall during thrusting rotated originally E-W striking structures to their current N-S strike.

The type of structures ranges from gentle folds (figure 16A) to small reverse faults with associated folding (figure 15B,C,D). The reverse faults show ramp-flat-ramp geometries (figure 15D), running horizontal along incompetent thinly bedded marlstones and ramping up through more competent sandstones.

The folds in the Bjelavici area range from symmetrical to strongly assymetric when directly associated with faulting, W-vergent (figure 7D). In the Desetnik area they are all strongly asymetrical, and NW/W-vergent (7E).

Discussion

The deformation stages that affected the Sarajevo-Zenica basin are discussed chronologically to define the inherited basin architecture and how they affected the inversion deformation.

Pre-inversion deformation events

D1: Compression, start of basin formation

The first cycle of deposition in the Sarajevo-Zenica basin started in the late Oligocene/early Miocene, which was recorded sediments deposited unconformably over the Bosnian Flysch basement. Which are located along the northern half of the NE basin margin (figure 2,4).
The NW-SE strike of the Late Oligocene - Early Miocene reverse faults coincides with the strike of the Dinaridic orogen. Implying a link with the older Late Cretaceous/Eocene thrusting that uplifted the Dinarides (Pamic et al., 1998; Pamic et al., 2002; Schmid et al., 2008). The inherited weak contacts from this thrusting event are prone to serve as a detachment horizon and are likely to have accommodated the Late Oligocene - Early Miocene Miocene thrusting.
Additionally the intersection lineations recorded in this package further support a NE-SW compression (figure 7H).
Syn-kinematic sediments and buried thrust faults cutting Late Oligocene - Early Miocene strata indicate the onset of deposition in the basin started during a contractional regime. Which formed a foredeep basin in the footwall unconformably over the Mesozoic cover of the Paleozoic metamorphic complex of the Mid-Bosnian schist mountains in front of the overriding Bosnian flysch hanging-wall. Basin formation due to contraction is common in intra-montane settings, either foredeep basins in the footwall (Lucente, 2004) or piggyback/wedge-top basins on top of the overriding hanging-wall (Korbar, 2009).
Other research suggests that strike-slip faulting penetrating deeply into the orogen initiated basin formation as a pull-apart basin (Hrvatovic, 2005). We observed strike-slip faults striking WSW-ENE in the oldest basin sediments (figure 8B & 14A), and strike-slip components in the movement of reverse faults (figure 9A). However the lack of syn-kinematic deposition along these strike-slip faults, favours a foredeep model for the basin initiation phase. The strike-slip faults with WSW-ENE strike could have formed in response to the NE-SW thrusting acting as transfer faults. The N-S striking strike-slip faults (figure 7F) also found in the Late Oligocene - Early Miocene strata are not related to this first basin deformation stage and were formed later during inversion.

The dating of the Late Oligocene - Early Miocene deposits in the Sarajevo-Zenica basin is not certain due to lack of good magnetostratigraphic dating. However it is clear these syn-kinematic sediments were deposited before the extensional opening of the DLS basins dated at ±18Ma.
Most other research suggests shortening in the Central Dinarides is timed to have occurred during Eocene times and was halted at the Eocene-Oligocene boundary when the subducted Adriatic slab got detached (Schmid et al., 2008). Our results imply that shortening continued until Late Oligocene - Early Miocene. This is supported by Late Oligocene - Early Miocene NE-SW contraction that was observed in a study of the East Bosnian Durmitor unit SW of our study area (Ilić & Neubauer, 2005).

D2: Miocene extension

After the initial Late Oligocene - Early Miocene foredeep basin development, large packages of turbiditic sediments and conglomerates were deposited as the basin opened further to the SW during the Miocene (figure 2).

Large packages of sediments were deposited syn-kinematically during major extension. Normal faults, some listric, are abundant along the whole Miocene extent of the SW basin margin. The Late Oligocene - Early Miocene strata are also affected by this extensional phase, lacking syn-kinematic sediments. Some normal faults are buried by subsequent Miocene sedimentation while others continue in the younger sediments, suggesting continued extension in the basin throughout the Miocene (figure 10B,C,D). Younging of the sediments towards the Busovača fault at the SW basin margin suggests the normal faults migrated towards the footwall as extension continued, creating a half-graben basin geometry (figure 5,16,17).

The normal faults strike approximately NW-SE with some striking in the range of NW-SE to NE-SW. These normal faults with strikes conflicting the main trend may have been rotated by the later inversion of the basin, which affected some areas more strongly than others.

The amount of offset and the listric geometry of the normal fault observed make it probable that they connect to a detachment horizon inherited from the Bosnian Flysch basement rocks (figure 3,16,17).

It is broadly proposed that the opening of the Pannonian basin at the NE margin of the Dinarides triggered the extensional phase in the DLS basins (Horvath et al., 2015). Which is supported by paleomagnetic dating of other DLS basin sediments which matches the age of this Pannonian extensional phase (de Leeuw et al., 2012). The Pannonian basin is located far from the Sarajevo-Zenica basin but it could still trigger the DLS basin extension. Thickening of the crust due to the uplift of the Dinarides created a high amount of potential energy and the Pannonian basin opening could therefore trigger a post-orogenic collapse of the Dinarides, leading to the opening of the DLS basins (Dewey et al., 1993).

This extensional phase created a much larger accommodation space than the contractional event at the onset of basin formation and formed NW-SE trending fault blocks of thick competent conglomerate and sandstone beds. This had a very profound effect on the structures formed during the later inversion phase that affected the basin which will be discussed in the next chapter.

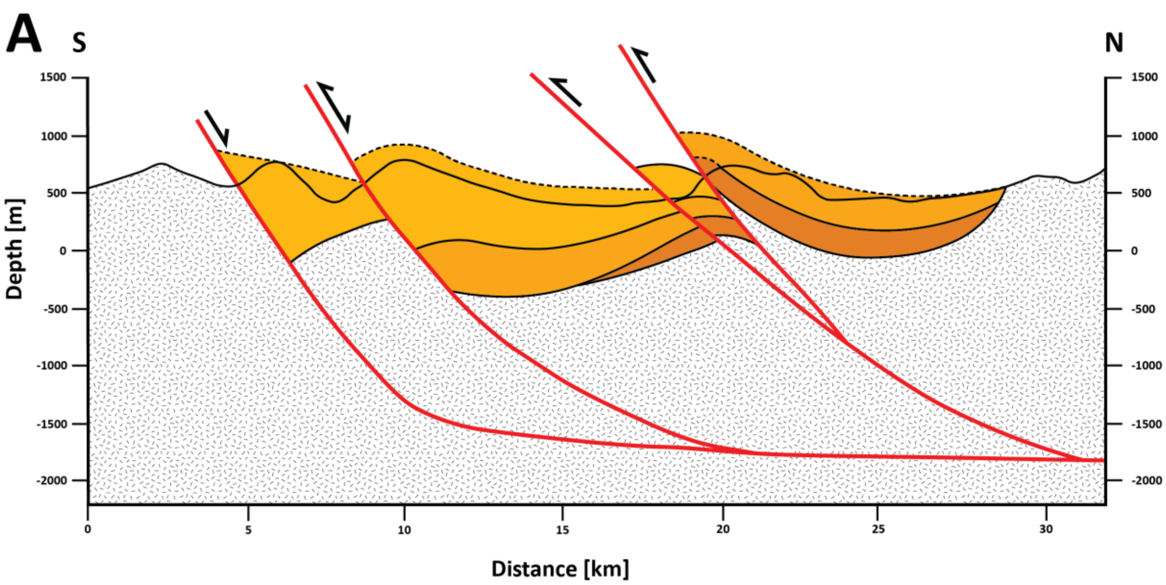


Figure 16: Cross-section A, N-S (see figure 6 for location and legend).

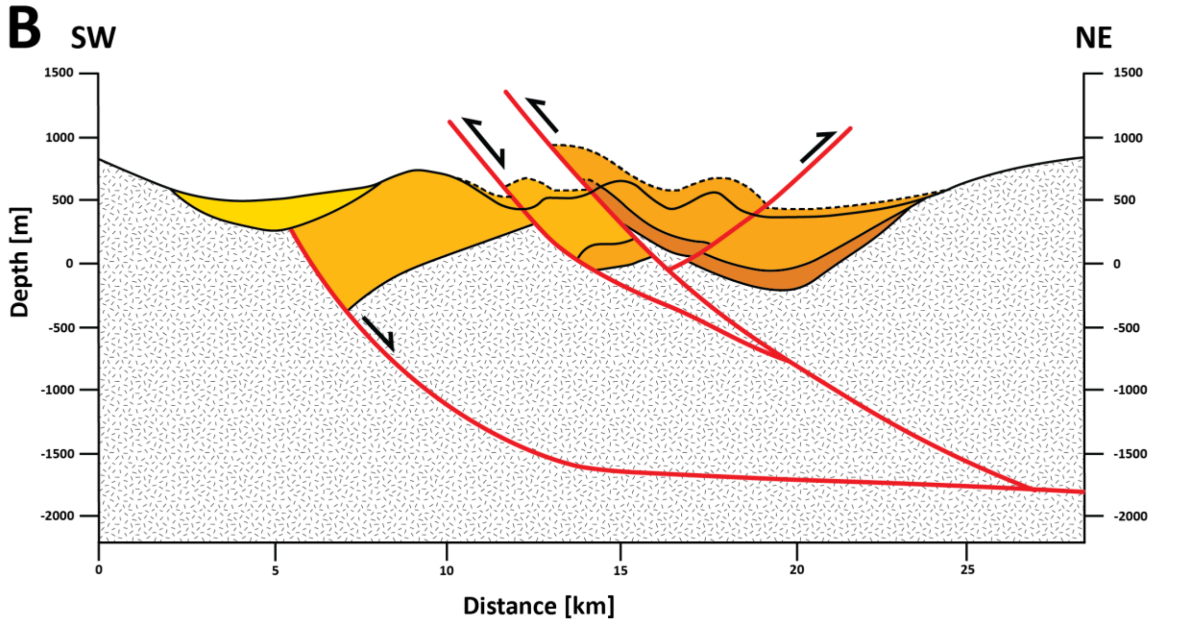


Figure 17: Cross-section B, NE-SW (see figure 6 for location and legend).

D3: Inversion - The effect of inherited structures and rheological stratification

After the basin fill was deposited at the end of the Miocene, the Sarajevo-Zenica basin was inverted by a N-S directed shortening event that affected the Dinarides from late Miocene to Pliocene (~8Ma) times. This likely still affects the basin until present (Ustaszewski et al., 2014; Ustaszewski et al., 2010; Hrvatović, 2006; Tari & Pamic, 1998; Tomljenović & Csontos, 2001). The N-S inversion is oriented oblique to the NW-SE structural trend of the basin inherited from the preceding deformation stages.

This inversion created folds, thrusts and strike-slip faults throughout the basin (figure 5).

The response of the basin fill to this phase of compression varies throughout the basin. The partitioning of the contractional strain caused by inversion was significantly influenced by the inherited internal geometry of the basin. Similar strain partitioning due to inherited basin geometries of a larger scale has been observed previously in fold-and-thrust belts (Flo et al., 1997). The middle of the basin is most strongly affected by inversion as most folding and reverse faults are concentrated in this zone. The main thrust zone striking WNW-ESE cuts the centre of the basin, direction top SSW, and is associated with a vertical omission of minimally 500m upto 1250m of stratigraphy. The throw along this fault zone varies, as in some locations along its strike basement is found thrusted onto the middle Miocene strata which would translate to an even larger vertical omission in the range of 1250 – 2000m. The largest throw along this fault is likely where it makes a slight bend, and due to the slightly sinistral component the fault throw in this bend would have been largest. Backthrusts direction top-N/NE are present in the hangingwall of the main thrust towards the NE where finer and incompetent lithologies make up the thrust sheet. The formation of backthrusts in rheologically weaker areas of the thrust hangingwall has been demonstrated in analog models (Corrado et al., 1998).

The exhumation of Triassic limestones by this fault exhibits that this structure prolongates to the basement décollements. This basement décollement is located somewhere between Mid Bosnian Schist mountains and the Bosnian flysch (figure 3), and was first established during the thrusting and uplifting of the Dinarides. The same contact was subsequently inverted negatively as a low-angle extension décollement during the D2 extensional phase, after which it was positively inverted due to the D3 oblique inversion compression. Hence this inherited décollement has played an integral role in the successive stages of deformation the area has undergone from the Late Cretaceous-Eocene till present (figure 18).

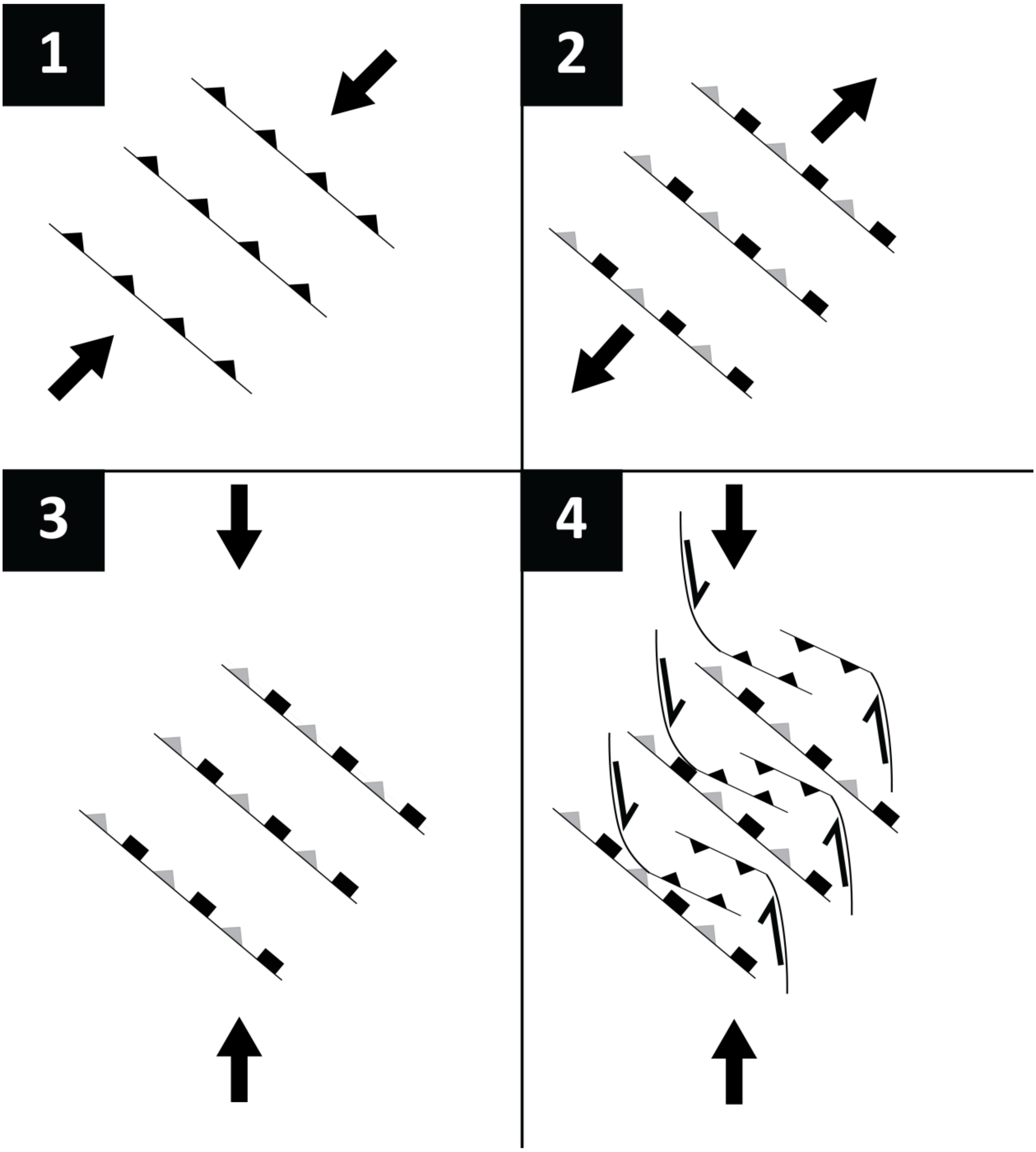


*Figure 18: **1,** Thrusting of the Dinarides nappes and formation of the Dinarides nappe stack. **2,** Negative inversion of the inherited reverse detachments from **1**, extension creates accommodation space which is filled with sediments. **3**, The system is put under oblique compression. **4,** Positive inversion occurs, reactivating inherited contacts and forming new thrust faults and dextral strike-slip faults through the basin fill.*

Folding in this central zone associated with the reverse faulting is oriented ~WNW-ESE. The orientation of deformation around the central thrust closer to the SW basin margin rotates towards NW-SE, which is an effect of the increased amount of coarser clastics that are located along the SW margin. These more competent rheologies concentrate the deformation better than the finer grained incompetent lithologies such as the turbiditic beds found in the basin centre, which increase towards the NE margin (Andric et al., 2017). Another effect of this rheologically strong unit along the margin is demonstrated by the assymetry of folding in the Prapatnica area, which is much more assymetrical compared to the Grdvac area located further away from the basin margin. Where the reverse faults encounter rheologically weaker lithologies faulting follows shallow detachments in the basin fill, the resulting folding is more symmetrical.

The northern and southern extent of the basin away from the central zone are less extremely affected by inversion and are deformed by minor reverse faults, inverted normal faults, and folds. A rotation in the strike of folding between the Grdvac and Prapatnica fault zone in the centre of the basin and the Modrinje-Lasva area is another example of how the type of inversion deformation is heterogeneous on basin scale. The NW-SE striking normal faults located close to the basin margin formed buttresses which concentrated the deformation and created the average NW-SE orientation of reverse faults and folds in this area. This agrees with analog modelling of obliquely inverted half-grabens where inversion only inverts the inherited normal faults when they are proximal to the basin margin. (Yagupsky et al., 2008; Scisciani et al., 2009).

The normal faults in the centre of the basin did not concentrate the inversion deformation in the same fashion as we observed in the NW extent of the basin. They formed oblique ramps oriented NW-SE, obliquely to the N-S compression with created the ~E-W striking reverse faulting and folding in this area (figure 19). This created numerous N-S striking tear faults in the hanging wall, to accommodate for the differential slip of the hanging wall segments over the oblique ramps. The formation of such tear faults parallel to shortening direction has been observed in analog modelling of obliquely inverted grabens (Brun et al., 1996)
The reverse faults in the central zone follow a ramp-flat-ramp geometry because of the alternation of competent coarse clastics such as conglomerates and sandstones and incompetent finer lithologies like thinly bedded marl and sandstone (figure 20). Analog modelling with sand-box models have demonstrated that the thrusts tend to cut shallow through the half-graben fill when there are suitable incompetent detachment horizons and ramp up steeply through competent horizons when the effectiveness of the detachments is reduced (Rowan et al., 2000).

Heterogeneity of inversion deformation is also apparent in the hanging wall of the main central thrust fault where the strike of some small-scale structures is N-S. Lack of further indications of a E-W oriented shortening that could have formed these structures, suggests strain partitioning to have caused these local variations in inversion deformation style. We interpret this rotation in structural orientation as an effect of the tear faulting in the hanging wall resulting from the oblique ramp the thrust sheet moves over. Lateral movement on these tear faults rotated segments of the hanging wall containing the initially ~E-W oriented deformation structures towards N-S.

The asymmetry of the basin created an overall rheological stratification where the competence of the basin decreases towards the NE basin margin. This created a partitioning of the inversion strain, towards to SW margin the competent basin sediments were deformed mainly by the reactivation of the inherited extensional structures. While the inversion strain created new structures in the less competent basin fill when moving towards the NE margin (figure 21).

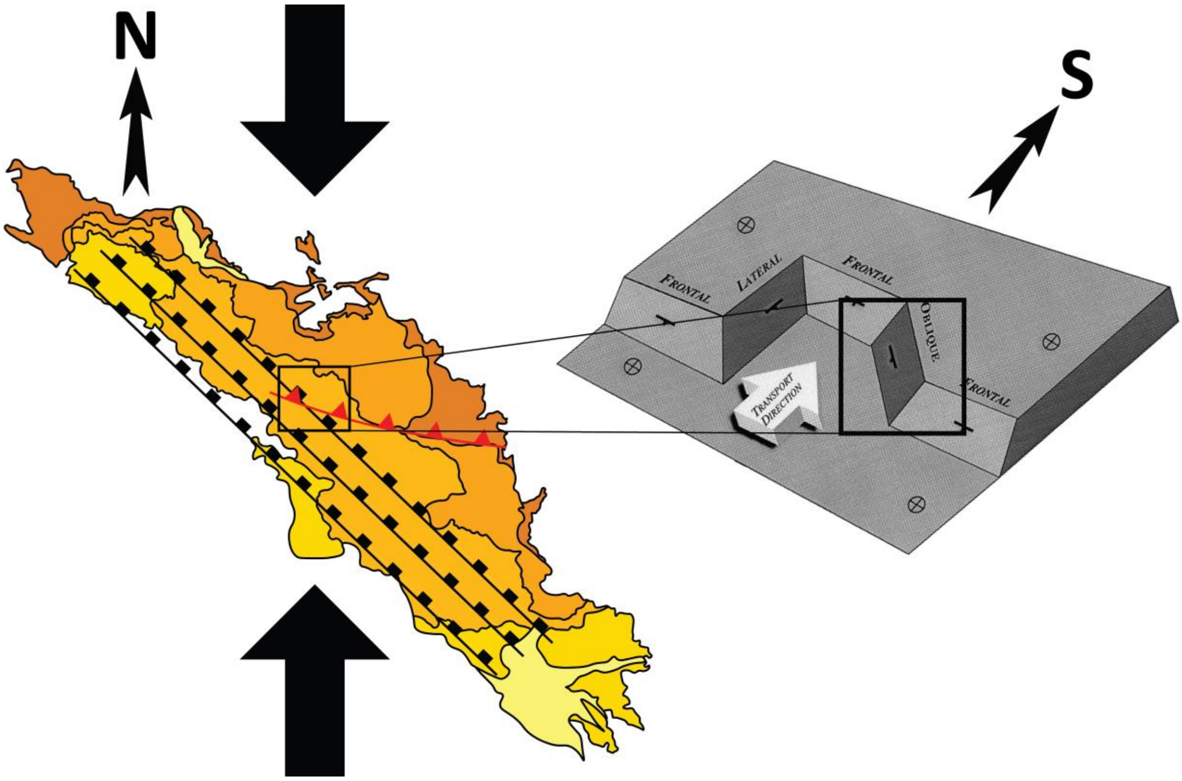


Figure 19: Diagram illustrating the oblique thrust ramps formed by the normal faults. (Mind the different orientations of the map and diagram)(Adapted from Wilkerson et al., 2002).

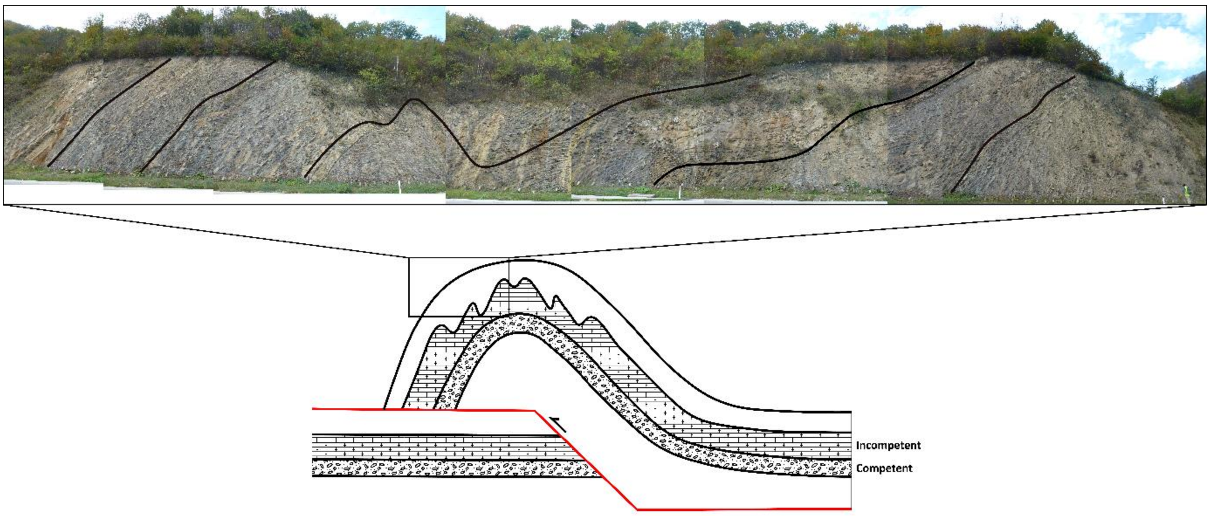


Figure 20: Highway section fault-propagation folding due to ramp-flat-ramp geometry of faulting.

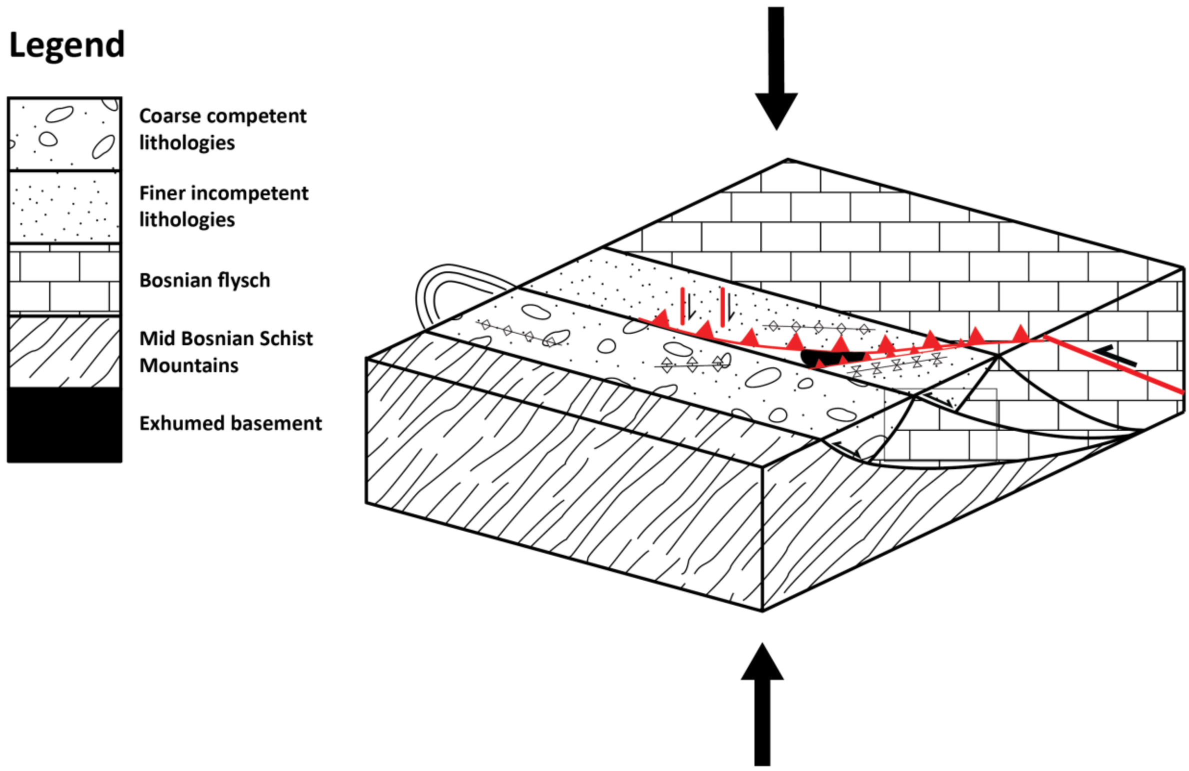


Figure 21: Simplified 3D representation of basin as two units, one competent along the SW margin, one incompetent along the NE margin. The competent unit along the SW margin is mainly deformed by inherited structures creating folds striking NW-SE, the incompetent unit along the NE margin is deformed by newly formed E-W striking thrusts and folding.

Conclusions

The mapping of structures in Sarajevo-Zenica basin has revealed a more detailed insight into the initiation, formation, and post-orogenic evolution of this basin. At the start of basin formation in the Late Oligocene - Early Miocene, reverse faults are the most prominent structures found. Syn-kinematic deposits linked to large thrust faults suggest a contractional regime at the time the earliest basin sediments were deposited. Thus the basin was initiated as a foredeep type basin during a phase of NE-SW compression, between two Dinaridic thrust sheets comprised of the Bosnian flysch and Mid Bosnian schist mountains. Other authors (Hrvatovic, 2006) have suggested a pull-apart style basin formation, and indeed abundant strike-slip faults are present in the Late Oligocene - Early Miocene edges of the basin. Nevertheless, the lack of syn-kinematic sediments associated with this strike-slip faulting indicate their development later during basin inversion. Except for a group of strike-slip faults striking WSW-ENE that could have formed as tear faults during the NE-SW oriented compression that created the foredeep basin.

After the basin formed as a foredeep, extension in the Pannonian basin likely triggered orogenic collapse in the Dinarides leading to a phase of extension during the Miocene (18-~13Ma), which has been recorded in several DLS basins. This extensional regime created a half-graben basin which generated a large accommodation space towards the SW basin margin where the normal faulting migrated towards.

The basin was obliquely inverted at the end of the Miocene, beginning of the Pliocene up till present time. As the convergence of the Adriatic plate into the Dinarides generates a N-S oriented compression on the area of the Dinarides where the Sarajevo-Zenica basin is located (Ustaszewski et al., 2014; Ustaszewski et al., 2010; Hrvatović, 2006; Tari & Pamic, 1998; Tomljenović & Csontos, 2001).

The most striking inversion structure observed is a ~E-W oriented thrust fault reaching all the way down to an inherited detachment in the Triassic basement in the centre of the basin. This structure inherited from before the basin was formed, concentrated the bulk of shortening in the centre of the basin. Away from this central zone the basin fill was deformed by many smaller reverse faults, and folds. Only the normal faults close to the basin margin were inverted. Displaying a heterogeneity in the type of inversion deformation throughout this basin. Deformation of the basin fill was affected by the inherited NW-SE trending half-graben structure of the basin that created oblique ramps, which produced N-S striking tear faults in the hanging wall of the thrust to accommodate for differential movement of hanging wall segments over the oblique ramps.

The normal faulting created rheology contrasts at the fault contacts, as competent lithologies are juxtaposed to more incompetent lithologies, which resulted in ramp-flat-ramp thrust trajectories. The increase of competent coarse clastics towards the SW basin margin and incompetent finer clastics towards the NE basin margin created a rheological stratification of the basin. The more competent the lithologies, the stronger the inherited NW-SE structural trend influenced inversion deformation. While in areas with more incompetent lithologies the inherited trend exerted much less control on the deformation.

References

Allmendinger, R. W. (2013). Stereonet 9, A computer program for stereographic projections, Department of Geology, Cornell University.

Allmendinger, R. W., Cardozo, N. C., and Fisher, D., 2012, Structural Geology Algorithms: Vectors & Tensors: Cambridge, England, Cambridge University Press, 289 pp.

Andric, N., Sant, K., Matenco, L., Tomljenovic, B., Pavelic, D., Mandic, O., ... & Demir, V. (2015, April). The link between tectonic and sedimentation in an asymmetric extensional basin: the late Miocene evolution of the Sarajevo-Zenica basin, Bosnia and Hercegovina. In *EGU General Assembly Conference Abstracts* (Vol. 17, p. 6644).

Andrić, N., Sant, K., Matenco, L., Mandic, O., Tomljenović, B., Pavelić, D., ... & Ooms, J. (2017). The link between tectonics and sedimentation in asymmetric extensional basins: Inferences from the study of the Sarajevo-Zenica Basin. *Marine and Petroleum Geology*, *83*, 305-332.

Bada, G., Horváth, F., Dövényi, P., Szafián, P., Windhoffer, G., & Cloetingh, S. (2007). Present-day stress field and tectonic inversion in the Pannonian basin. *Global and Planetary Change*, *58*(1), 165-180.

Bonini, M., Sani, F., & Antonielli, B. (2012). Basin inversion and contractional reactivation of inherited normal faults: A review based on previous and new experimental models. *Tectonophysics*, *522*, 55-88.

Brun, J. P., & Nalpas, T. (1996). Graben inversion in nature and experiments. *Tectonics*, *15*(3), 677-687.

Butler, R. W. H. (1989). The influence of pre-existing basin structure on thrust system evolution in the Western Alps. *Geological Society, London, Special Publications*, *44*(1), 105-122.

Butler, R. W., Tavarnelli, E., & Grasso, M. (2006). Structural inheritance in mountain belts: an Alpine–Apennine perspective. *Journal of Structural Geology*, *28*(11), 1893-1908.

Cloke, I. R., Moss, S. J., & Craig, J. (1997). The influence of basement reactivation on the extensional and inversional history of the Kutai Basin

Corrado, S., Di Bucci, D., Naso, G., & Faccenna, C. (1998). Influence of palaeogeography on thrust system geometries: an analogue modelling approach for the Abruzzi–Molise (Italy) case history. *Tectonophysics*, *296*(3), 437-453.

Delvaux, D., & Sperner, B. (2003). New aspects of tectonic stress inversion with reference to the TENSOR program. *Geological Society, London, Special Publications*, *212*(1), 75-100.

Dewey, J. F., Ryan, P. D., & Andersen, T. B. (1993). Orogenic uplift and collapse, crustal thickness, fabrics and metamorphic phase changes: the role of eclogites. *Geological Society, London, Special Publications*, *76*(1), 325-343.

Flo, T., & James, P. (1997). Influence of basin architecture on the style of inversion and fold-thrust belt tectonics—the southern Adelaide Fold-Thrust Belt, South Australia. *Journal of Structural Geology*, *19*(8), 1093-1110.

Fossen, H. (2016). *Structural geology*. Cambridge University Press.

Frehner, M., & Schmalholz, S. M. (2006). Numerical simulations of parasitic folding in multilayers. *Journal of Structural Geology*, *28*(9), 1647-1657.

Horváth, F., Musitz, B., Balázs, A., Végh, A., Uhrin, A., Nádor, A., ... & Wórum, G. (2015). Evolution of the Pannonian basin and its geothermal resources. *Geothermics*, *53*, 328-352.

Hrvatović, H., & † Pamić, J. (2005). Principal thrust-nappe structures of the Dinarides. *Acta Geologica Hungarica*, *48*(2), 133-151.

Hrvatović, H. (2006). Geological guidebook through Bosnia and Herzegovina. *Geological Survey of Federation Bosnia and Herzegovina, Sarajevo*, *172*.

Ilić, A., & Neubauer, F. (2005). Tertiary to recent oblique convergence and wrenching of the Central Dinarides: constraints from a palaeostress study. *Tectonophysics*, *410*(1), 465-484.

Jovanović, R., Mojićević, M., Tokić, S., Rokić, Lj. (1971). Basic Geological Map of the SFRY, 1:100.000, Sheet Sarajevo (K-34I). Federal Geological Institute, Belgrade.

Korbar, T. (2009). Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. *Earth-Science Reviews*, *96*(4), 296-312.

Lucente, C. C. (2004). Topography and palaeogeographic evolution of a middle Miocene foredeep basin plain (Northern Apennines, Italy). *Sedimentary Geology*, *170*(3), 107-134.

Matenco, L., & Radivojević, D. (2012). On the formation and evolution of the Pannonian Basin: Constraints derived from the structure of the junction area between the Carpathians and Dinarides. *Tectonics*, *31*(6).

Matenco, L., Munteanu, I., Ter Borgh, M., Stanica, A., Tilita, M., Lericolais, G., ... & Oaie, G. (2016). The interplay between tectonics, sediment dynamics and gateways evolution in the Danube system from the Pannonian Basin to the western Black Sea. *Science of the Total Environment*, *543*, 807-827.

McClay, K. R., Insley, M. W., & Anderton, R. (1989). Inversion of the Kechika Trough, Northeastern British Columbia, Canada. *Geological Society, London, Special Publications*, *44*(1), 235-257.

McClay, K. R., & Buchanan, P. G. (1992). Thrust faults in inverted extensional basins. In *Thrust tectonics* (pp. 93-104). Springer Netherlands.

Milojević, R. (1964). Geologic Composition and Tectonic Pattern of Middle-bosnia Coal Basin with Special Review of Development and Economic Value of Coal-bearing Facies. p. 190.

Missenard, Y., Taki, Z., de Lamotte, D. F., Benammi, M., Hafid, M., Leturmy, P., & Sébrier, M. (2007). Tectonic styles in the Marrakesh High Atlas (Morocco): The role of heritage and mechanical stratigraphy. *Journal of African Earth Sciences*, *48*(4), 247-266.

Pamić, J., Tomljenović, B., & Balen, D. (2002). Geodynamic and petrogenetic evolution of Alpine ophiolites from the central and NW Dinarides: an overview. *Lithos*, *65*(1), 113-142.

Pamić, J., Gušić, I., & Jelaska, V. (1998). Geodynamic evolution of the Central Dinarides. *Tectonophysics*, *297*(1), 251-268.

Rowan, M. G., & Linares, R. (2000). Fold-evolution matrices and axial-surface analysis of fault-bend folds: application to the Medina Anticline, Eastern Cordillera, Colombia. *AAPG bulletin*, *84*(6), 741-764.

Scisciani, V. (2009). Styles of positive inversion tectonics in the Central Apennines and in the Adriatic foreland: Implications for the evolution of the Apennine chain (Italy). *Journal of Structural Geology*, *31*(11), 1276-1294.

Sepehr, M., Cosgrove, J., & Moieni, M. (2006). The impact of cover rock rheology on the style of folding in the Zagros fold-thrust belt. *Tectonophysics*, *427*(1), 265-281.

de Leeuw, A., Mandic, O., Krijgsman, W., Kuiper, K., & Hrvatović, H. (2012). Paleomagnetic and geochronologic constraints on the geodynamic evolution of the Central Dinarides. *Tectonophysics*, *530*, 286-298.

Schmid, S. M., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., ... & Ustaszewski, K. (2008).

The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences*, *101*(1), 139-183.

Tari, V., & Pamić, J. (1998). Geodynamic evolution of the northern Dinarides and the southern part of the Pannonian Basin. *Tectonophysics*, *297*(1), 269-281.

Tomljenović, B., & Csontos, L. (2001). Neogene–Quaternary structures in the border zone between Alps, Dinarides and Pannonian Basin (Hrvatsko zagorje and Karlovac Basins, Croatia). *International Journal of Earth Sciences*, *90*(3), 560-578.

Ustaszewski, K., Kounov, A., Schmid, S. M., Schaltegger, U., Krenn, E., Frank, W., & Fügenschuh, B. (2010). Evolution of the Adria-Europe plate boundary in the northern Dinarides: From continent-continent collision to back-arc extension. *Tectonics*, *29*(6).

Ustaszewski, K., Herak, M., Tomljenović, B., Herak, D., & Matej, S. (2014). Neotectonics of the Dinarides–Pannonian Basin transition and possible earthquake sources in the Banja Luka epicentral area. *Journal of Geodynamics*, *82*, 52-68.

Wilkerson, M. S., Apotria, T., & Farid, T. (2002). Interpreting the geologic map expression of contractional fault-related fold terminations: lateral/oblique ramps versus displacement gradients. *Journal of Structural Geology*, *24*(4), 593-607.

Yagupsky, D. L., Cristallini, E. O., Fantín, J., Valcarce, G. Z., Bottesi, G., & Varade, R. (2008). Oblique half-graben inversion of the Mesozoic Neuquén Rift in the Malargüe Fold and Thrust Belt, Mendoza, Argentina: New insights from analogue models. *Journal of Structural Geology*, *30*(7), 839-853.

Appendix

Layout format:

*optional

GPS:
Location (descriptive):
Lithology:
Formation (age):
***Other observations:**
Pictures/sketches:
PICTURE/scanned sketch
Measurements: Stereoplots (axial planes, hinges) beddings

1.1

GPS: 44.16783, 17.76682

Location: Vitez

Lithology: silty/sandy marl, high organic content, snail (radix fossil)

Formation (age): (Quarternary on map) But likely M3

Measurements:

- Fault F1
  - Apparent normal
  - 2cm displacement
  - 128/80
- Bedding 286/30

2.1

GPS: 44.15839, 18.10211

Location: Bijele Vodje, above Kakanj mine

Lithology: Conglomerates (coarsening upwards), interbedded with red silts/fine ss (pinches out towards brecciated limestone, and cold sheared is fault/shear zone), fault zone contains cataclasite, grey marls left of fault zone.

Formation (age): K2

Other observations: (Red lithology to the right seems to be pinching towards the fault)

Pictures/sketches:

Panorama of outcrop, Liviu,Nevena & Jolien for scale

Measurements:

- Fault F1
  - Apparent reverse, with sinistral component
  - 46/72, ss lineation 120/42
- Fault F2
  - Apparent normal
  - 34/60, ss lineation 48/64
  - F2'= 74/58, ss lineation 34/55
- Layer parallel shear in the limestone breccia
  - 38/10 ss plane, 62/8 ss lineation

- Beddings: B1 80/22, B2 94/26, B3 147/7, B4 148/9, B5 124/11, B6 96/20, B7 108/30, B8 84/22, B9 86/29

2.2

GPS: 44.1554, 18.10099

Location: Bijele Vodje, above Kakanj mine

Lithology: White/yellow limestone (fractured/cleavage), Grey marls

Formation (age): Ol,M3

Other observations: Domino style faultblocks

Pictures/sketches:

Measurements:

- Fault:
  - Apparent normal
  - 80cm at limestones, offset decreases upwards (listric)
  - 18/38
- Bedding: B1 172/31, B2 143/23

2.3

GPS: 44.15164, 18.09851

Location: Bijele Vodje, above Kakanj mine

Lithology: Dark grey, very coarse conglomerate alternated with fine-medium ss (fining upwards), marl & limestones on top.

Formation (age): Ol,M3

Other observations: Apparent angular contact between dark grey lithology and more yellowish lithology (unconformity?).

Pictures/sketches:

Measurements:

- ➢ Fault: F1
  - Apparent normal
  - Low angle fault (listric→bottom of fault)
  - 342/49
- ➢ Bedding: B1 185/19, B2 264/24, B3 164/20~

2.4

GPS: 44.14826, 18.1037

Location: Bijele Vodje, above Kakanj mine

Lithology: Grey marls and reddish silty marls with caliche horizons.

Formation (age): M1,2

Other observations: Possibly not a fault but pinching channels in the grey marls.

Pictures/sketches:

Measurements:

- ~Fault
  - Apparent reverse~
  - 1m offset
  - 52/73 and 50/86, ss lineation 122/37
- Bedding: difficult to measure, random readings

2.5

GPS: 44.0418, 18.18105

Location: Smrsnica

Lithology: Thinly bedded 0.5-5cm carbonate rock with little to no quartz, pack/grainstone, containing ostracods and snails

Formation (age): 2M2

Other observations: Normal faults and conjugate riedels extensive throughout section.

Pictures/sketches:

Measurements:

- Fault F1
  - Apparent normal 310/85
  - R1 105/78

- Fault F2
  - Apparent normal 310/73
  - R1 130/69
- Bedding: B1 48/34, B2 30/50, B3 178/26

2.6

GPS: MISSING

Location: Caino, football pitch across from local hangout place

Lithology: Grey silty marls with some thin sandier beds.

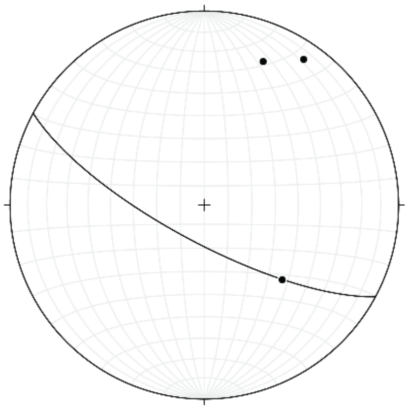
Formation (age): Miocene

Other observations: Very tight folding → hinge collapse, no slumping → therefore must be due to compression

Pictures/sketches:

Measurements:

- Bedding: B1 202/69, B2 214/80
- Measured fold hinge: 82/49
- Calculated fold hinge/axial plane: 133/44, 75/208



Poles to bedding and axial plane + fold hinge

2.7

GPS: 44.0266, 18.20938

Location: Gracanica/Caino

Lithology: Grey silty marls with bioturbation, 2-10mm finely laminated.

Formation (age): M2,3

3.3

GPS: 43.95728, 18.1875

Location: Buci/Stuparici

Lithology: Medium-fine ss beds (fining upwards and containing rip-up clasts (turbidites)), and a mega/event/tsunamitebed (regression, faulting → forced) of coarse badly sorted pebble size conglomerate, interbedded with the typical grey silty marls

Formation (age): M2,3

Other observations: A reverse fault in a coarser bed sandwiched inbetween 2 weaker marl beds is observed (accommodation of deformation).

Pictures/sketches:

Measurements:

- Fault F1
  - Apparent reverse
  - 347/89
- Cleavage: C1 186/77, C3 186/84
- Bedding: B1 179/64, B2 176/59, B3 188/66

3.6

GPS: 44.08358, 18.06744

Location: Gornja Prapatnica

Lithology: Silty marls with some 5mm pebbles, no clear grading, rip-up clasts.

Formation (age): M2,3

Assymetric fold hinge estimate: 112/10

Measurements:

- Assymetric fold hinge estimate: 112/10
- Bedding: 190/30

3.7

GPS: Not known (inbetween 3.6 -3.8)

Location: Gornja Prapatnica

Lithology: Silty marls, bioturbated, thinly bedded 2-10mm

Formation (age): M2,3

Measurements:

- Bedding: B1 182/41, B2 183/29

3.8

GPS: 44.08825, 18.04389

Location: On the road between Gornja Prapatnica and Sebinje

Lithology: Silty marls

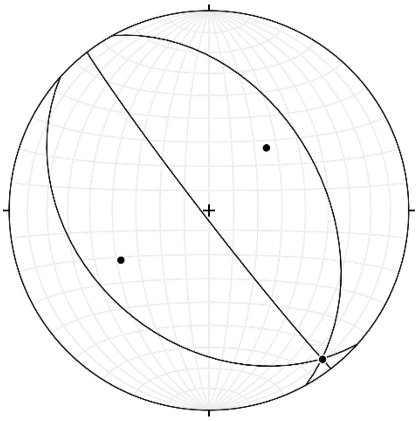
Formation (age): M2,3

Other observations: Hinge collapse

Pictures/sketches:

Measurements:

- Bedding: B1 60/44, B2 66/41, B3 222/35
- Fold hinge/axial plane: 143/7, 232/87



3.11

GPS: 44.04788, 18.15245

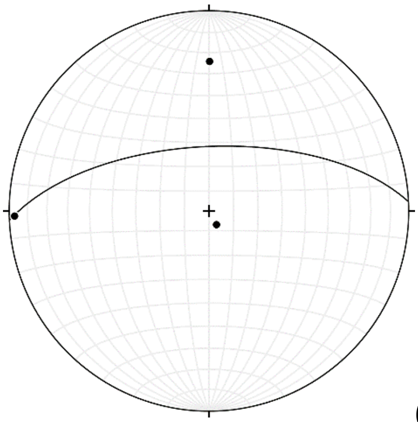
Location: Grdevac

Lithology: Silty marls, with some fine-medium ss layers 2-5cm thick

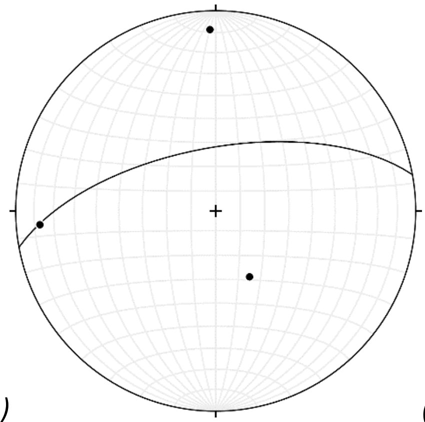
Formation (age): M2,3

Measurements:

- Bedding: B1 332/6, B2 5/46, B3 180/64, B4 333/30, B5 178/80
- Fold hinge/axial plane: (b: B1-B3) 269/3, 357/64
  (a: B4-B5) 266/13, 350/64



(b)



(a)

4.2

GPS: 44.06358, 18.10355

Location: Highway section

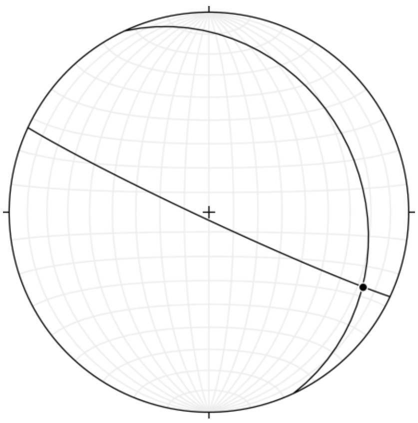
Lithology: Dark grey silty marls

Formation (age): M2/M2,3

Pictures/sketches:

Measurements:

- Bedding: B1 205/87, B2 199/75
- Cleavage: C1 24/65
- Intersection lineation: 116/16



4.3

GPS: 44.06183, 18.10435

Location: Highway section

Lithology: Alternation of dark grey silty marls, conglomerates (max pebble size, sub rounded, average sorting), medium-coarse ss (2-15cm beds)

Formation (age): M2,3

Other observations: Chevron fold → fault must be closeby

Pictures/sketches:

4.5

GPS: 44.04759, 18.10869

Location: Highway section

Lithology: Grey silty marls with some thin fine-medium ss beds (0.5-1cm)

Formation (age): M2,3

Other observations: Slumping, fine grained lacustrine sediment invaded by "turbidites"

Measurements:

- Bedding: 284/7

4.6

GPS: 44.04487, 18.13157

Location: Dobrinje/Buzici

Lithology: Grey-yellow silty marls

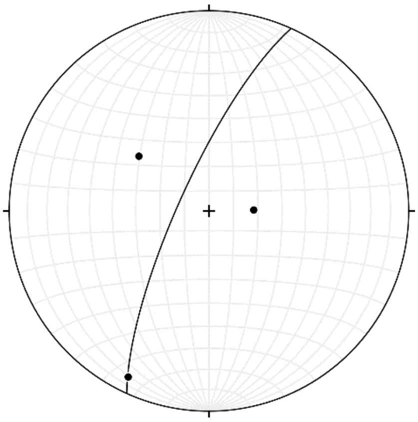
Formation (age): M2,3

Other observations: Likely in the footwall

Pictures/sketches:

Measurements:

- Bedding: B1 268/18, B2 128/37, B3 156/43
- Fold hinge/axial plane (DD): 206/9, 294/78



4.7

GPS: 44.05048, 18.15021

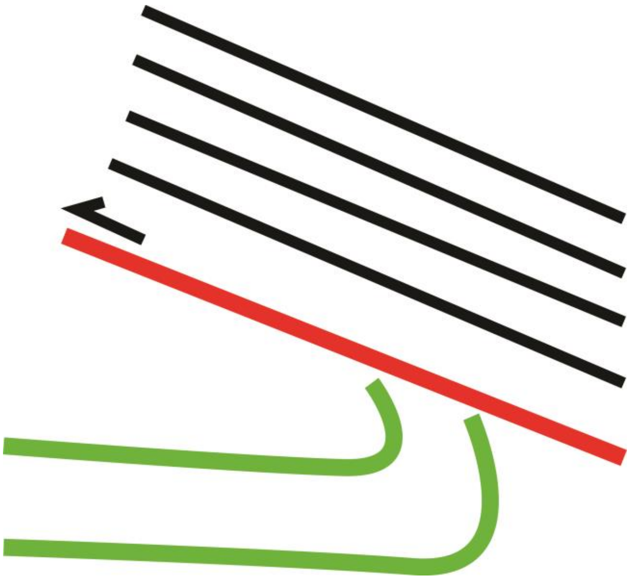
Location: Grdevac

Lithology: Grey-yellow silty marls

Formation (age): M2,3

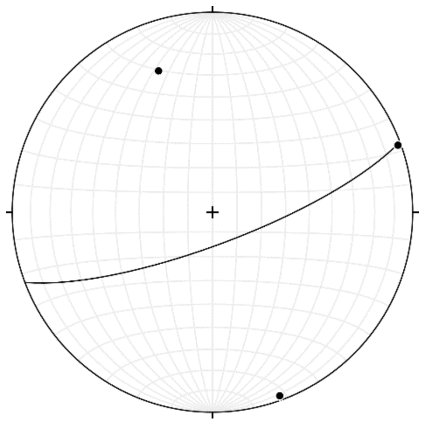
Other observations: Likely in the footwall

Pictures/sketches:



Measurements:

- Bedding: B1 340/87, B2 159/65
- Fold hinge/axial plane (Footwall syncline)(DD): 70/2, 159/77



4.8

GPS: 44.05023, 18.16175

Location: Grdevac, Mali Trnovci road

Lithology:

Formation (age): M2,3 - Ol

Other observations:

Measurements:

- Bedding: B1 6/45, B2 200/76, B3 10/68
- Fold hinge/axial plane (DD): 287/11, 14/75 (a), 286/15, 15/86 (b)

4.9

GPS: 44.05267, 18.16387

Location: Grdevac, Mali Trnovci road

Lithology: Mud breccia

Formation (age): M2,3 - Ol

Other observations: A not very well lithified lithology which at first look appears to be a non lithified badly sorted/rounded conglomerate. No clear detachment visible between the Miocene and overlying Oligocene but this “mud” breccia zone is its likely location. As it contains the yellow Oligocene limestones and greyer Miocene marls in a reddish brown matrix.

Pictures/sketches:

4.10-4.11

GPS: 44.05129, 18.16347

Location: Dobrinje/Buzici

Lithology: Grey-yellow silty marls interbedded with fine-medium ss, Yellow orange “mottled” Oligocene limestones

Formation (age): M2,3, Ol/M3

Other observations: Oligo-miocene bedding reflects the orientation of the thrust fault, inbetween the Miocene turbidites and Oligocene limestones we find the mud breccia at 4.9.

Pictures/sketches:

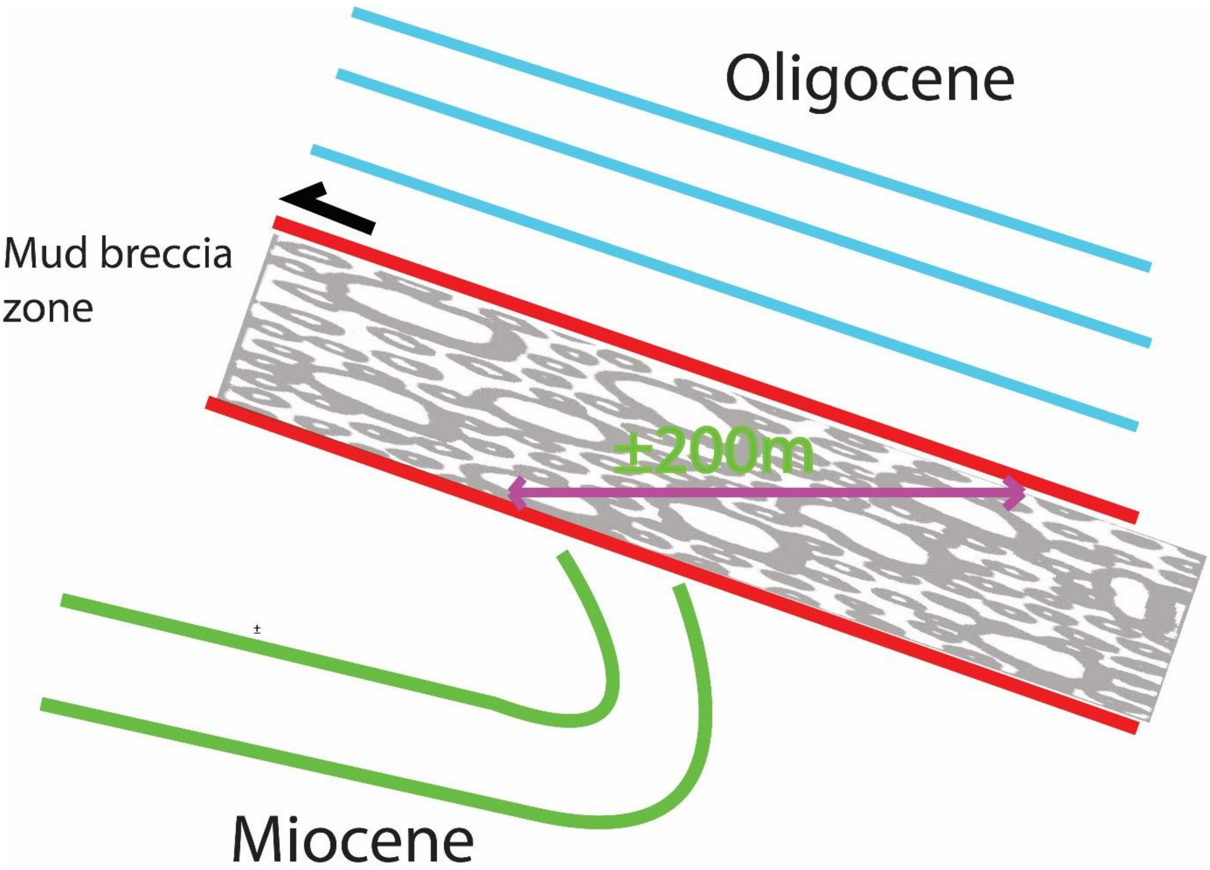
Miocene turbidites

Oligocene Limestone

Oligocene Limestone

Hypotetical fault orientation
Ol/M3 bedding
M2,3 bedding

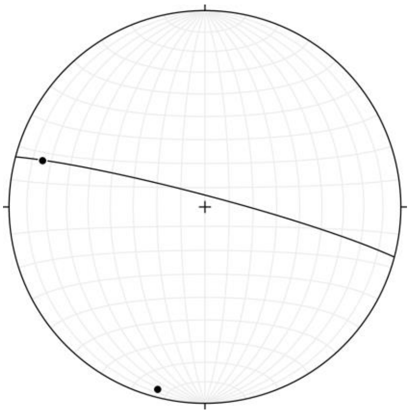
Mud breccia



Measurements:

- Bedding: B1 10/68, B2 200/75, B3 14/45

- Fold hinge/axial plane (DD): 268/15, 85/15
- Fault: bedding parallel- ~14/45?



5.9

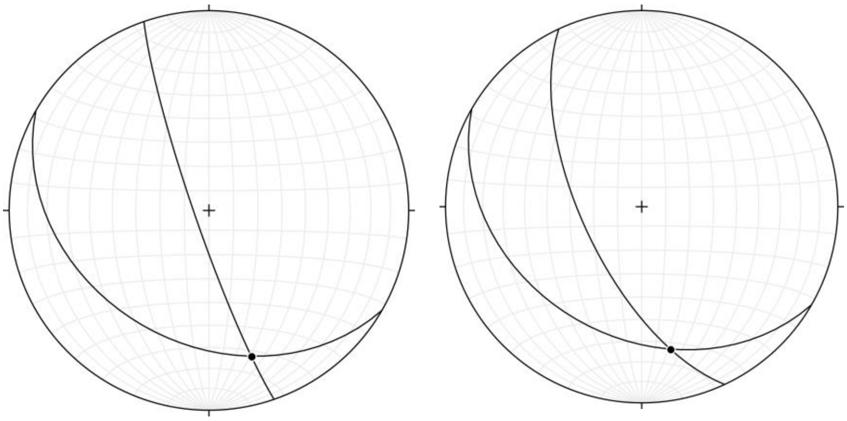
GPS: 44.25647, 17.74173

Lithology: Calcareous mudstone

Formation (age): 2Ol/M

Measurements:

- Bedding: 210/34
- Cleavage: (a) 251/84, (b) 245/65
- Intersection lineation: (a) 164/25, (b) 169/27



a *b*

5.11

GPS: 44.24825, 17.74007 (5.12)

Location: Road to Guca Gora

Lithology: Pack/wackestones

Formation (age): 2Ol/M

Pictures/sketch:

The outcrop continues from top right to bottom left side

Measurements:

- Bedding: 58/35 (5.10)
- Faults:
  - F1 243/65, R1 243/60
  - F2 238/65, R2 245/70
  - F3 19/74, R3 ~26/82
  - F4 74/85, SS lineation 159/30

5.12

GPS: 44.24825, 17.74007

Location: Road to Guca Gora

Lithology: Massively bedded pack/wacke/grainstones containing shells

Formation (age): 2Ol/M

Other observations: Strange structure with a "fracture" with normal drag of a layer on both sides but there is no normal displacement (see strate indicated in green in top part of pano), → possibly a ramp anticline.

Pictures/sketch:

Outcrop continues from top right to bottom left (pano cut in two for ease of reading)

Measurements:

- Bedding: B1 67/10, B2 56/22
- Faults: F1 75/82, ~R1 94/70 (not in sketch does not fit on further consideration), SS lineation 98/80 (apparent reverse)

5.13

GPS: 44.24767, 17.73916

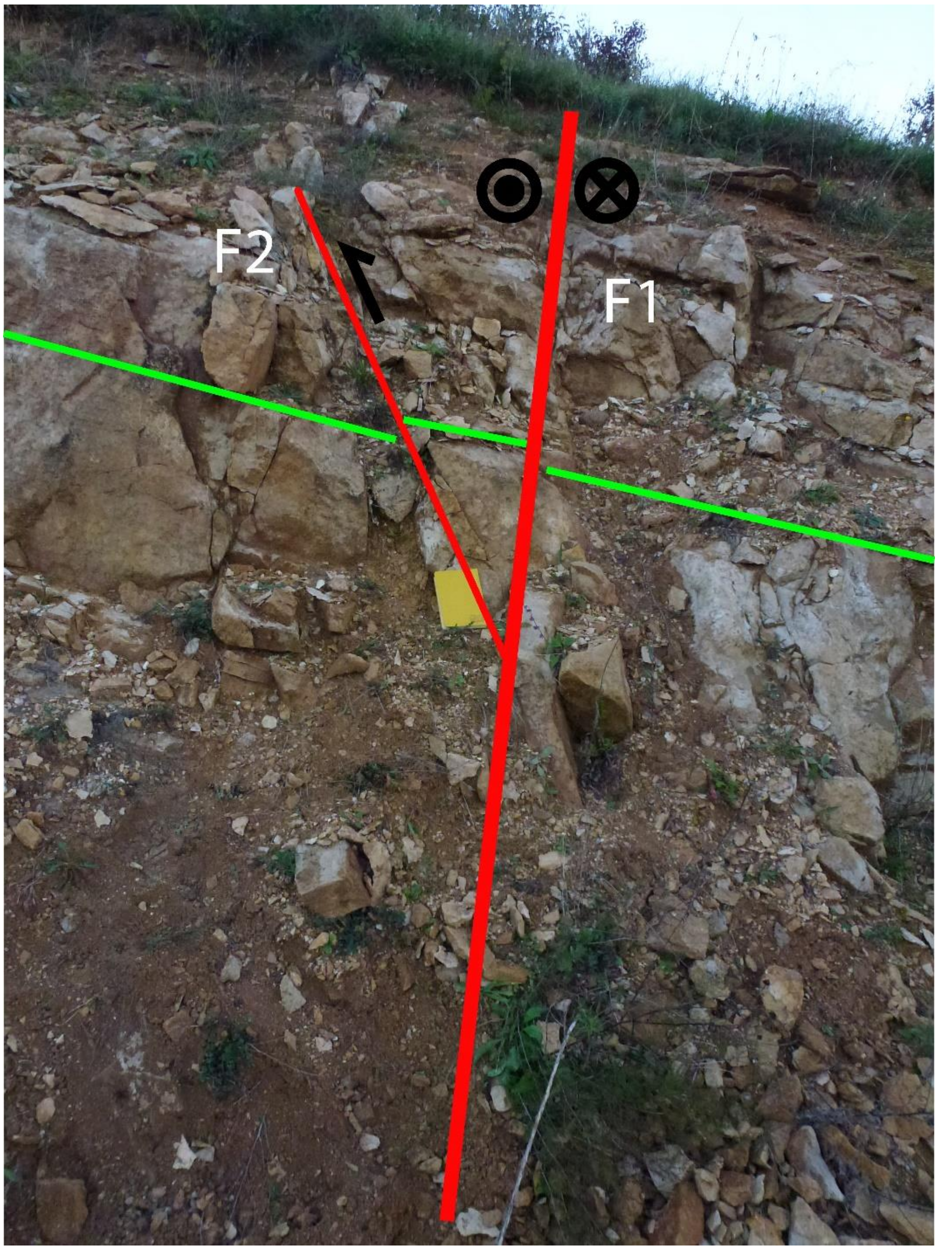
Location: Road to Guca Gora

Lithology: Travertine limestones with a band of organic rich brecciated limestone on top on top of that you find a lithology similar to 5.12

Formation (age): 2Ol/M

Other observations: Possible positive flower structure (strike-slip), Brecciation is stronger to the left of the outcrop than to its right.

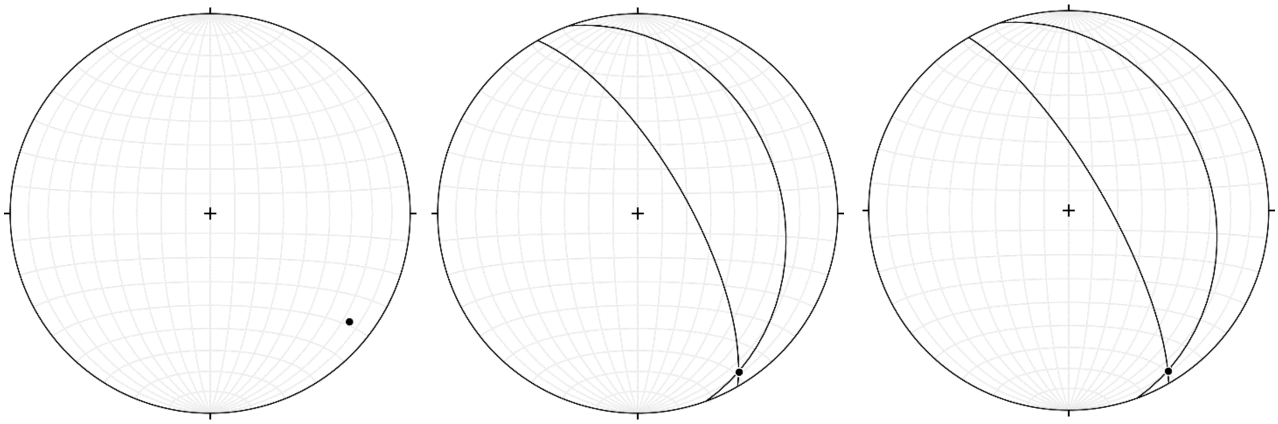
Pictures/sketch:



Possible positive flower?

Measurements:

- Bedding: B1 74/20, B2 78/20
- Contact travertine/limestone: 70/29 (7.3)
- Cleavage: (travertine) 213/70 (a), (limestone) 60/70 (b), 60/75 (c)
- Faults: F1 253/75 (sinistral), F2 80/50
- Intersection lineation: 128/13 (a), 148/7 (b), 148/6 (c)



(a) *(b)* *(c)*

6.1

GPS: 44.13013, 17.89607

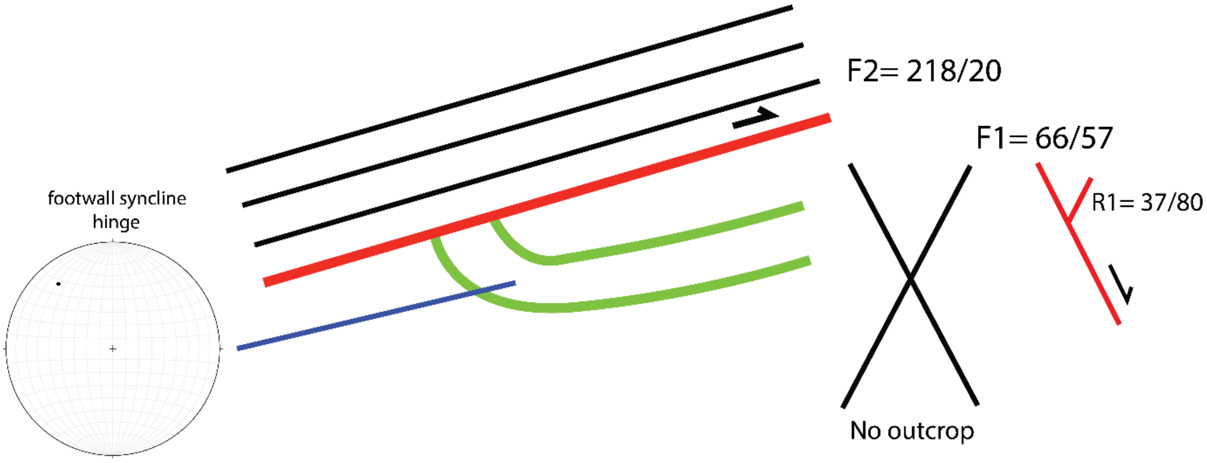
Location: Strane, Lasva road to Vitez

Lithology: Clast supported pebble conglomerate, average sorting, well rounded (schist, quartz)

Formation (age): M2,3

Other observations: Drag syncline in the footwall

Pictures/sketch:



Measurements:

- Bedding: B1 22/40, B2 13/40, B3 270/38, B4 264/35, B5 ~280/35
- Faults:
    - F1 66/57, R1 37/80, SS lineation 176/26 (apparent normal)
    - F2 218/20 (apparent reverse)
    - Hinge footwall syncline: 320/27, 320/21

6.2

GPS: 44.13101, 17.898

Location: Across the Lasva river from Strane

Lithology: Clast supported pebble conglomerate, poor sorting, medium rounded (schist, quartz)

Formation (age): M2,3

Measurements:

- Bedding: B1 ~314/19, B2 205/20
- Faults:
    - F1 14/52, R1 0/85 (apparent normal)
    - F2 43/50 (apparent normal)

6.3

GPS: 44.13463, 17.91368

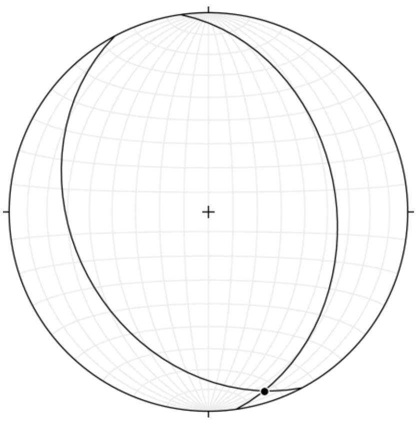
Location: Lasva road, Grablje west of Titanic

Lithology: Clast supported pebble conglomerate, poor sorting, medium rounded (schist, quartz)

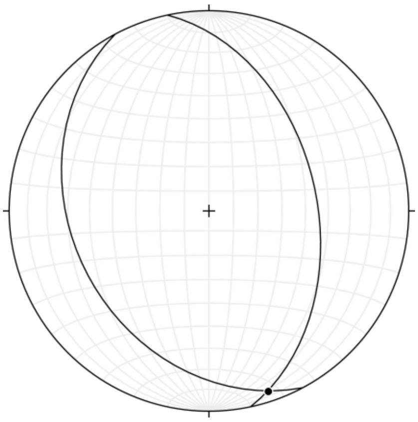
Formation (age): M2,3

Measurements:

- Bedding: 242/32
- Cleavage: C1 82/36 (a), C2 78/45 (b)
- Intersection lineation: (a) 163/7, (b) 162/6



(a)



(b)

6.4

GPS: 44.13435, 17.917522

Location: Lasva road, close to Titanic

Lithology: Clast supported pebble conglomerate, poor sorting, medium rounded (schist, quartz)

Formation (age): M2,3

Other observations: We observe a riedel zone but not the true fault, so probably it has not developed properly. The bedding used is the one measured at 6.3 as bedding is not always clear, possibly due to it being at the lower part of a large listric fault or layer parallel slip surfaces.

Measurements:

- Bedding: 242/32
- Faults:
  - F1 114/50, R1 118/62
  - F2 128/42, R2 86/52

6.5

GPS: 44.13572, 17.91981

Location: Lasva road, west of gasstation

Lithology: Clast supported pebble conglomerate, poor sorting, medium rounded (schist, quartz) and medium/coarse sandstone layers ±1m.

Formation (age): M2,3

Measurements:

- Bedding: 269/12
- Cleavage: C1 240/65 (possible riedel if normal fault, 75/78), C2 245/75, C3 262/80, C4 75/72
- Fault: 44/40, R 84/55 (apparent normal)

6.6

GPS: 44.13417, 17.92411

Location: Lasva road, opposite to gasstation

Lithology: Matrix supported granule/pebble conglomerate, poor sorting, medium rounded (schist, quartz), and medium/coarse sandstone layers ±1m.

Formation (age): M2,3

Measurements:

- Fault: 82/67, R 84/55 (apparent normal, offset ±0.5m seems to increase toward to top → listric)

6.7

GPS: 44.13495, 17.9226

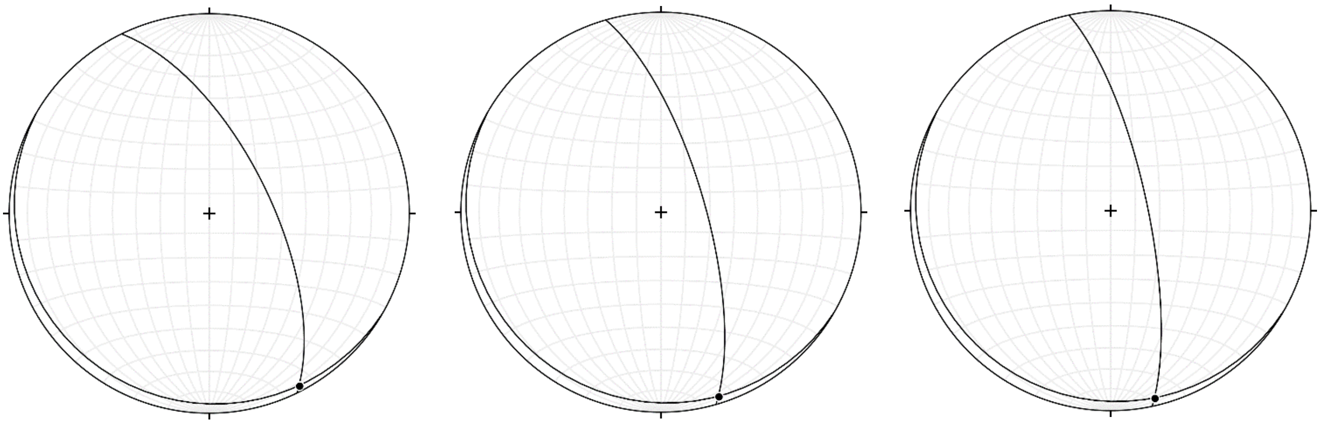
Location: Lasva road, west of gasstation opposite to "watermill"

Lithology: Matrix supported granule/pebble conglomerate, poor sorting, medium rounded (schist, quartz), and medium/coarse sandstone layers ±1m.

Formation (age): M2,3

Measurements:

- Bedding: 210/6
- Cleavage: C1 64/65 (a), C2 74/72 (b), C3 78/75 (c)
- Intersection lineation: 153/3 (a), 163/3 (b), 167/4 (c)



(a) *(b)* *(c)*

6.8

GPS: 44.1356, 17.92041

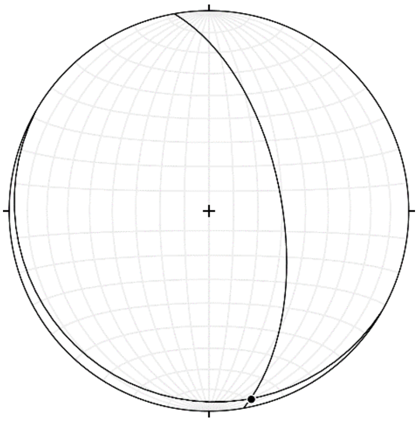
Location: Lasva road, west of gasstation opposite to "watermill"

Lithology: Matrix supported granule/pebble conglomerate, poor sorting, medium rounded (schist, quartz), and medium/coarse sandstone layers ±1m.

Formation (age): M2,3

Measurements:

- Bedding: 210/6 (6.9)
- Cleavage: 80/60
- Intersection lineation: 167/4



6.9

GPS: 44.13469, 17.92804

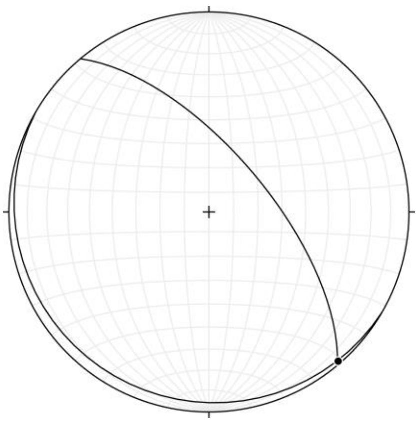
Location: Lasva road, east of gasstation

Lithology: Matrix supported (more than before) granule/pebble conglomerate, poor sorting, medium rounded (schist, quartz, chert (becomes prominent from here), and more medium/coarse sandstone layers (±1-2m) start to appear.

Formation (age): M2,3

Measurements:

- Bedding: 210/6
- Cleavage: 50/66, (possible riedel 95/85)
- Intersection lineation: 139/2



6.10

GPS: 44.13844, 17.93037

Location: Lasva road, just before Lasva village (exit/bridge)

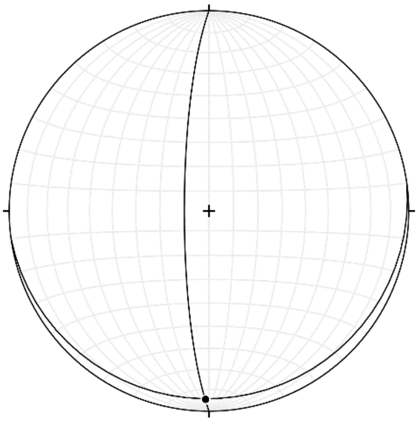
Lithology: Matrix supported (more than before (6.1<6.10) granule/pebble conglomerate, poor sorting, medium rounded (schist, quartz, chert (becomes prominent from here), and more medium/coarse sandstone layers (±1-2m) start to appear.

Formation (age): M2,3

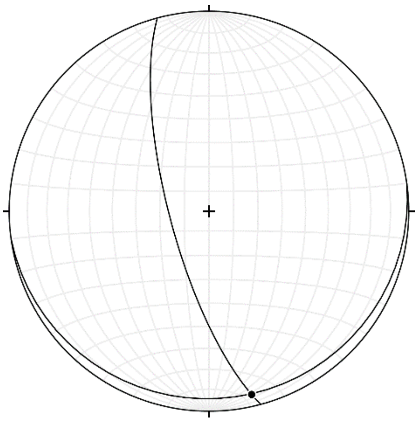
Other observations: Cleavage often looks like faults but they often terminate. Possibly due to a syndepositional nature of the faulting they muddy matrix seals them during lithification. Offset is impossible/difficult to judge unless a specific boulder is cracked in offset along the fault.

Measurements:

- Bedding: 172/6
- Cleavage: C1 270/80 (a), C2 255/74 (b)
- Intersection lineation: 181/7 (a), 167/7 (b)



(a)



(b)

6.11

GPS: 44.13433, 17.93629

Location: Mega section before Lasva road exit

Lithology: Light grey marly siltstone containing bands of organic matter, interbedded with fine-medium sandstone beds with planar/wavy bedding planes, some coarser layers with pebbles (max 7mm) are present. On top of this package lies a clast supported pebble conglomerate, which is moderately sorted and sub-angular/rounded containing chert and limestone. The contact of the conglomerate with the underlying package is erosional.

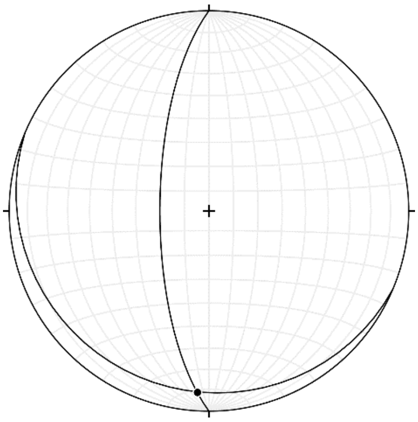
Formation (age): M2,3

Other observations: 6.11 roughly lies on top of 6.10

Measurements:

- Bedding: 203/11 (average of two measurements)
- Cleavage: 270/70

- Intersection lineation: 184/10



7.2

GPS: 44.23297, 17.82729

Location: Stranjani to Pojske road

Lithology: Ugar mylotonized limestone

Formation (age): K3,2

Other observations: At the contact between K3,2 and Ol,M

Pictures/sketches:

Measurements:

- Bedding: 234/30

7.4

GPS: 44.24747, 17.73892

Location: Guca Gora road

Lithology: Brecciated porous hard limestone containing snail shells

Formation (age): Ol2,M

Other observations: No clear contact + porosity → possibly a reef

Pictures/sketches:

Measurements:

- Bedding: ~74/10

7.5

GPS: 44.2455, 17.73738

Location: Guca Gora road

Lithology: Brecciated porous hard limestone containing snail shells

Formation (age): Ol2,M

Other observations: Less brecciated than a 7.4

Pictures/sketches:

Measurements:

- Bedding: 130/25

7.6

GPS: 44.24472, 17.73635

Location: Guca Gora road

Lithology:

Formation (age): Ol2,M

Other observations:

7.7

GPS: 44.24091, 17.72042

Location: South of Krpeljici

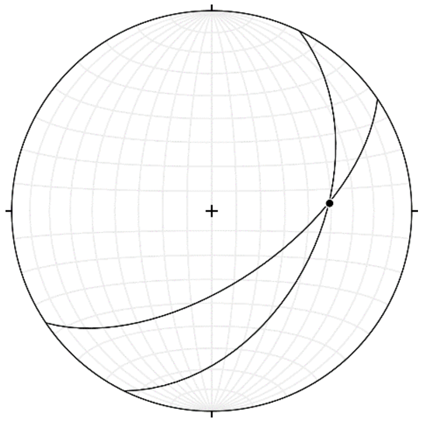
Lithology: Laminated porous grainstone

Formation (age): Ol2,M

Other observations:

Measurements:

- Bedding: 116/45
- Cleavage: 146/60
- Intersection lineation: 86/41



7.8

GPS: 44.24217, 17.72153

Location: South of Krpeljici

Lithology:

Formation (age): Ol2,M

Other observations:

Pictures/sketches:

Measurements:

- Bedding: 116/45
- Cleavage: 146/60
- Intersection lineation: 86/41

7.9

GPS: 44.24229, 17.72216

Location: South of Krpeljici

Lithology:

Formation (age): Ol2,M

Other observations:

Pictures/sketches:

Measurements:

- Bedding:

7.10

GPS: 44.24276, 17.73101

Location: Guca Gora football pitch

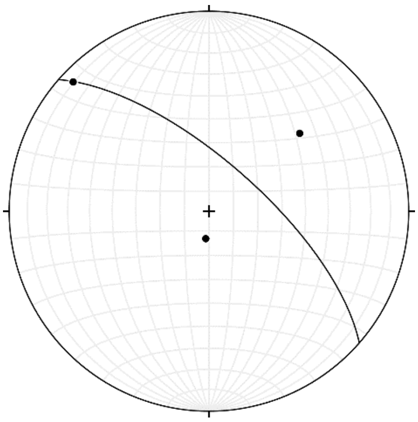
Lithology: Yellow marls and limestones

Formation (age): Ol2,M

Pictures/sketches:

Measurements:

- Bedding: B1 8/11, B2 229/50
- Fold hinge/axial plane: 314/6, 41/70



7.13

GPS: 44.22432, 17.7463

Location: Cifluk, (Pebble quarry on side of road probably made by the locals)

Lithology: Clast supported, poorly sorted, sub-rounded pebble conglomerate (smaller clasts are more angular than rounded).

Formation (age): Ol3,M

Other observations: Mud diapir (see picture), likely formed by the loading of the conglomerates on the underlying marl/mud layer.

Pictures/sketches:

Mud diapir.

7.14

GPS: 44.20462, 17.75042

Location: East of Ricice

Lithology:

Formation (age): M1,2

Measurements:

- Bedding 120/18

8.1

GPS: 44.15726, 18.10171

Location: Bijele Vodje Mine, next to red/white-yellow lithology transition

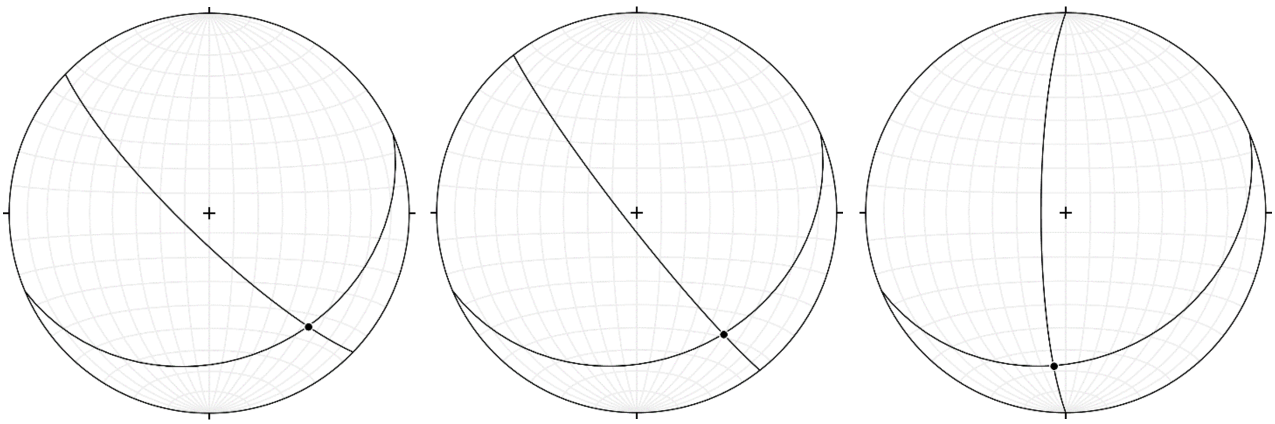
Lithology: Yellowish (hard/fractured) limestones

Formation (age): Ol2,M

Pictures/sketches:

Measurements:

- Bedding 157/27 (average point 2.2)
- Cleavage C1 224/80 (a), C2 232/85 (b), C3 270/80 (c)
- Intersection lineations: 139/26 (a), 145/26 (b), 185/24 (c)



(a) *(b)* *(c)*

8.2

GPS: 44.15556, 18.10086

Location: Bijele Vodje Mine, next to red/white-yellow lithology transition

Lithology: Yellowish (hard/fractured) limestones

Formation (age): Ol2,M

Measurements:

- Fault 10/52, apparent normal 3-10cm offset, riedel 18/70

10.1

GPS: 44.15468, 18.10095

Location: Side road from Bijele Vodje Mine to Vrtliste mine.

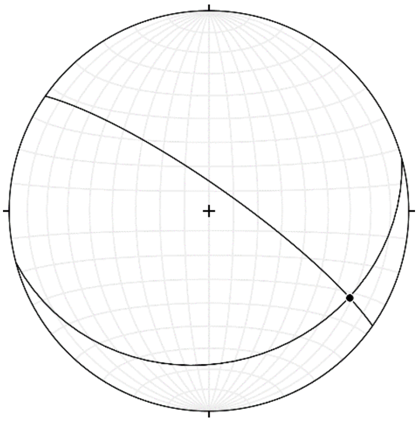
Lithology: Grey/purple alternation of silty marls containing sand/pebble conglomerate (well sorted) channel, and a lot of caliche (mottling)

Formation (age): M1,2 on map

Picture/sketches:

Measurements:

- Bedding 165/25
- Cleavage 35/80
- Intersection lineation: 122/19



10.2

GPS: 44.14796, 18.10397

Location: Across the illegal miners in Vrtliste mine.

Lithology: Silty marls and coal

Formation (age): M1,2 on map

Other observations: Base of the coal, first layer of coal on top of the silty marl M1,2 sequence.

Picture/sketches:

Measurements:

- Bedding 150/20

10.5

GPS: 44.13947, 18.09706

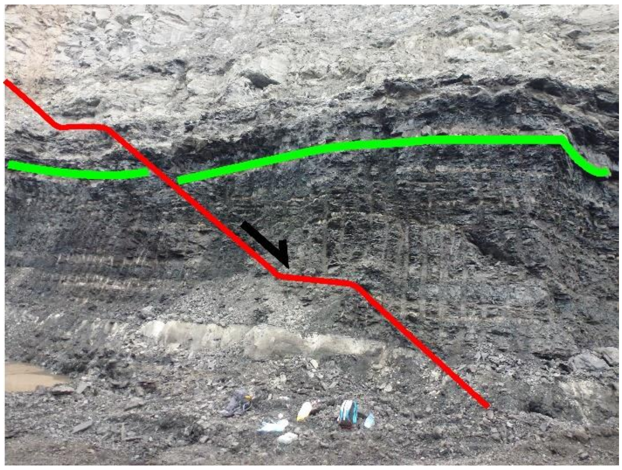
Location: Inside Vrtliste mine (during lunch break)

Lithology: Coal

Formation (age): M1,2 on map

Other observations: Unclear whether the fault continues, some limestone layers to the top show planes. Riedel indicating normal movement visible

Picture/sketches:



Measurements:

- ➢ Bedding 180/10 (coal)
- ➢ Fault 197/65 (small plane at bottom of fault), 194/55 (guestimate), (apparent normal, offset 0.5/0.75m)

11.1

GPS: 43.84182, 18.39701

Location: Gasstation intersection close to the Olympic village.

Lithology: Stratified conglomerate, average sorting, containing white pebbles/cobbles. Fine-medium ss channel towards the top.

Formation (age): At the border between 2M3 and 3M3

Other observations:

Measurements:

- ➢ Bedding ~275/20

11.2

GPS: 43.902, 18.33241

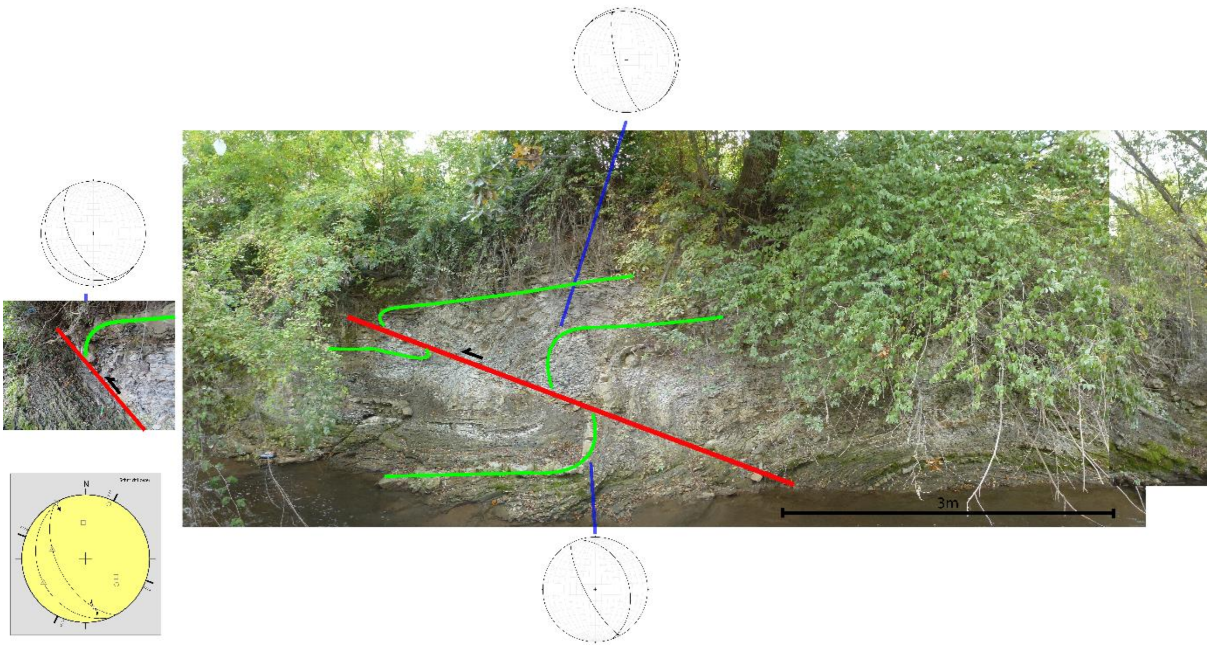
Location: Vogosca behind gasstation in the river creek wall.

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

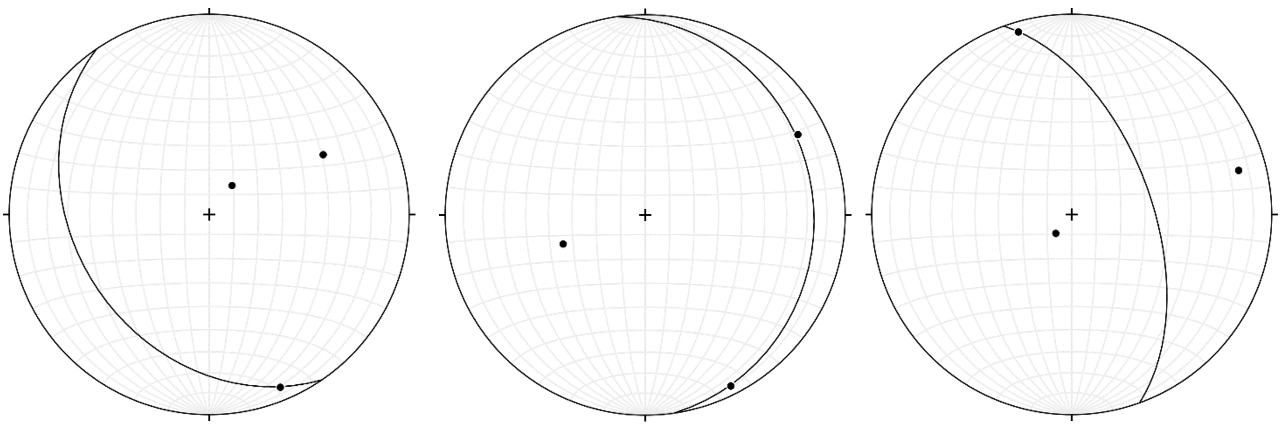
Other observations: Whitish colour of the beds is due to a gypsum workplace from where the pictures were taken.

Picture/sketches:

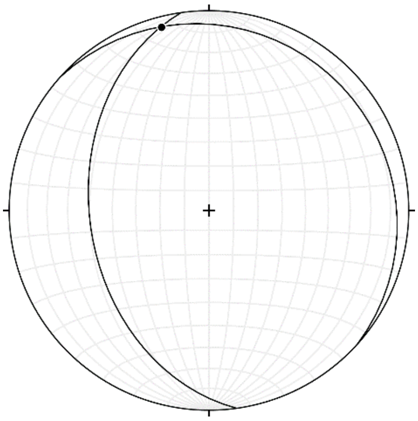


Measurements:

- Bedding: B1 42/10, B2 255/75, B3 242/75, B4 71/36, B5 217/15, B6 242/54, B7 85/35
- Cleavage 262/40 (in F1 ((large picture) dragfold)
- Fracture zone below F2: 184/76 (cleavage? Orientation)
- Fold hinges/axial planes: 158/8, 236/33 (dragfold hangingwall F1)(a), 154/5, 82/17(dragfold footwall F1)(b) , 344/5, 340/57 (dragfold hanging wall F2)(c)
- Intersection lineations: 345/6 (d)
- Fault:
  - F1 248/25, ss lineation 150/1 (apparent reverse)
  - F2 242/54 (fault in the cutout), ss lineation 168/25 (apparent reverse)



(a) *(b)* *(c)*



(d)

11.3

GPS: 43.90205, 18.33314

Location: Vogosca behind gasstation in river

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

Other observations:

Measurements:

- Bedding: 21/21

11.4

GPS: 43.90214, 18.3333

Location: Vogosca behind gasstation in river

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

Measurements:

- Bedding: B1 58/24, B2 68/30

11.5

GPS: 43.90214, 18.3335

Location: Vogosca behind gasstation in river

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

Pictures/sketches:

Measurements:

- Bedding: B1 46/65, B2 235/80
- Fault: 81/79 (apparent strike slip, but likely is was a reverse fault which got titled or could be cleavage due to folding)

11.6

GPS: 43.90214, 18.3335

Location: Vogosca behind gasstation in river

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

Measurements:

- Bedding: 72/40
- Fault: 276/74 (apparent reverse), riedel 279/85

11.7

GPS: 43.90214, 18.33374

Location: Vogosca behind gasstation in river

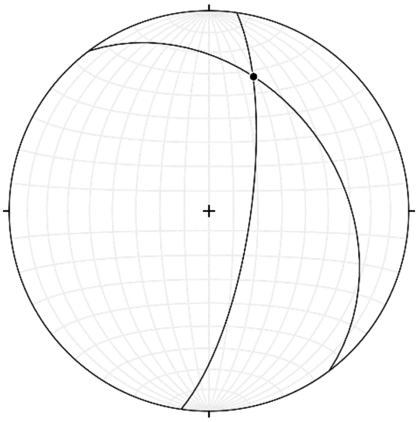
Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10-15cm sandbeds and some coal interbeds of mm scale that are often discontinuous

Formation (age): M2 on map

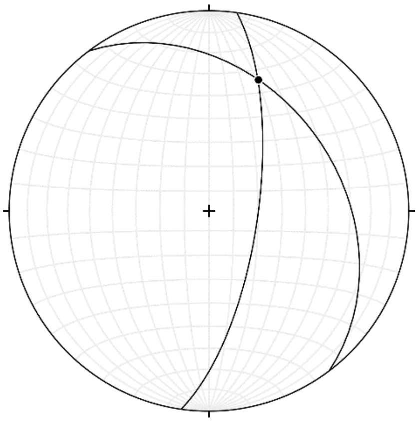
Pictures/sketches:

Measurements:

- Bedding: 53/35
- Cleavage: C1 98/73 (a) (possibly a fault because it looks like an apparent sinistral offset of 5cm), C2 98/70 (b)
- Intersection lineations: 18/30 (a), 20/31 (b)



(a)



(b)

11.8

GPS: 43.90264, 18.33461

Location: Vogosca, outcrop across the road from the river/creek of the last stops

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 5-10cm sandbeds

Formation (age): M2 on map

Measurements:

- ➢ Bedding: 1/34

11.9

GPS: 43.90398, 18.32942

Location: Vogosca just before the bridge to Krivoglavci

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 20 cm sandbeds

Formation (age): M2 on map

Measurements:

- ➢ Bedding: 30/16

11.10

GPS: 43.97403, 18.25168

Location: Podlugovi

Lithology: Thinly bedded marls/silts (1-3cm), interbedded by 10cm sandbeds

Formation (age): M2 on map

Measurements:

- ➢ Bedding: 40/25

12.1

GPS: 44.09448, 18.10929

Location: Beginning of the highway section.

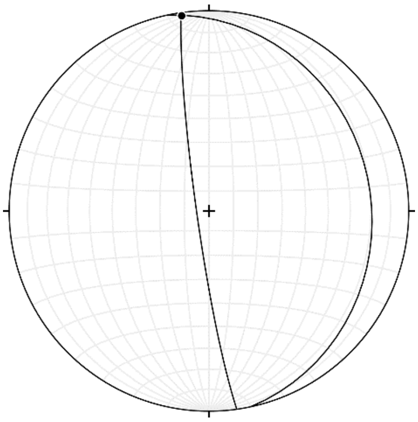
Lithology: Calc-arenite and marls, containing organic material, very similar to the highway section

Formation (age): 2M2 on map

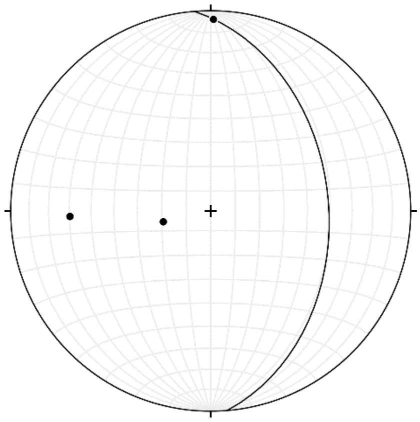
Pictures/sketches:

Measurements:

- Bedding: B1 52/35, B2 216/12, B3 192/5, B4 216/7, B5 88/60, B6 78/20, B7 82/13, B8 162/45
- Cleavage: C(5,6) 262/85
- Fault: 70/65 (apparent normal, offset difficult to judge due to monotonous lithology)
- Intersection lineation: 352/1 (a)
- Fold hinge/axial plane: 5/1, 85/41 (b)



(a)



(b)

12.2

GPS: 44.09331, 18.11021

Location: Start of highway section, north

Lithology: Calc-arenites, with floodcasts at the bottom of the beds and silty marls interbedded, thickness 5-20mm

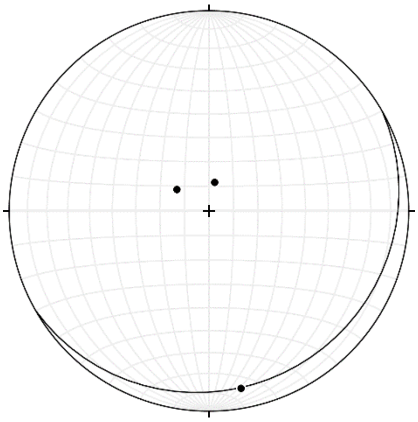
Formation (age): 2M2

Other observations: Seems to be a fault dragging the layer creating a footwall syncline B7-B6, but gives a strange measurement.

Pictures/sketches:

Measurements:

- Bedding: B1 210/25, B2 272/15, B3 330/9, B4 282/8, B5 244/15, B6 190/12, B7 124/16
- Floodcast: 240/25
- Fold hinge/axial plane: 170/11, 150/12



12.3

GPS: 44.09247, 18.11033

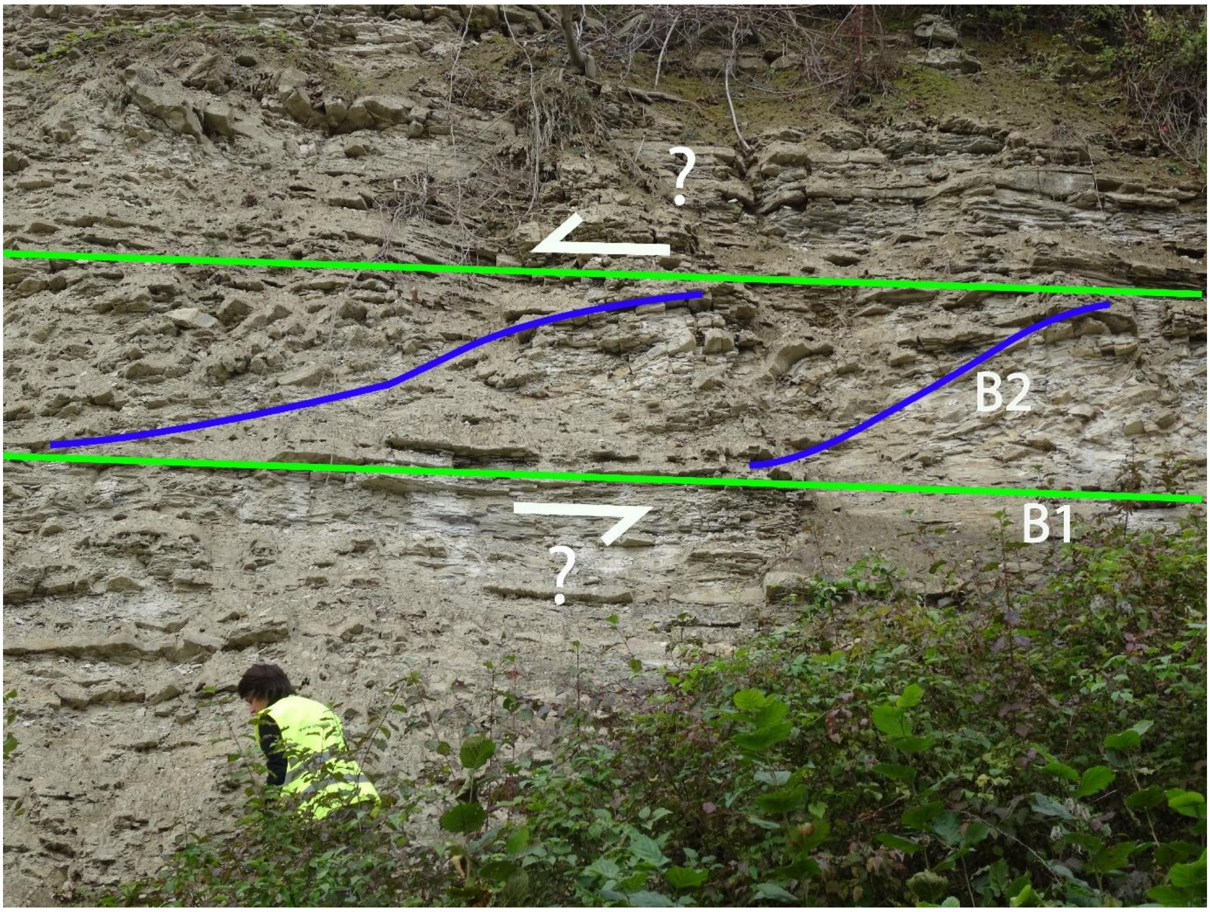
Location: Start of highway section, north

Lithology: Calc-arenites (thickness 5-20mm), and silty marls interbedded

Formation (age): 2M2

Other observations: Appears to be some sort of shear band caused by layer parallel shear or crossbeds.

Pictures/sketches:



Measurements:

- Bedding: B1 68/5 (horizontal beds), B2 207/30 (cross/shearbeds)

12.4

GPS: 44.09221, 18.11114

Location: Start of highway section, north

Lithology: Calc-arenites, at the bottom of the beds and silty marls interbedded, thickness 5-20mm

Formation (age): 2M2

Other observations: Appears to be some sort of shear band caused by layer parallel shear or crossbeds.

Measurement:

- Bedding: 204/15

12.5

GPS: 44.09205, 18.11126

Location: Start of highway section, north

Lithology: Yellow-grey Calc-arenites (3-10cm), with bands high in organic matter and brown-orange silty marls interbeds (1-10cm), some slumping on a 0.5-2m scale.

Formation (age): 2M2

Other observations: Appears to be some sort of shear band caused by layer parallel shear or crossbeds.

Pictures/sketches:

Measurement:

- Bedding: 225/10

12.6

GPS: 44.08802, 18.11195

Location: Highway section, across the main part of the termoelektrana plant.

Lithology: Medium-coarse sandstone megabeds containing some brown-orange marl “rip-up” clasts

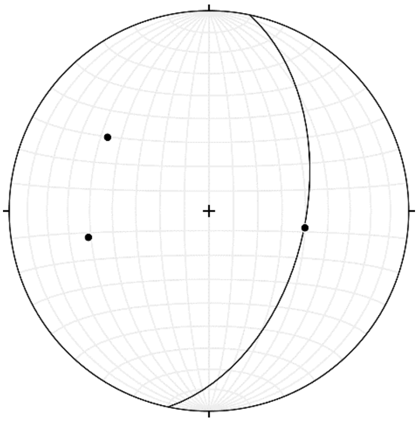
Formation (age): 2M2

Other observations: Lithology becomes a lot sandier and coarser (pebbles appear)

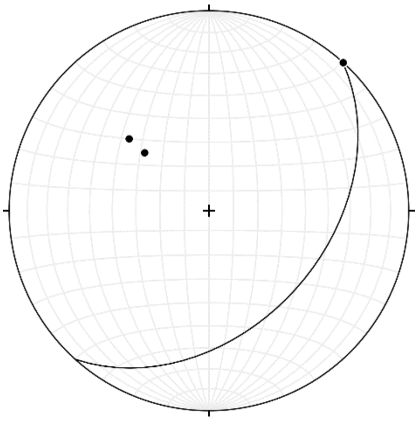
Pictures/sketches:


Measurements:

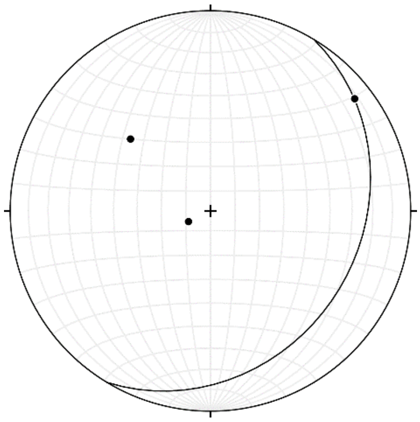
- Bedding: B1 78/52, B2 126/53, B3 132/36, B4 132/45, B5 66/10, B6 148/41
- Fold hinges/ axial planes: 100/50, 102/50 (a), 42/0, 132/41 (b), 52/10, 121/26 (c), 167/40, 140/43 (d)



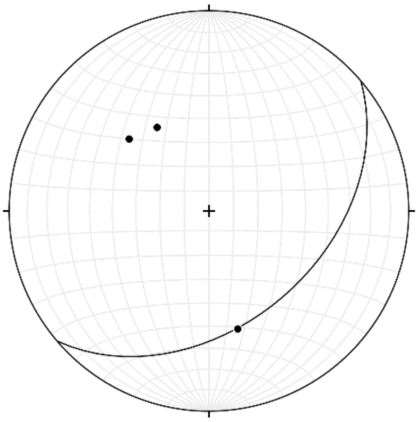
(a)



(b)



(c)



(d)

12.7

GPS: 44.08704, 18.11265

Location: Highway section, across from termoelektrana plant

Lithology: Calc-arenites, with floodcasts at the bottom of the beds and silty marls interbedded,

Formation (age): 2M2

Measurements:

- Bedding: 242/5
- Floodcast: 234/15

12.8

GPS: 44.07015, 18.10517

Location: Highway section, south of Prapatnice and Gora

Lithology: Calc-arenites, provenance schist/ quartz (more than 12.7) and silty marl interbeds.

Formation (age): 2M2, close to M2,3 border

Other observations: Bottom of the slope.

12.9

GPS: 44.05199, 18.11142

Location: Road behind coffeeplace in Dobrinje, house with all the chickens

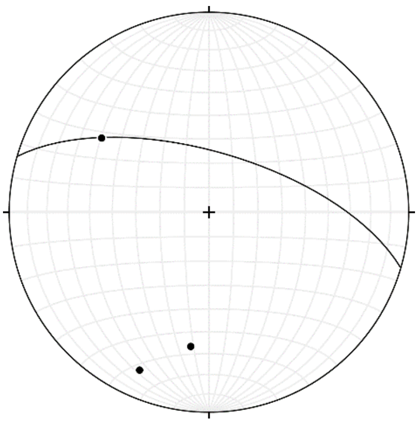
Lithology: Thinly bedded yellow marls and fine sandstones

Formation (age): M2,3

Other observations: Fining upwards en fining downwards so possible a fold between b1 and b3 (see stereoplot).

Measurements:

- Bedding: B1 24/75, B2 127/55, B3 8/57
- Fold hinge/axial plane: 305/35, 16/65



12.10

GPS: 44.05246, 18.1113

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones

Formation (age): M2,3

Measurements:

- Bedding: 20/40

12.11

GPS: 44.05276, 18.11081

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones

Formation (age): M2,3

Measurements:

- Bedding: 5/68

12.12

GPS: 44.05414, 18.10993

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones

Formation (age): M2,3

Measurements:

- Bedding: B1 10/55, B2 38/48

12.13

GPS: 44.05276, 18.11073

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones

Formation (age): M2,3

Measurements:

- Bedding: 358/55

12.14

GPS: 44.0531, 18.11025

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, fining upwards, containing some coarser badly sorted, sub rounded, clast supported pebble conglomerate beds with a schist provenance.

Formation (age): M2,3

Pictures/sketches:

Measurements:

- Bedding: 345/22

12.15

GPS: 44.05448, 18.11069

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, containing some coarser badly sorted, sub rounded, clast supported pebble conglomerate beds with a schist provenance.

Formation (age): M2,3

Measurements:

- Bedding: 14/48

12.16

GPS: 44.05454, 18.11053

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, and conglomerate beds similar to 12.14, 12.15.

Formation (age): M2,3

Measurements:

- Bedding: 42/16

12.17

GPS: 44.05474, 18.11011

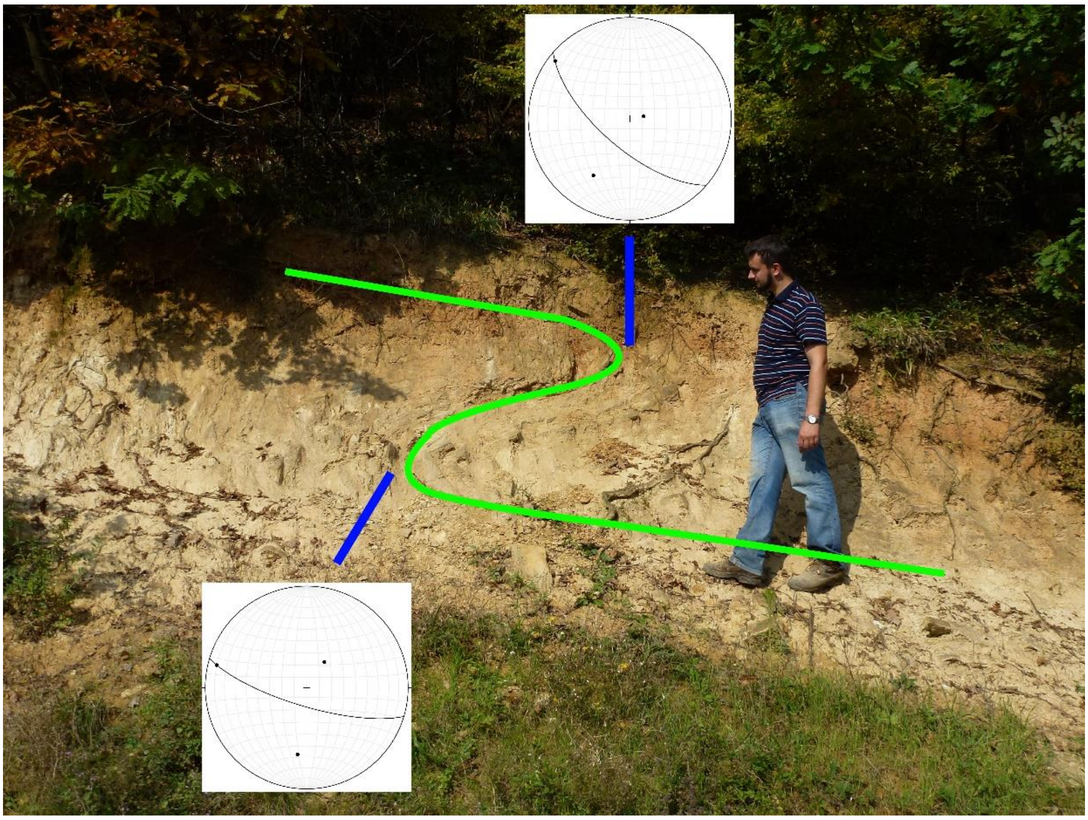
Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, and conglomerate beds with schist provenance similar to 12.14, 12.15.

Formation (age): M2,3

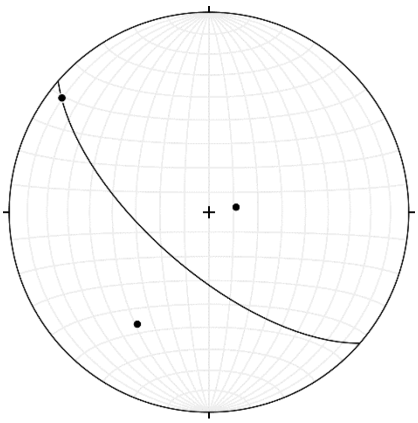
Other observations: This might be a slump and not a compressional feature, but in the field it did not look like a slump.

Pictures/sketches:

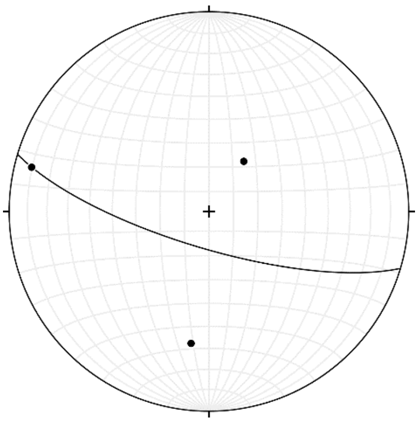


Measurements:

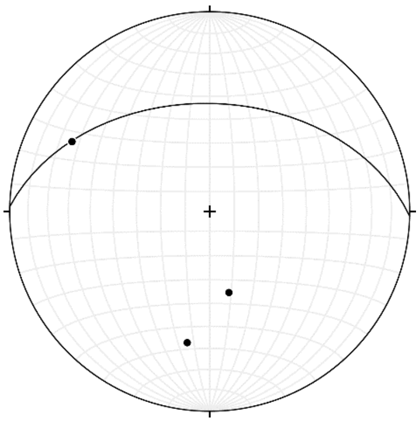
- Bedding: B1 12/35, B2 33/56, B3 258/11, B4 214/25, B5 215/72, B6 8/56, B7 10/56, B8 347/34, B9 18/45, B10 2/37
- Fold hinges/axial planes: 308/7, 221/67 (a), 284/9, 197/75 (b), 297/23, 1/45 (syncline not visible to the right of the picture) (c)



(a)



(b)



(c)

12.18

GPS: 44.05477, 18.10885

Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, with large chaotic matrix/clasdt supported conglomerate beds, with huge schist blocks inside (upto 40 cm, see picture)

Formation (age): M2,3

Pictures/sketches:

Measurements:

Bedding: 12/43

12.19

GPS: 44.05389, 18.1104

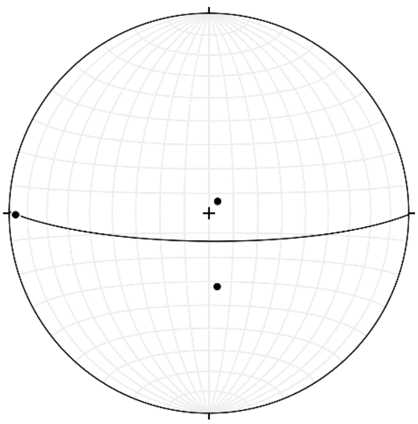
Location: Dobrinje-Gora back road

Lithology: Thinly bedded yellow marls and fine sandstones, with large chaotic matrix/clasdt supported conglomerate beds, with huge schist blocks inside (upto 40 cm, see picture)

Formation (age): M2,3

Measurements:

- Bedding: B1 213/6, B2 354/30
- Fold hinge/axial plane: 270/3, 180/79



12.21

GPS: 44.05198, 18.11976

Location: Dobrinje village (large parking spot in front of the houses, outcrop in the curve of the road

Lithology: Marls with some sandier layers, and some clast supported conglomerate layers with schist provenance.

Formation (age): M2,3

Other observations: All fining upwards no clear folding.

Measurements:

- Bedding: B1 195/65, B2 195/76, B3 195/86

12.20, 22-24

GPS: around 44.04956, 18.12079 (12.22) & 44.04876, 18.12167 (12.23)

Location: Limestone block east of Dobrinje

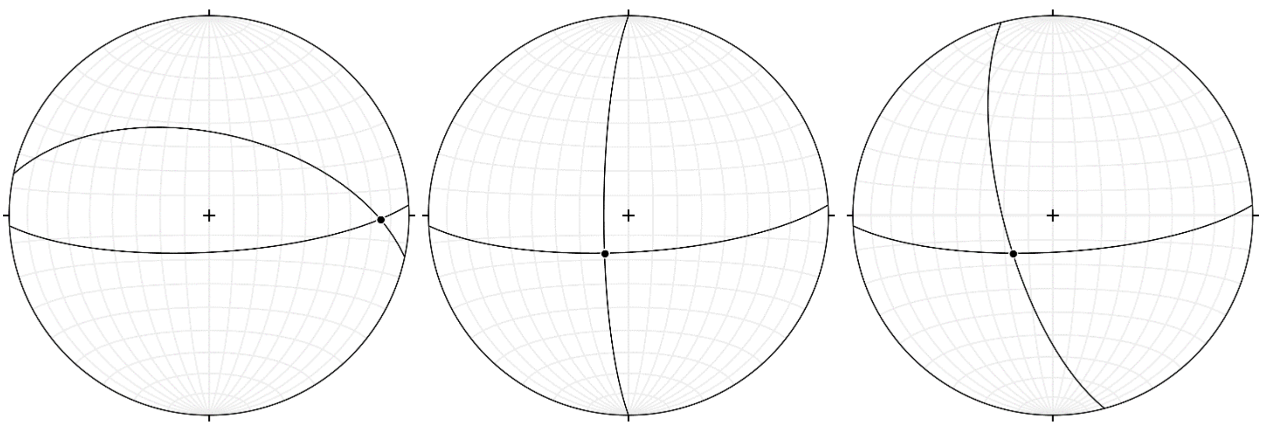
Lithology: Recrystallized limestone (Triassic), brecciated strongly is some parts.

Formation (age): M2,3 on the map

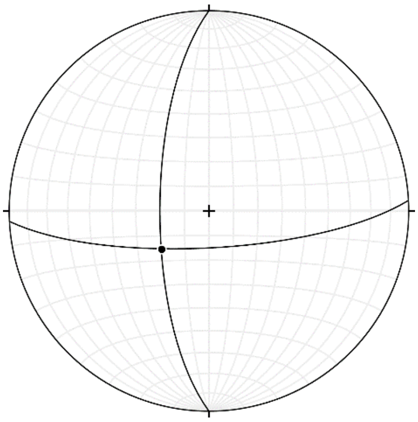
Other observations: Either a huge block of Triassic rolled down paleorelief to be found inbetween the M2,3 or the thrust contact which is very close has brought it to the surface. But why do we only find this piece? West of the highway similar blocks are visible/found.

Measurements:

- Planes in the limestones (origin unclear, likely cleavage): 205/31, ss lineation w110, 58/72, ss lineation 134/16
- Bedding: 177/75
- Cleavage: C1 12/56 (a), C2 270/80 (b), C3 255/70 (c), C4 270/70 (d)
- Intersection lineations: 91/16 (a), 212/75 (b), 227/68 (c), 232/65 (d)



(a) (b) (c)



(d)

13.3

GPS: 43.95627, 18.16715

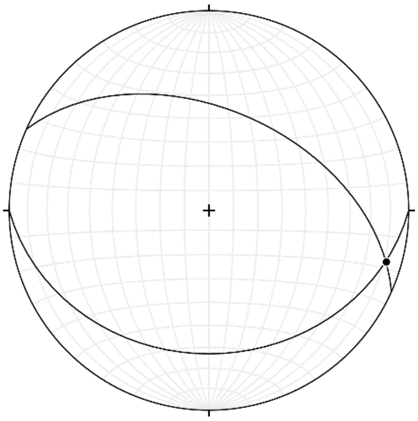
Location: Close to Grajani, on the Visoko/Kiseljak road

Lithology: Marls and fine-medium sand beds interbedded

Formation (age): M2,3

Measurements:

- Bedding: 180/29
- Cleavage: 24/48
- Intersection lineation: 106/9



13.4

GPS: 43.96935, 18.18412

Location: South of Visoko, east of Pyramid Sunca and west of Zbilje

Lithology: Marls and fine-medium sand beds interbedded, turbidite beds are quite thin 1-2cm

Formation (age): M2,3

Measurements:

- Fault: 4/61, riedels 314/45, 354/50 (apparent reverse)

13.5

GPS: 44.03242, 18.18737

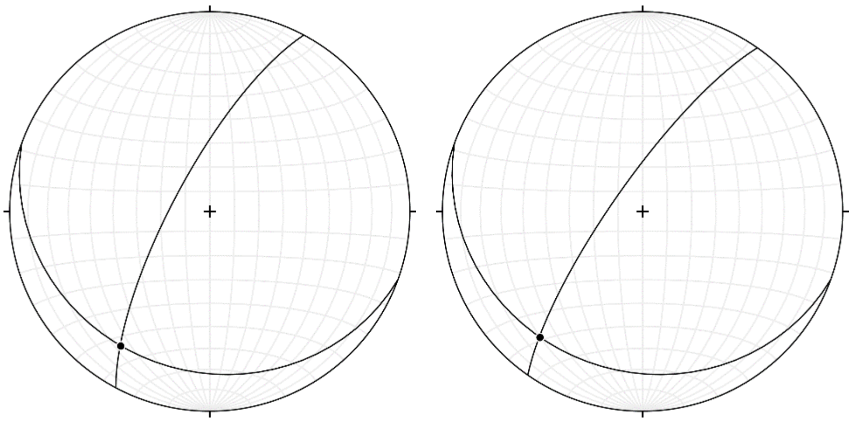
Location: South of Smrsnica, busstop for the school children

Lithology: Thick fine-medium sandbeds overlain by thin sandbeds interbedded with marls containing ostracods (turbidites).

Formation (age): M2,3

Measurements:

- Bedding: 200/21
- Cleavage: 298/75, 305/78
- Intersection lineations: 214/20 (a), 219/20 (b)



(a) *(b)*

14.3

GPS: 44.18704, 17.81627

Location: Close to Preocica

Lithology: Stratified, sub-rounded, clast/matrix supported conglomerate interbedded with fine-medium sandbeds.

Formation (age): M2,3

Measurements:

- Bedding: 200/21
- Cleavage: 298/75, 305/78
- Intersection lineations: 214/20 (a), 219/20 (b)

14.4

GPS: 44.11415, 17.95306

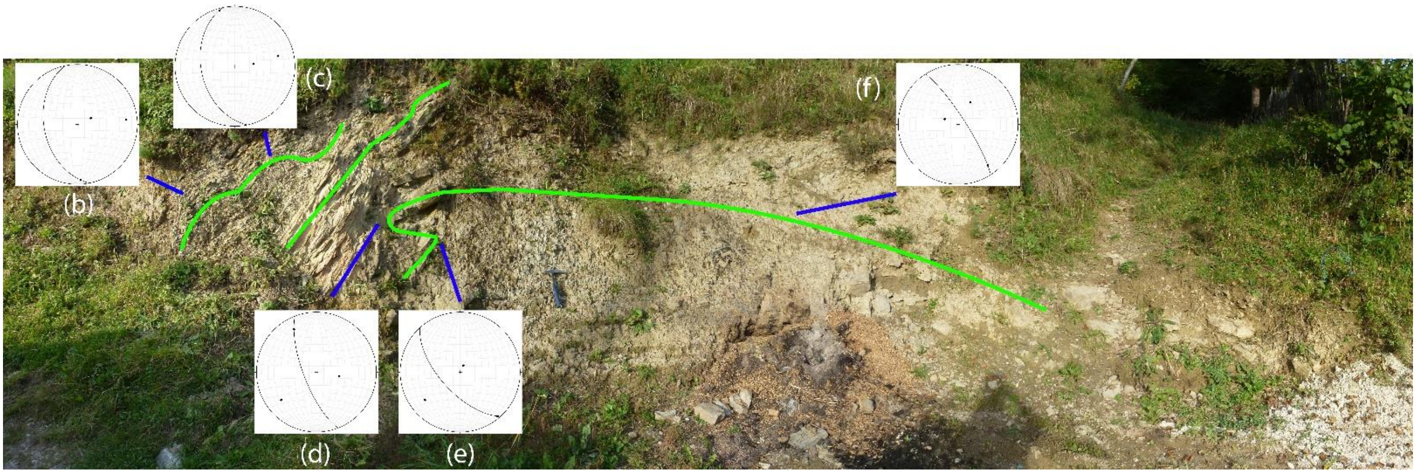
Location: On the road to Gornja Visnjica, (fire place cutout infront of driveway of house, very steep road)

Lithology: Thinly bedded grey marls interbedded with 2-10cm fine sandstone beds.

Formation (age): M2,3

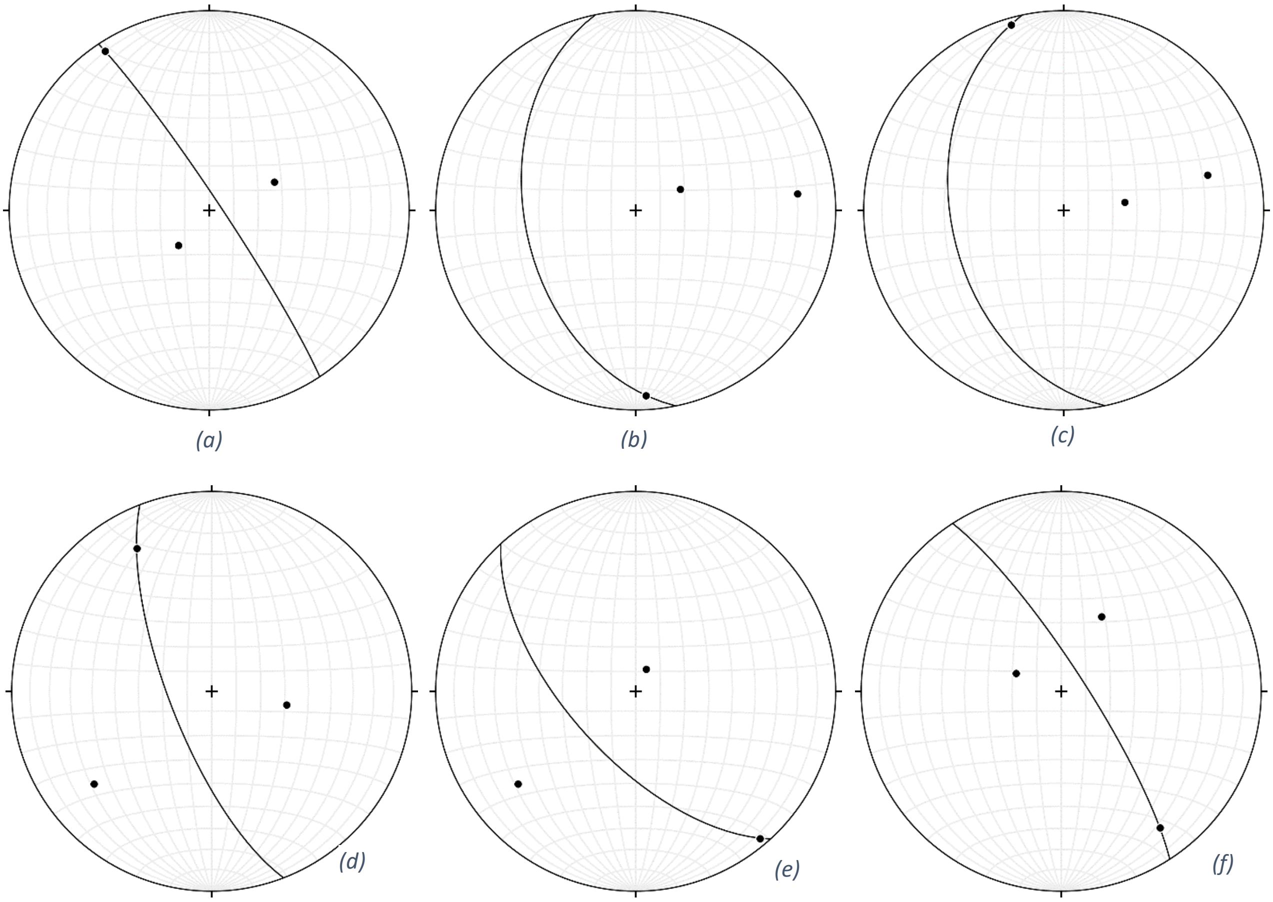
Other observations: Structure seems like it is the collapsed hinge of a large fault, clearly less competent layers (marls) are “destroyed” more than the more competent sandstone

Pictures/sketches:



Measurements:

- Bedding: B1 246/29, B2 42/19, B3 264/70, B4 244/20, B5 256/63, B6 262/25, B7 248/44, B8 235/25, B9 268/50, B10 280/31, B11 245/58, B12 52/64, B13 204/10, B14 122/20, B15 210/20, B16 208/35
- Fold hinges/axial planes: 327/5, 56/85 (a), 177/8, 258/44 (b), 344/4, 258/43 (c), 332/20, 249/73 (d), 140/4, 228/63 (e), 144/17, 57/80 (f)



15.1

GPS: 44.09636, 18.14241

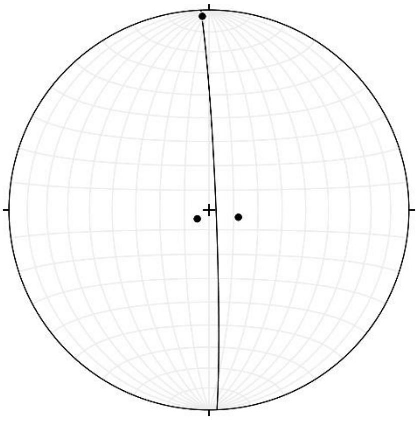
Location: South of Bjelavici close to Brezani

Lithology: Grey marls rich in organic content.

Formation (age): 2M2

Measurements:

- Bedding: B1 283/12, B2 56/6
- Fold hinge/axial plane: 358/3, 88/87



15.2

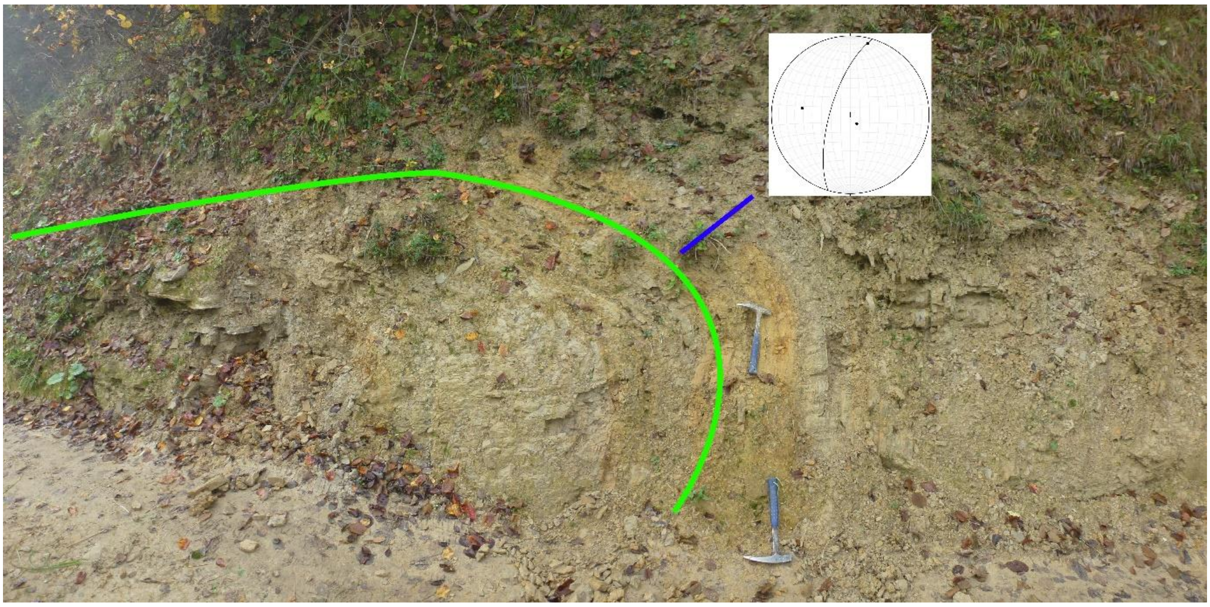
GPS: 44.0964, 18.1413

Location: South of Bjelavici close to Brezani

Lithology: Grey-orange/yellow marls rich in organic content, some thin (1-2cm) fine sandstone beds.

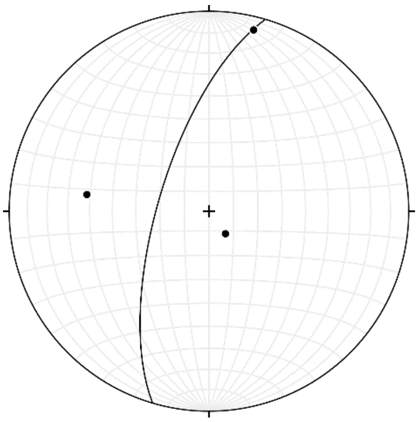
Formation (age): 2M2

Pictures/sketches:



Measurements:

- Bedding: B1 324/11, B2 277/88, B3 98/52, B4 200/6 (structureless bedding)
- Fold hinge/axial plane: 14/7, 286/69



15.3

GPS: 44.09647, 18.14126

Location: South of Bjelavici close to Brezani

Lithology: Grey marls rich in organic content.

Formation (age): 2M2

Measurements:

- Bedding: 56/9

15.4

GPS: 44.09658, 18.14105

Location: South of Bjelavici close to Brezani

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter.

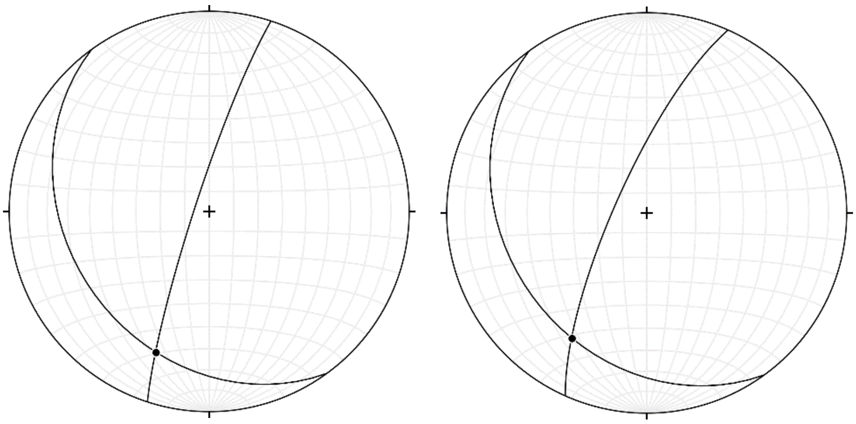
Formation (age): 2M2

Other observations: Strange vertical bedding in the hangingwall, would be expected in the footwall.

Pictures/sketches:

Measurements:

- Bedding: B1 190/15, B2 288/84, B3 294/77
- Fault: F1 290/34, (apparent reverse)
- Fold hinge: 182/14 (estimated in the field)
- Cleavage: C1 234/30
- Intersection lineations: [b2] 201/26 (a), [b3] 211/28 (b)



(a) *(b)*

15.5

GPS: 44.09662, 18.14079

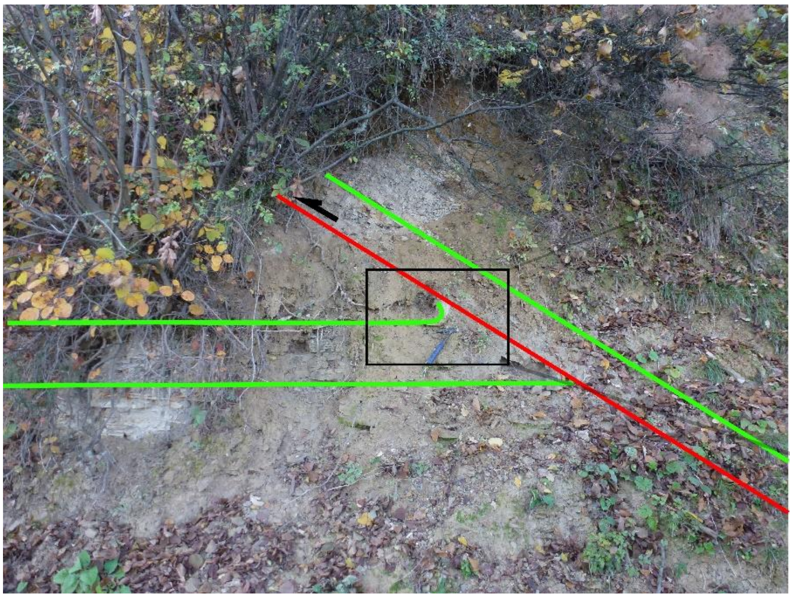
Location: South of Bjelavici close to Brezani

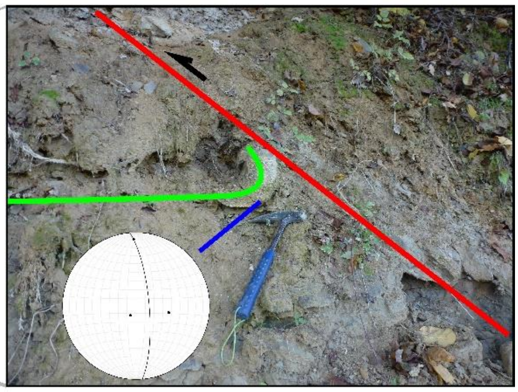
Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter.

Formation (age): 2M2

Other observations: Thrust fold, interpreted in the field as an overturned syncline.

Pictures/sketches:





Measurements:

- Bedding: B1 33/12, B2 281/37
- Fault: 33/12 (bedding parallel), (apparent reverse)
- Fold hinge/axial plane: 358/10, 85/76

15.6

GPS: 44.09664, 18.14025

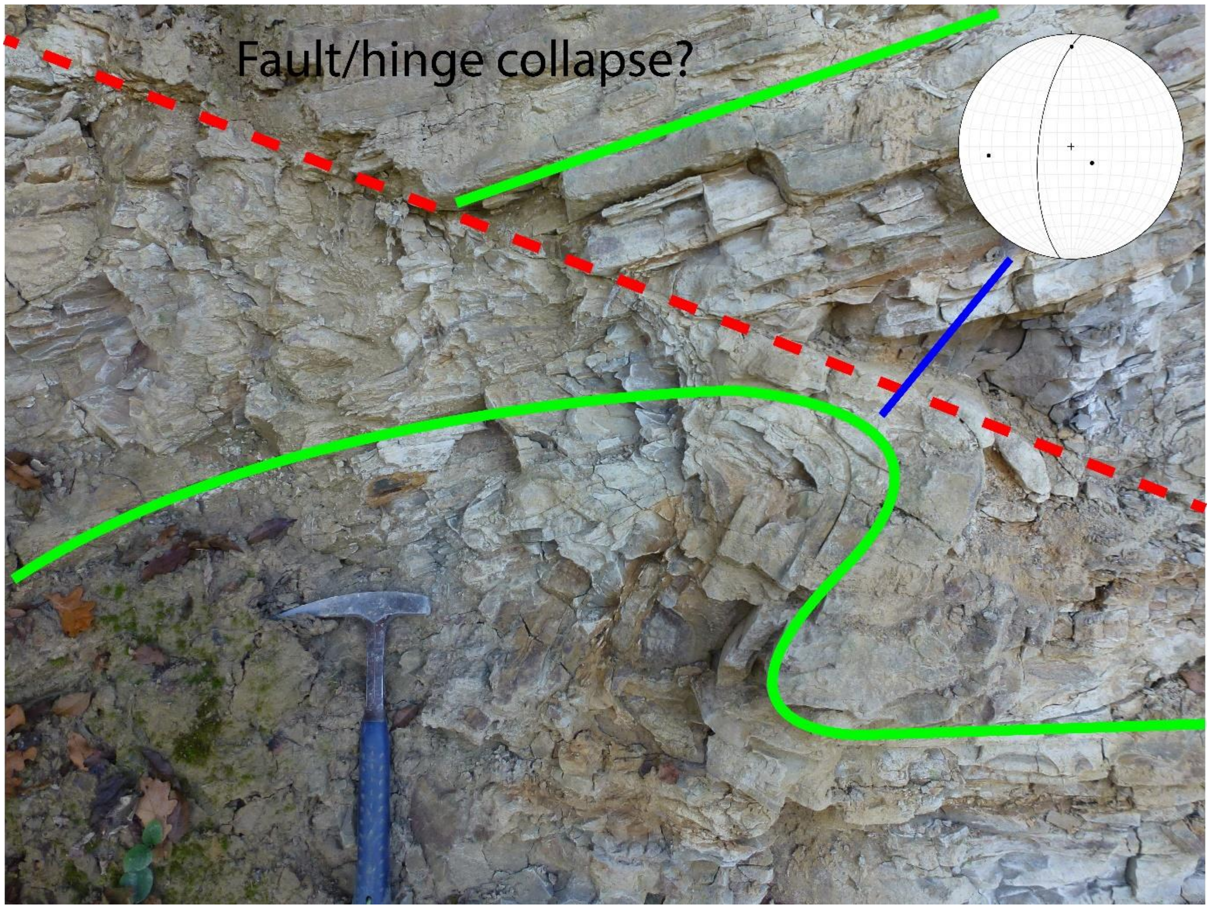
Location: South of Bjelavici close to Brezani

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter, and thicker sandbeds appear (5-20cm).

Formation (age): 2M2

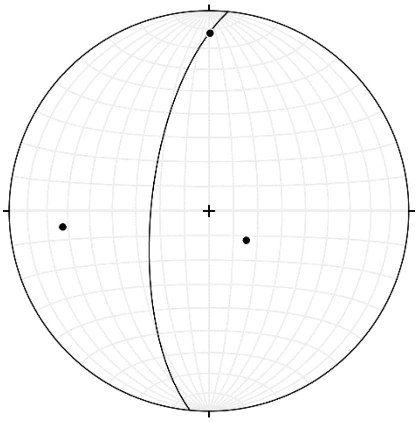
Other observations: Looks like a fault running through but it does not continue, possibly a hinge collapse feature.

Pictures/sketches:



Measurements:

- Bedding: B1 96/22, B2 84/63, B3 308/19, B4 82/17, B5 75/10
- Fault: no measurement
- Fold hinge/axial plane: 12/0, 276/66



15.7

GPS: 44.09695, 18.13997

Location: South of Bjelavici close to Brezani

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter, and thicker sandbeds appear (5-20cm).

Formation (age): 2M2

Measurements:

- Bedding: 115/24

15.8

GPS: 44.09702, 18.13901

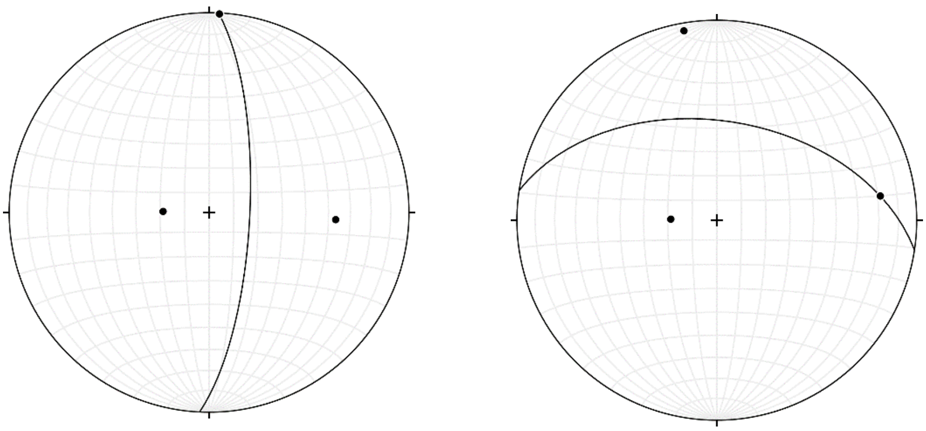
Location: South of Bjelavici close to Brezani

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter, and thicker sandbeds appear (5-20cm).

Formation (age): 2M2

Measurements:

- Bedding: B1 276/50, B2 270/50, B3 92/19, B4 170/86
- Fold hinges/axial planes: [b1-b2,b3] 3/0, 93/73 (a), [b3,b4] 81/19, 9/45 (b)



(a) *(b)*

15.9

GPS: 44.09702, 18.13901

Location: South of Obre, on the hill east of the termoelektrana plant.

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter, and sandbeds appear (5-20cm).

Formation (age): 2M2

Measurements:

- Bedding: 278/22

15.11

GPS: 44.08549, 18.13445

Location: Road to Slapnica, east of termoelektrana plant dumpsite.

Lithology: Thinly bedded (1-5cm) silty brown/grey marl rich in organic matter, and sandbeds appear (5-20cm).

Formation (age): 2M2

Measurements:

- Bedding: 188/10

15.12

GPS: 44.08597, 18.13184

Location: Road to Slapnica, east of termoelektrana plant dumpsite, at the intersection with Dobrinje back road

Lithology: Silty marls interbedded with fine-medium sandstone beds (1-10cm) fining upwards.

Formation (age): 2M2

Measurements:

- Bedding: 120/4

15.13

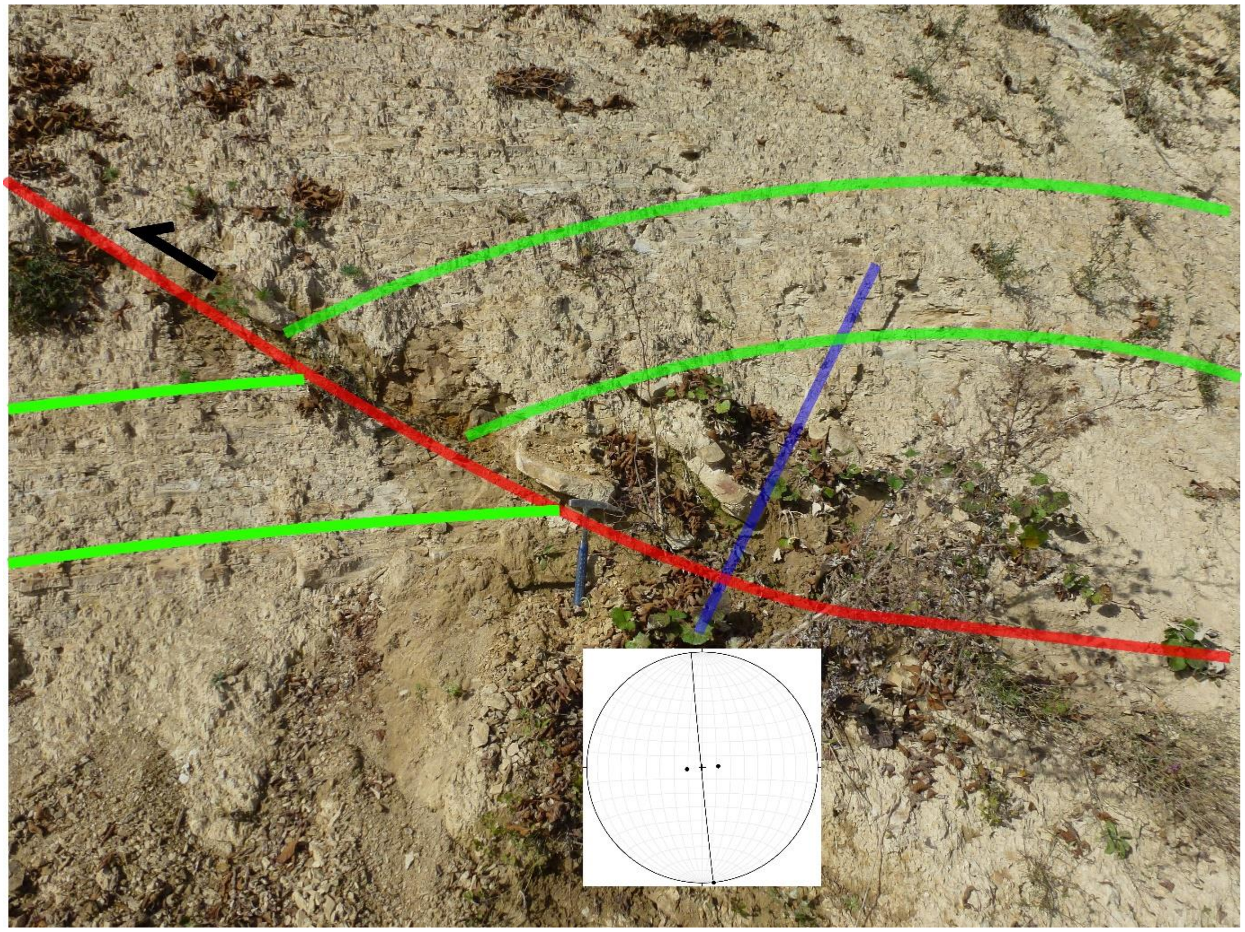
GPS: 44.08684, 18.12753

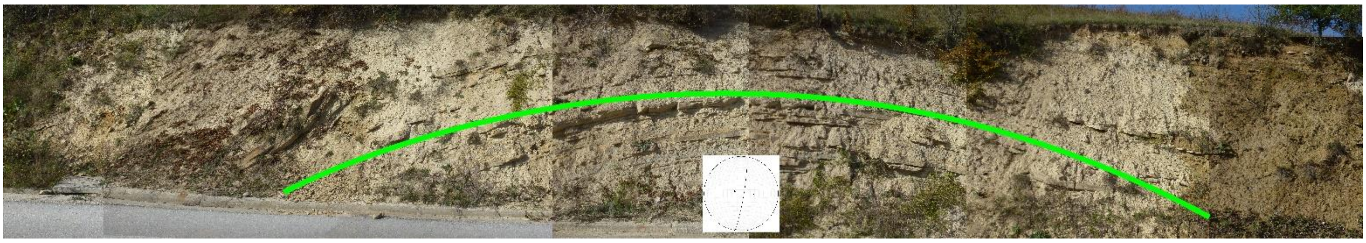
Location: Road to Slapnica, above termoelektrana plant dumpsite.

Lithology: Silty marls interbedded with some fine-medium sandstone beds (1-5cm).

Formation (age): 2M2

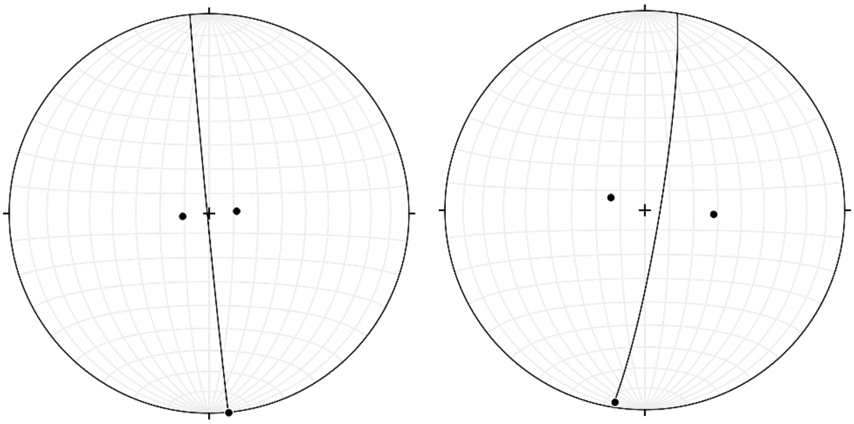
Pictures/sketches:





Measurements:

- Bedding: B1 85/11, B2 264/11, B3 111/15, B4 273/28
- Faults: F1 270/58 (apparent reverse), F2 75/21 (antithetic to F1 but that would make F1 normal, possibly an inverted/tilted normal fault.)
- Fold hinges/axial planes: 175/0, 265/89 (a), 189/3, 99/84 (b)



(a) (b)

15.14

GPS: 44.08727, 18.12664

Location: Road to Slapnica, above termoelektrana plant dumpsite.

Lithology: Silty marls interbedded with some non graded fine sandstone beds (5-10cm), weak wavy lamination.

Formation (age): 2M2

Pictures/measurements:

Measurements:

- Bedding: B1 150/9

15.15

GPS: 44.08783, 18.11973

Location: Road to Slapnica, at intersection with Dobrinje road, above termoelektrana plant dumpsite.

Lithology: Silty marls interbedded by fine sandstones (5-7cm) with minor fining upward.

Formation (age): 2M2

Pictures/measurements:

Measurements:

- Bedding: B2 162/11

15.16

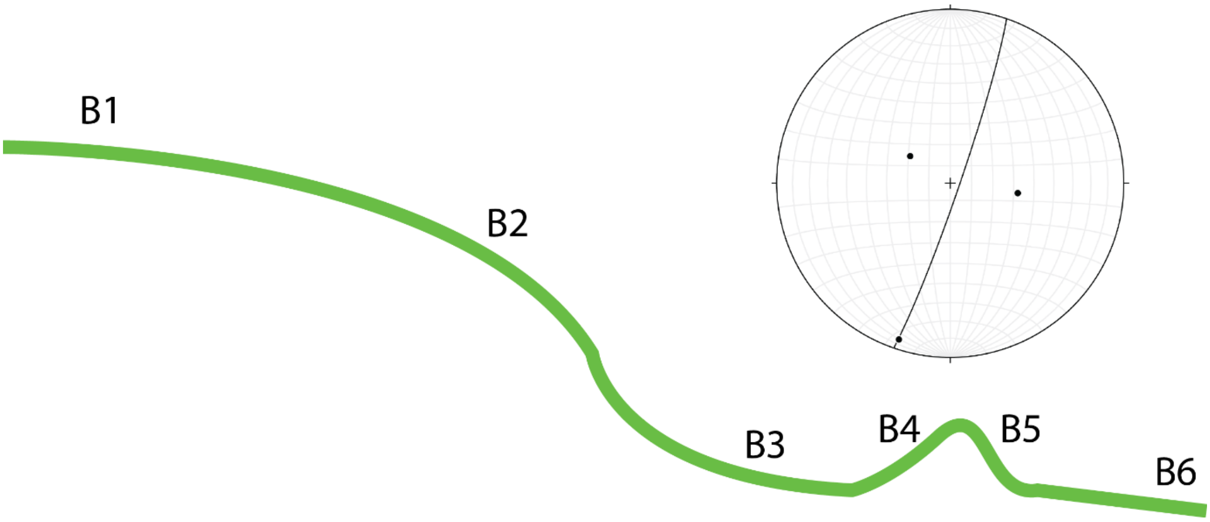
GPS: 44.08636, 18.11901

Location: Back road to Dobrinje, below the termoelektrana plant dumpsite.

Lithology: Brown silty marls interbedded by fine sandstones (1-5cm).

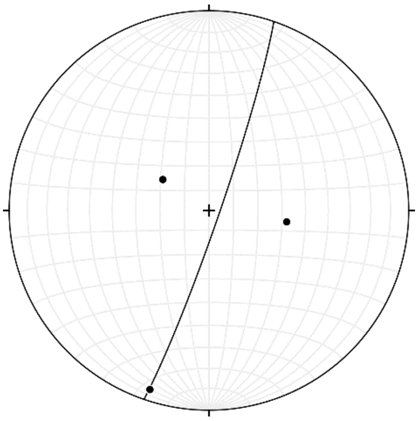
Formation (age): 2M2

Pictures/measurements:



Measurements:

- Bedding: B1 189/10, B2 131/32, B3 204/5, B4 278/32, B5 124/23, B6 178/9
- Fold hinge/axial plane: 199/7, 109/86 (B4,B5)



15.17

GPS: 44.08622, 18.11913

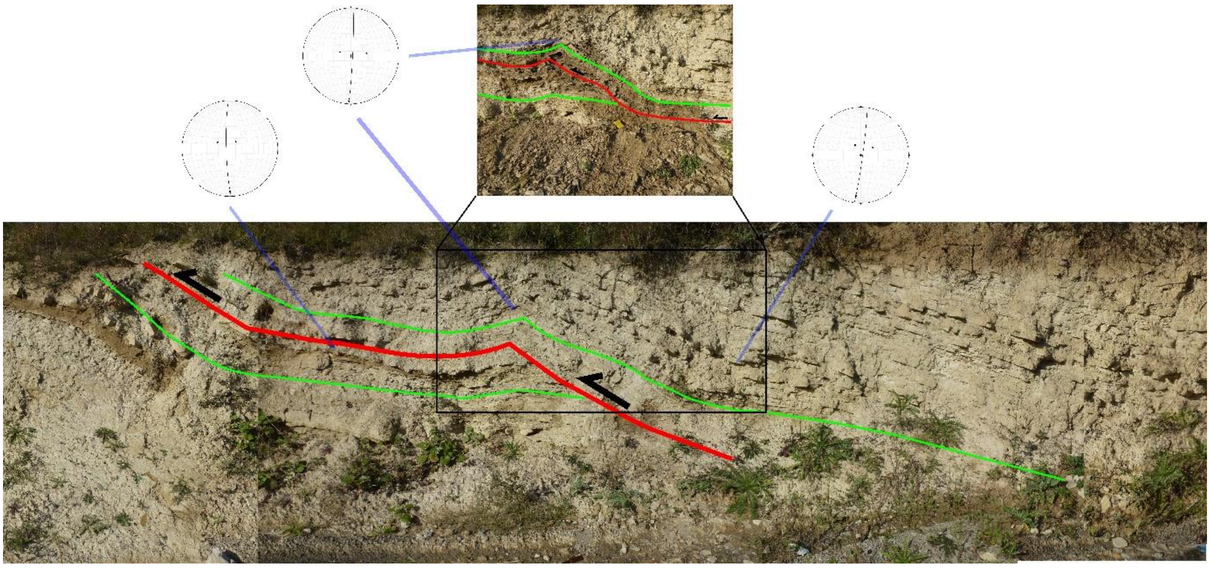
Location: Back road to Dobrinje, below the termoelektrana plant dumpsite.

Lithology: Brown silty marls interbedded by fine sandstones (1-5cm), ash layer in the bottom of the outcrop (5mm-10mm).

Formation (age): 2M2

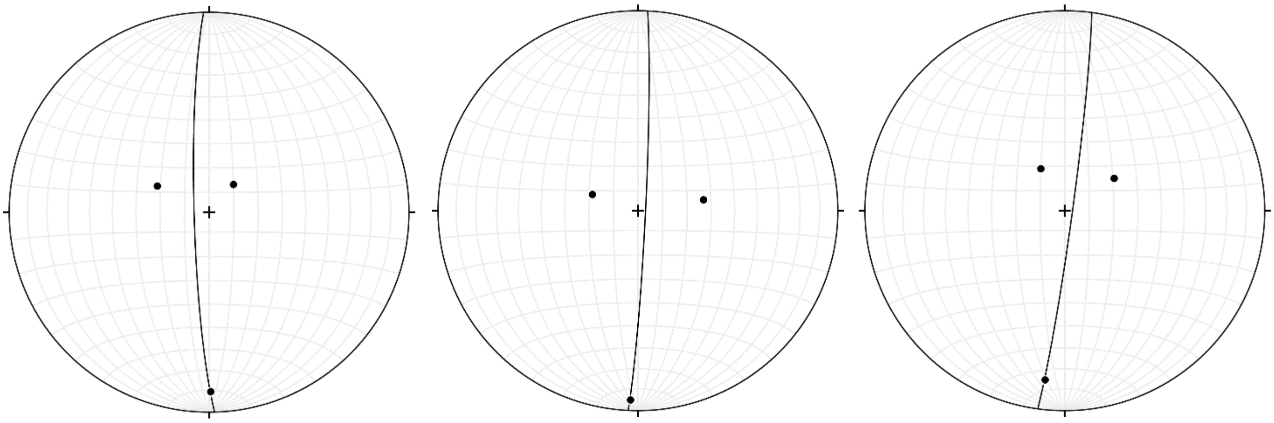
Other observations: A slumped sandstone bed enters the marl layers right (W) of the 'chevron' fold. The rheological difference between the silty marls and sandstones is demonstrated by an unfaulted sandstone layer beneath the thrust (sort of a detachment) and the much more extreme deformation of the 'rheologically weak' silty marls the top.

Pictures/sketches:



Measurements:

- Bedding: B1 220/15, B2 117/24, B3 184/16, B4 240/24, B5 260/27, B6 110/20, B7 150/20, B8 236/24, B9 166/9
- Fault: 115/26 (apparent reverse)
- Fold hinge/axial plane: 180/12, 268/84 (B1,B2 anticline)(a), 182/6, 93/87 (B5,B6 anticline)(b), 187/16, 98/87 (B7,B8 syncline)(c)



(a) *(b)* *(c)*

15.18

GPS: 44.05862, 18.10856

Location: Back road to Dobrinje, east of Seoce and highway, opposite to highway bridge .

Lithology: Fine-medium sandstone beds, fining upwards (2-12cm) with coarse sand at the bottom of the beds., with likely some silty marls inbetween (badly exposed)

Formation (age): M2,3

Measurements:

- Bedding: B1 212/66

16.1

GPS: 44.08492, 18.10431

Location: West of highway and termoelektrana plant, north of Donja Prapatnica

Lithology: Silty marl with high sand content, interbedded with fine-medium sandstone beds (5cm), wavy appearance, fine to no grading.

Formation (age): 2M2

Measurements:

- Bedding: 260/21

16.2

GPS: 44.08957, 18.10083

Location: West of highway and termoelektrana plant, north of Kujavce.

Lithology: Silty marl with occasional 30cm fine-medium sandstone beds, wavy character, slumped layers and loading structures (soft-sediment deformation).

Formation (age): 2M2

Measurements:

- Bedding: 220/10

16.3

GPS: 44.08999, 18.09923

Location: West of highway and termoelektrana plant, north of Kujavce.

Lithology: Silty marl with fine-medium sandstone beds.

Formation (age): 2M2

Measurements:

- Bedding: 54/10

16.4

GPS: 44.08946, 18.10186

Location: West of highway and termoelektrana plant, north of Kujavce.

Lithology: Silty marl with fine-medium sandstone beds.

Formation (age): 2M2

Measurements:

- Bedding: 242/20

16.5

GPS: 44.09024, 18.10193

Location: West of highway and termoelektrana plant, north of Kujavce.

Lithology: Silty marl with fine-medium sandstone beds.

Formation (age): 2M2

Measurements:

- Bedding: 314/8

16.6

GPS: 44.09113, 18.10203

Location: West of highway and termoelektrana plant, north of Kujavce.

Lithology: Silty marl with fine-medium sandstone beds.

Formation (age): 2M2

Measurements:

- Bedding: 300/0

16.7

GPS: 44.07888, 18.09235

Location: West of highway and termoelektrana plant, and Donja Prapatnica.

Lithology: Silty marl with fine sandstone beds, wavy character, fining upwards, some coarser pebble layers at the bases of beds, and amalgamated beds.

Formation (age): 2M2

Measurements:

- Bedding: 200/39

16.8

GPS: 44.08236, 18.09143

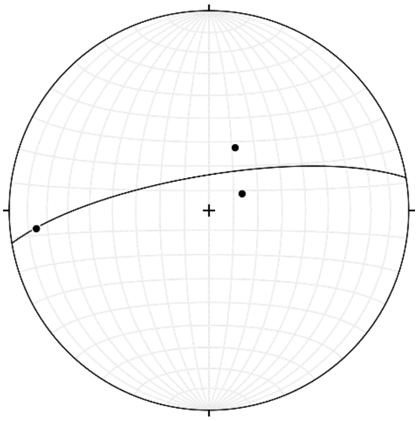
Location: West of highway and termoelektrana plant, and Donja Prapatnica, road to Javor.

Lithology: Fine sandstone beds (5-10cm) alternating quickly with siltier intervals, erosive bases, coarse lenses inside sandstone beds with chert clasts (±1cm), intraclasts → mudchips, slumping .

Formation (age): 2M2, close to border with M2,3

Measurements:

- Bedding: B1 200/38, B2 202/28, B3 242/15
- Fold hinge/axial plane: 264/14, 351/76



16.9

GPS: 44.08715, 44.08715

Location: West of highway and termoelektrana plant, and Donja Prapatnica, road to Javor.

Lithology: Fine sandstone beds (5-10cm) alternating quickly with siltier intervals, erosive bases, coarse lenses inside sandstone beds with chert clasts (±1cm), intraclasts → mudchips, slumping .

Formation (age): 2M2

Measurements:

- Bedding: B1 124/14

16.10

GPS: 44.08887, 18.08586

Location: Close to Javor.

Lithology: Fine sandstone beds (5-10cm) alternating quickly with siltier intervals, erosive bases, coarse lenses inside sandstone beds with chert clasts (±1cm), intraclasts → mudchips, slumping .

Formation (age): M2,3, close to 2M2

Measurements:

- Bedding: B1 170/11

16.11

GPS: 44.08392, 18.06261

Location: Close to Gornja Prapatnica, next to gravejard.

Lithology: Fine sandstone beds (5-10cm) alternating quickly with siltier intervals, laminar appearance, high sandstone percentage.

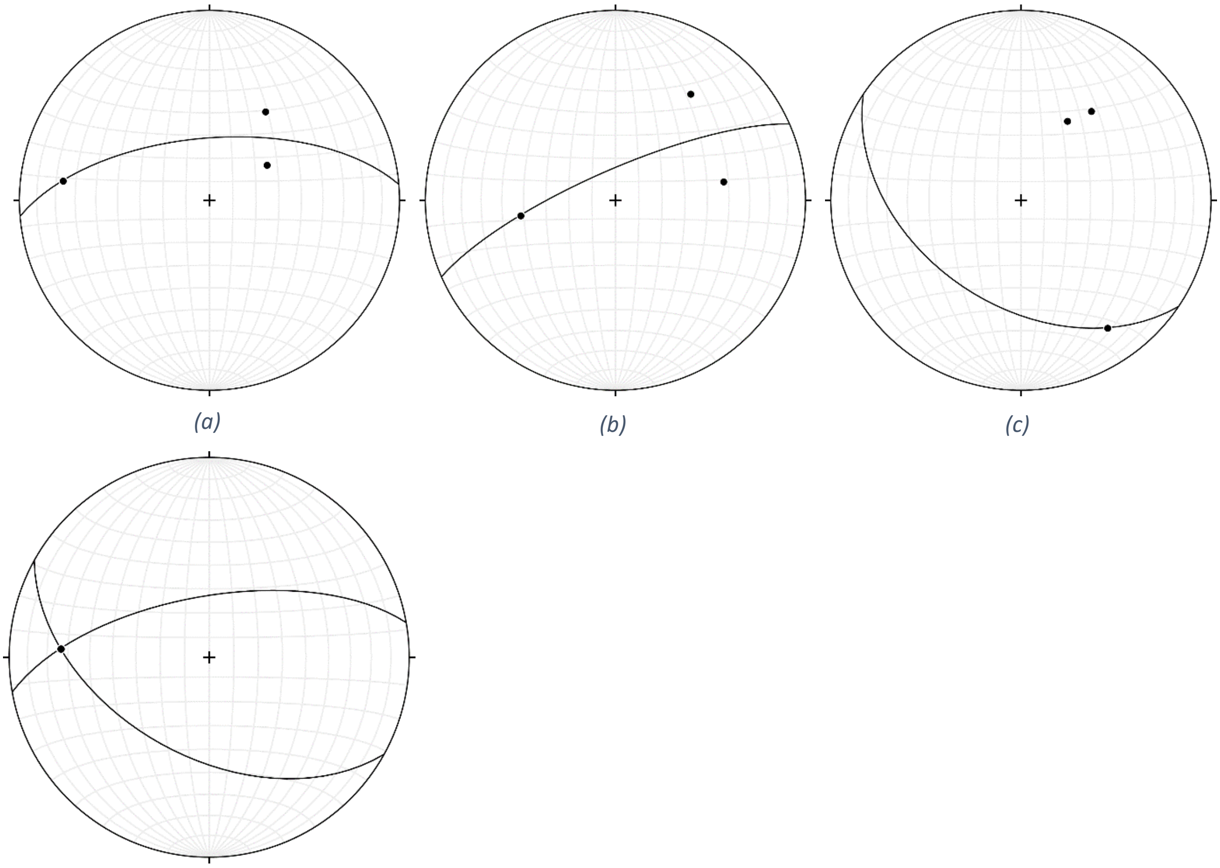
Formation (age): M2,3

Pictures/sketches:

PICTURES KARIN

Measurements:

- Bedding: B1 215/43, B2 209/49, B3 238/29, B4 215/58, B5 260/48, B6 210/40, B7 218/50
- Cleavage: C2 350/65
- Fold hinges/axial planes: 278/23, 355/63 (B1B2av,B3)(a), 264/48, 336/77 (B4,B5)(c), 146/20, 214/45 (B6,B7)(d)
- Intersection lineation: 273/26 (C2, B2)(b)



(a) *(b)* *(c)* *(d)*

16.12

GPS: 44.08401, 18.06239

Location: Close to Gornja Prapatnica, next to gravejard.

Lithology: Cobble size conglomerate, predominantly Bosnian schist.

Formation (age): M2,3

Other observations: North of 16.11

Measurements:

- Bedding: B1 350/20

16.13

GPS: 44.08419, 18.06205

Location: Close to Gornja Prapatnica, next to gravejard.

Lithology: Fine-medium non-graded sandstone, intraclasts and silty marl interbeds of 1 cm max, lithology becoming more and more sand dominated.

Formation (age): M2,3

Measurements:

- Bedding: B1 192/42

16.14

GPS: 44.08479, 18.06106

Location: Close to Gornja Prapatnica, next to gravejard.

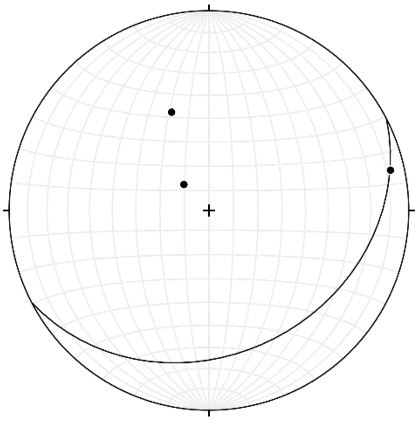
Lithology: Fine-medium non-graded sandstone.

Formation (age): M2,3

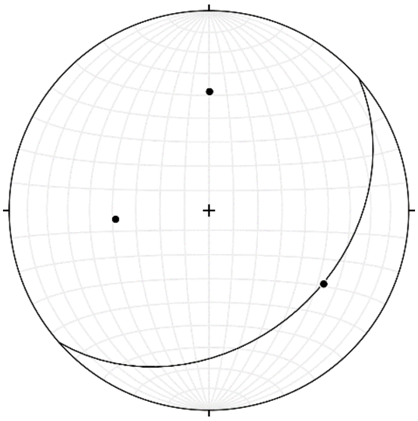
Pictures/sketches:

Measurements:

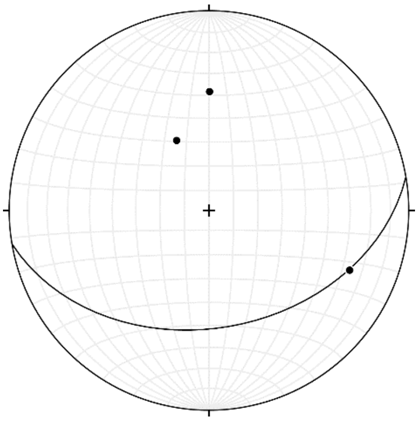
- Bedding: B1 173/44, B2 136/15, B3 159/44, B4 85/39, B5 155/32, B6 165/30, B7 170/40, B8 180/50
- Fold hinges/axial planes: 77/8, 153/29 (B2,B3 syncline)(a), 123/33, 139/34 (B4,B8 anticline)(b), 113/25, 170/41 (B5,B8 anticline)(c), 103/15, 174/39 (B6,B8 anticline)(d), 126/31, 129/31 (B4,B7 anticline)(e)



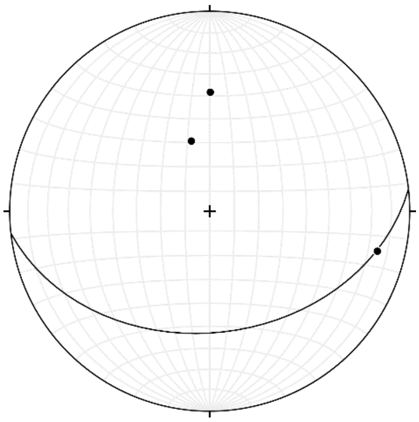
(a)

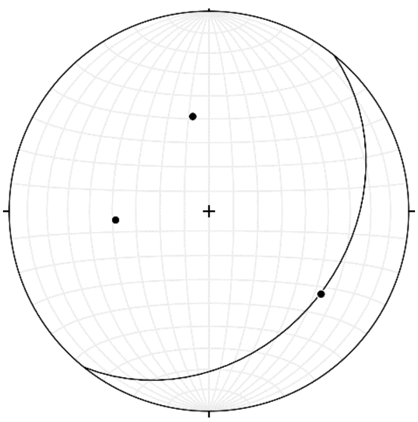


(b)



(c)





(e)

(d)

16.15

GPS: 44.08502, 18.06083

Location: Close to Gornja Prapatnica, next to gravejard.

Lithology: Fine-medium non-graded sandstone.

Formation (age): M2,3

Pictures/sketches:

Measurements:

- Bedding: B1 123/26, B2 103/22

16.16

GPS: 44.08795212, 18.0442009 (same as 3.8)

Location: Road to Sebinje.

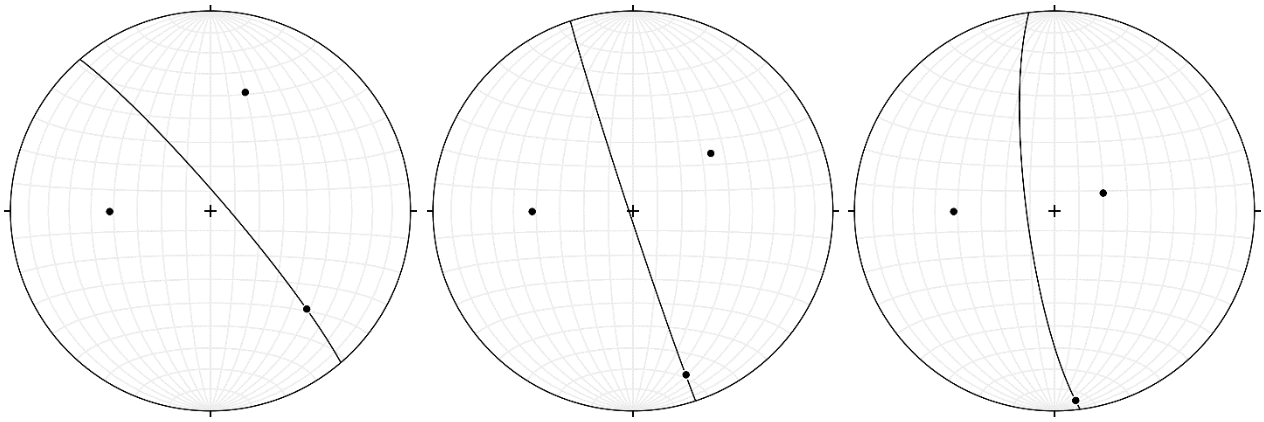
Lithology: Fine-medium sandstone interbedded with silty marls.

Formation (age): M2,3

Pictures/sketches: see 3.8

Measurements:

- Bedding: B1 90/42, B2 233/40, B3 249/21, B4 196/52
- Fold hinges/axial planes: 136/32, 49/84 (B1,B4 syncline)(a), 162/15, 252/89 (B1,B2) syncline)(b), 174/6, 263/79 (B5,B8 syncline)(c)



(a) *(b)* *(c)*

16.17

GPS: 44.08859, 18.04977

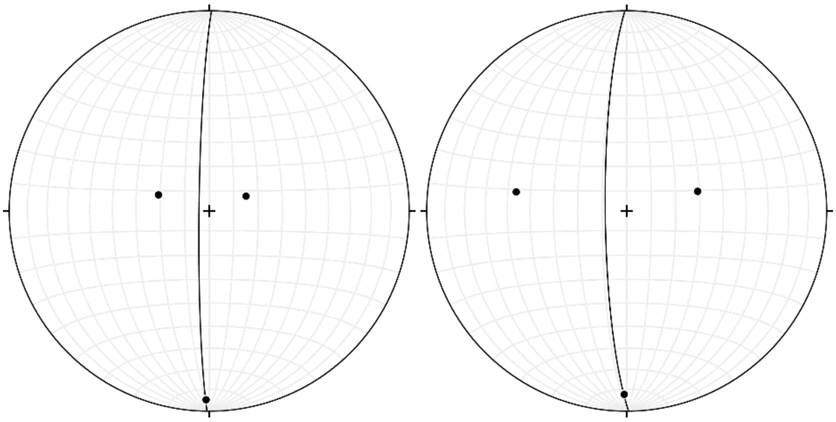
Location: Road to Sebinje.

Lithology: Fine sandstone dominated interbedded with silty marls lenses/layers (cm max).

Formation (age): M2,3

Measurements:

- Bedding: B1 254/30, B2 247/16, B3 108/22, B4 100/47
- Fold hinges/axial planes: 181/10, 270/81 (B1,B4 anticline)(a), 181/7, 271/86 (B2,B3)(b)



(a) *(b)*

16.18

GPS: 44.08996, 18.04145

Location: Road to Sebinje.

Lithology: Thinly bedded silty marl (no sandstone), organic matter content high

Formation (age): M2,3

Measurements:

- Bedding: B1 203/40

16.19

GPS: 44.09007, 18.04209

Location: Road to Sebinje.

Lithology: Thinly bedded silty marl (no sandstone), organic matter content high

Formation (age): M2,3

Measurements:

- Bedding: B1 212/48

16.20

GPS: 44.09017, 18.0429

Location: Road to Sebinje.

Lithology: Thinly bedded silty marl (no sandstone), organic matter content high

Formation (age): M2,3

Measurements:

- Bedding: B1 250/33, B2 197/37, B3 219/34

16.21

GPS: 44.12307285, 17.98738158

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Thinly bedded silty marl interbedded with fine-medium sandstone beds (5cm).

Formation (age): 1M2 close to border of M2,3

Measurements:

- Bedding: B1 221/19

17.1

GPS: 44.11331, 17.98682

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Brown silty marl interbedded with medium sandstone beds (5cm).

Formation (age): M2,3

Measurements:

- Bedding: ~B1 248/33

17.2

GPS: 44.11278, 17.98971

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Brown silty marl interbedded with medium sandstone beds (5cm).

Formation (age): M2,3

Measurements:

- Bedding: ~B1 313/13

17.3

GPS: 44.11131, 17.99034

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Conglomerate (clast size: pebble, average 1.2cm, max 5cm, sub-angular/sub-rounded, amalgamated beds, granula matrix, Bosnian schist, quartz, ferrigenous cement (debatable)), non erosive base, interbedded with silty marl (rhytmites (like Medrassa river section)

Formation (age): M2,3

Measurements:

- Bedding: B1 225/21

17.4

GPS: 44.10975, 17.99107

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Conglomerate (clast size: pebble, average 1.2cm, max 5cm, sub-angular/sub-rounded, amalgamated beds, granula matrix, Bosnian schist provenance, quartz, ferrigenous cement (debatable)), interbedded with silty marl and fine medium sandstone beds (5cm).

Formation (age): M2,3

Measurements:

- Bedding: ~B1 350/20

17.5

GPS: 44.10938782, 17.99154678

Location: Mountain road between Jehovina and Sopotnica.

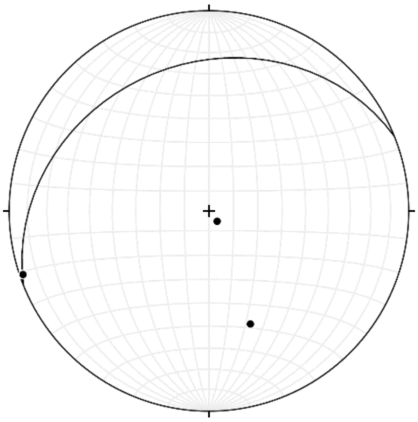
Lithology: ------ likely similar to 17.4

Formation (age): M2,3

Bedding-ArcGIS.docx

Measurements:

- Bedding: ~B1 355/15, B2 340/50, B3 322/5
- Fold hinge/axial plane: 251/2, 338/27



17.6

GPS: 44.10655, 17.99345

Location: Mountain road between Jehovina and Sopotnica.

Lithology: Grey silty marl

Formation (age): M2,3

Measurements:

- Bedding: 308/18

17.7-17.8

GPS: 44.10608544, 17.9926137 & 44.10582, 17.99242

Location: Mountain road between Jehovina and Sopotnica, giant outcrop along lumberjack road, just before climb to Hum.

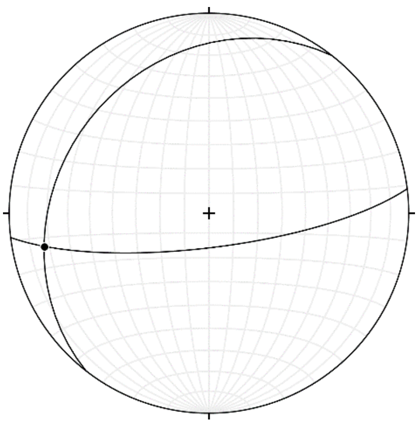
Lithology: Cobble-boulder conglomerate, schist provenance, clast supported but also parts with a granula matrix showing pebble imbrication, sub-rounded/sub-angular, erosive bases. Some limestone clasts (often brecciated)(Triassic/Permian, not Ugar). No finer grained lithology present.

Formation (age): M2,3

Pictures/sketches:

Measurements:

- Bedding: 308/25
- Cleavage: unclear what it is no clear sense of direction or movement visible, 173/76
- Intersection lineation: 259/17



17.9

GPS: No GPS point

Location: Mountain road between Jehovina and Sopotnica, past giant outcrop along lumberjack road, just before climb to Hum.

Lithology: Conglomerate, matrix supported sub-rounded/angular, poorly sorted, schist and quartz pebbles.

Formation (age): M2,3

Measurements:

- Bedding: 318/25

17.10

GPS: 44.10685, 17.98879

Location: On the climb to the top of mount Hum.

Lithology: Conglomerate, clast supported, pebble/cobble, coarse granula matrix, poorly sorted, schist and quartz pebbles.

Formation (age): M2,3

Measurements:

- Bedding: 235/20

17.11/conglotop

GPS: 44.09836, 17.98602 & 44.09787, 17.98374

Location: At the summit of mount Hum, grass field with rocks sticking out.

Lithology: Conglomerate, clast/matrix supported, pebble/cobble, coarse granula matrix, well rounded, moderately sorted, schist and quartz pebbles, weathered white.

Formation (age): M2,3

Pictures/sketches:

Measurements:

- Bedding: 214/19

17.12

GPS: (17.13) 44.15069, 17.95484

Location: Road in hill above Lasva dynamite section and Janjici.

Lithology: Homogenous, planar fine grained sandstone beds, fining upwards, amalgamated.

Formation (age): M2,3

Measurements:

- Bedding: 245/18

17.16

GPS: (17.17) 44.15093, 17.95653

Location: On the top of the hill above Lasva dynamite section and Janjici.

Lithology: Homogenous, planar fine grained sandstone beds, fining upwards, amalgamated.

Formation (age): M2,3

Measurements:

- Bedding: 216/20

18.1

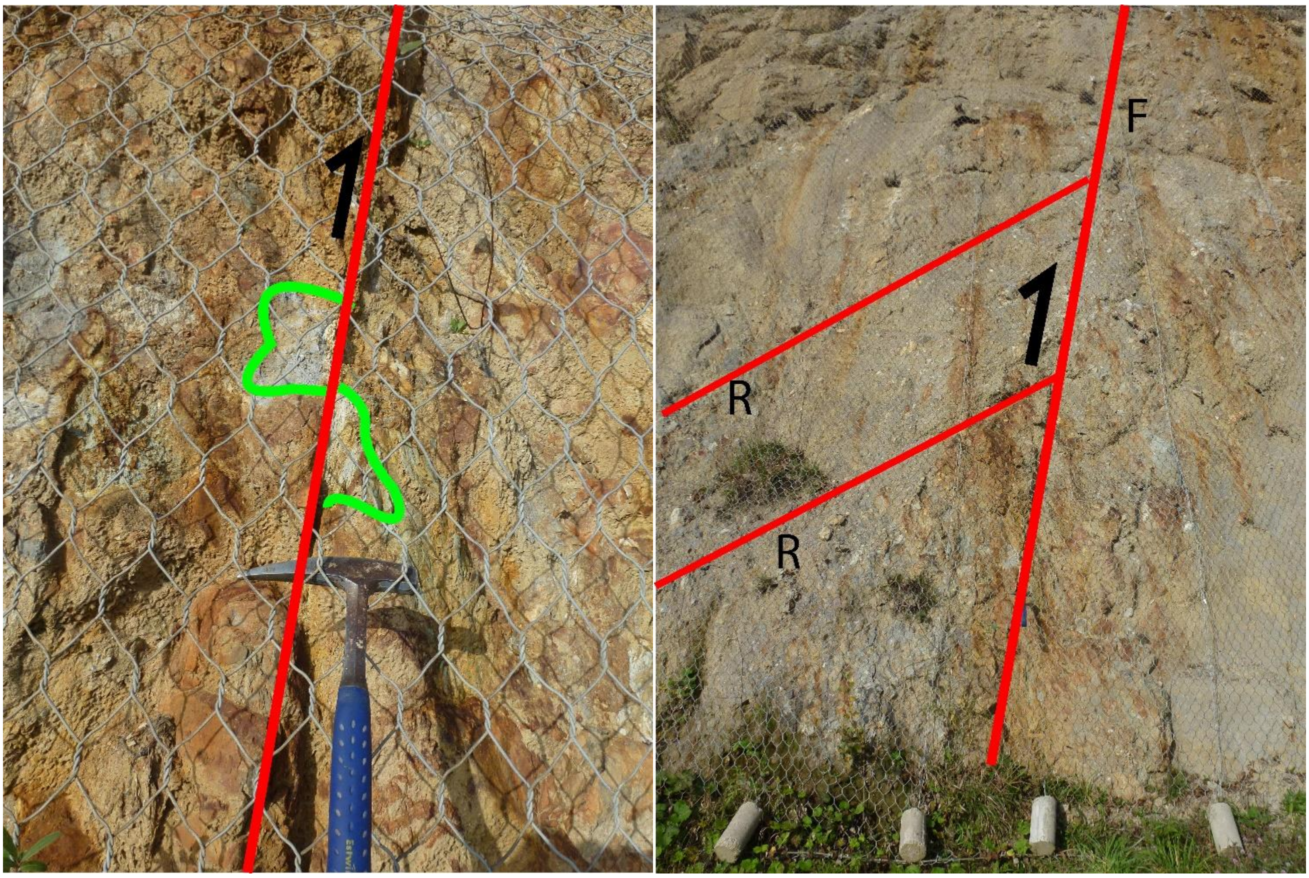
GPS: 44.06326, 18.1038

Location: Highway section, at the valley splitting it up into two.

Lithology: Pebble conglomerate, schist provenance, clast supported, sub-rounded/sub-angular,

Formation (age): 2M2 close to border with M2,3

Pictures/sketches:



Measurements:

- Bedding:
- Fault:
- Riedels:

18.2

GPS: 44.06868, 18.10651, 44.06871, 18.10636 (b), 44.06899, 18.10679 (c)

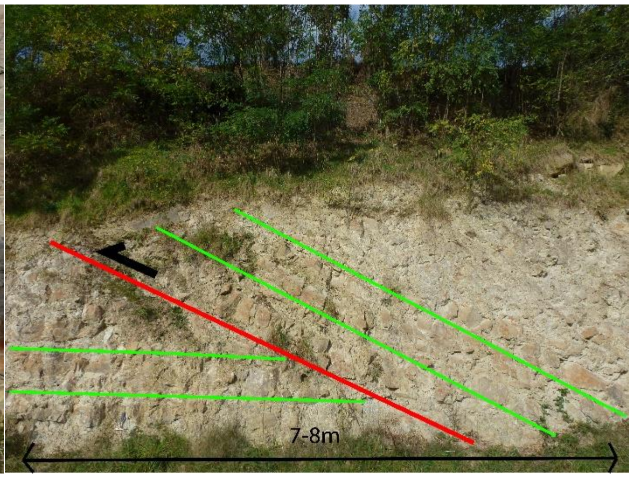
Location: Highway section, close to northern start of the section.

Lithology: Silty marls and sandstones (fine-medium), megabeds of pebble conglomerate with fine muddy/carbonate matrix, schist provenance, and a brecciated lithology which seems to contain the stemcrust boundstone particles similar to the Guca-Gora Oligocene lithology (c).

Other observations: Very strongly lithified → high carbonate content/ deep burial. (b) The conglomerate might well be a lithified version of the mud-breccia/cataclasite we find near Grdevac, with the same orange/brown 'rip-up clasts'.

Formation (age): 2M2 close to border with M2,3

Pictures/sketches:



Measurements:

- ➢ Fault: 64/44, ss lineation 46/40

18.3

GPS: 44.06817, 18.10608

Location: Highway section, close to northern start of the section.

Lithology: Silty marls with sandstone 'channels' (50cm high 2-3m wide), erosive bases and fining upwards.

Other observations: Very strongly lithified → high carbonate content/ deep burial. The conglomerate might well be a lithified version of the mud-breccia we find near Grdevac.

Formation (age): 2M2 close to border with M2,3

Measurements:

- ➢ Bedding: 277/28

18.4

GPS: 44.06812, 18.10585

Location: Highway section, close to northern start of the section.

Lithology: Silty marls with sandstone 'channels' (50cm high 2-3m wide), erosive bases and fining upwards, loading & soft sediment deformation visible.

Formation (age): 2M2 close to border with M2,3

Pictures/sketches:

Measurements:

- Bedding: 252/30

18.5

GPS: 44.06761, 18.1055

Location: Highway section, close to northern start of the section.

Lithology: Silty marls alternated with fine-medium sandstone, and some 2-10mm matrix supported conglomerate 'channels'.

Formation (age): 2M2 close to border with M2,3

18.6

GPS: 44.06713, 18.1055

Location: Highway section, close to northern start of the section.

Lithology: Medium-coarse sandstone, wavy crossbedding, planar, finiung upwards (30cm beds), alternated with a clast supported conglomerate, well rounded and Ugar or Permian carbonate clasts, no schist!.

Formation (age): 2M2 close to border with M2,3

Measurements:

- Bedding: ~338/42

18.7

GPS: 44.06682, 18.10538

Location: Highway section, close to northern start of the section.

Lithology: Thinly bedded (5-7cm) silty marls alternated with fine-medium sandstone, mostly planar, some erosive surfaces, fining upwards, some thin (mm scale) coal lenses within the sandstone beds.

Formation (age): 2M2 close to border with M2,3

18.8

GPS: 44.06665, 18.105

Location: Highway section, close to northern start of the section.

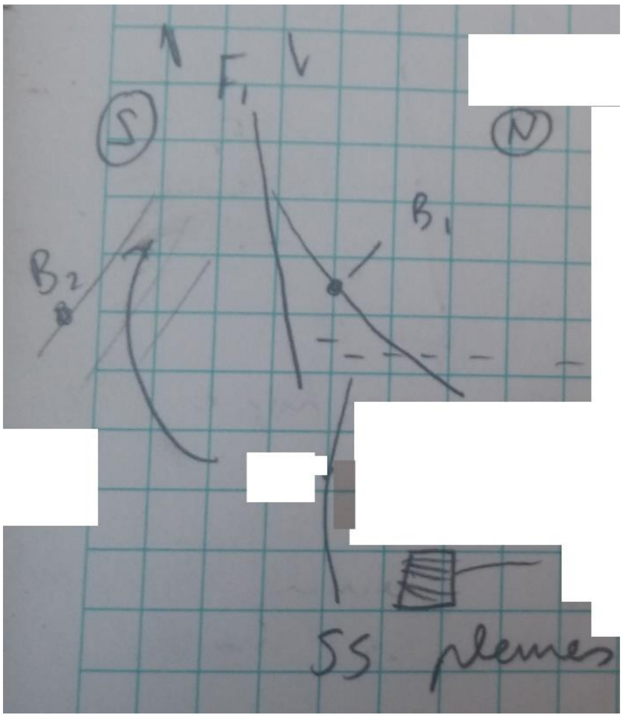
Lithology: Sandstone beds alternated with conglomerate beds, with some silty marl beds inbetween.

Formation (age): 2M2 close to border with M2,3

Other observations: Vertical layers left of the fault suggest thrusting but other sings say it is a normal fault, such as the drag in the hanging wall, it might be a reactivated normal fault. Also some layer parallel slip seems to have occurred.

A z-shape (S-N) is visible especially in the siltier intervals (rheology).

Pictures/sketches:



Measurements:

- Bedding: B1 342/50, B2 ~248/54
- Fault: F1 348/72
- Layer parallel movement: Plane: 306/76, ss lineation 30/6

18.9

GPS: 44.06632, 18.10482

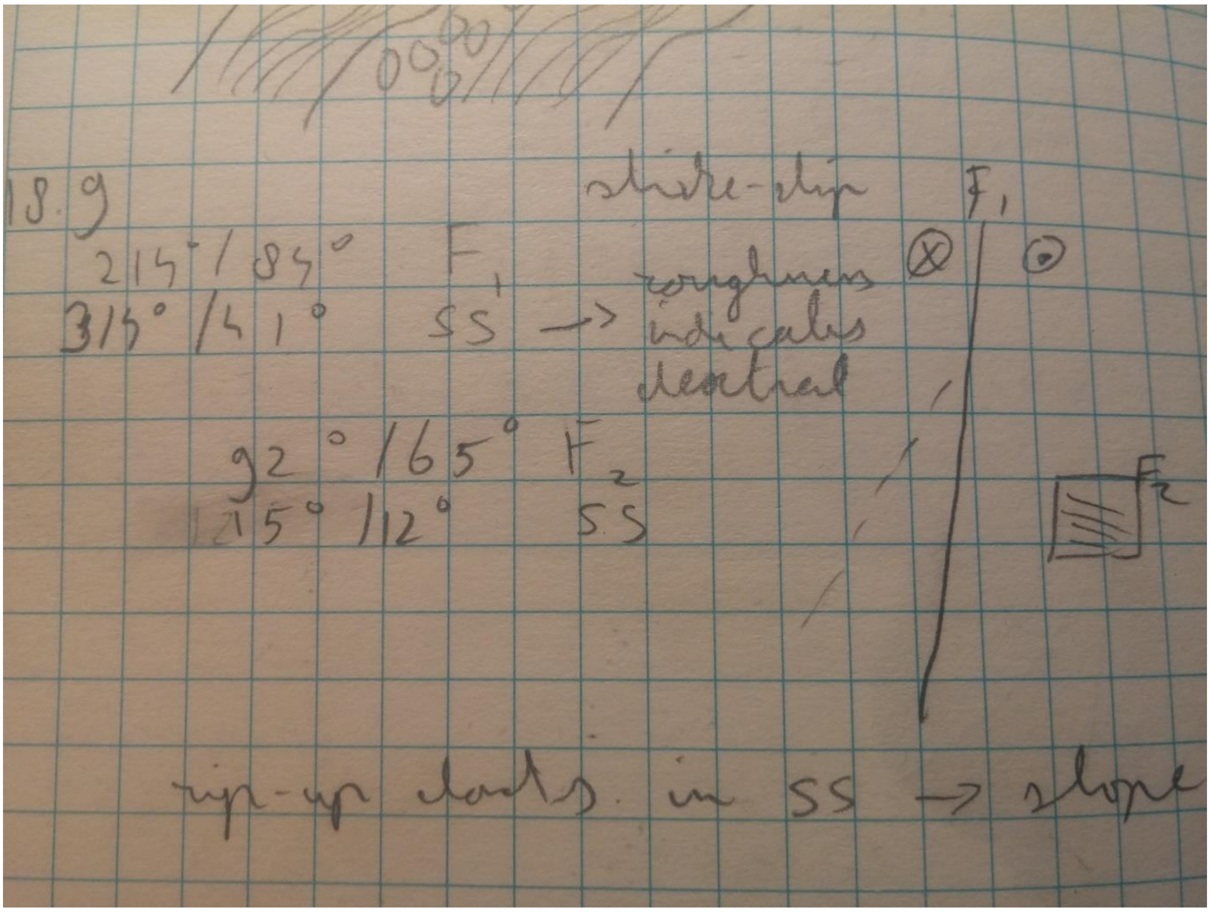
Location: Highway section, northern part of the section.

Lithology: Sandstone beds alternated with conglomerate beds, with some silty marl beds inbetween, rip-up clast are present in the sandstone beds (indicating slope).

Formation (age): 2M2 very close to border with M2,3

Other observations: Roughness of the ss lineations indicated dextral movement.

Pictures/sketches:



Measurements:

- Fault: F1 214/84, ss lineation 15/12, F2 92/65, ss lineation 314/41

18.10

GPS: 44.06626, 18.10401

Location: Highway section, middle part of the section.

Lithology: Thinly bedded fine sandstones (2-10cm) alternated with silty marls.

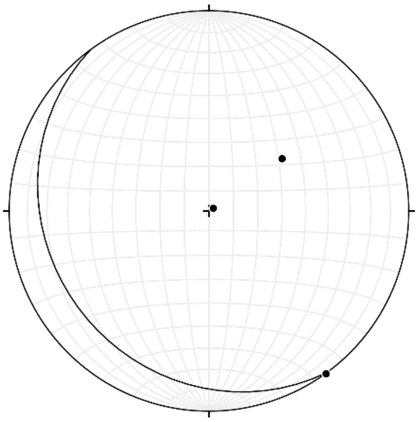
Formation (age): 2M2, right on the border with M2,3

Other observations: Metal wire mesh for scale, 10cm per vertical honeycomb. Is the plane a fault or cleavage, drag does not make sense if it was a fault. Therefore we assume it to be strong cleavage that maybe accommodated a little movement.

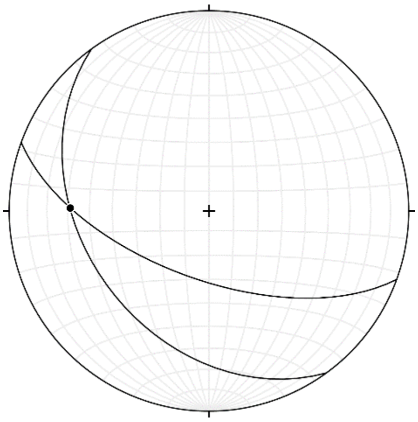
Pictures/sketches:

Measurements:

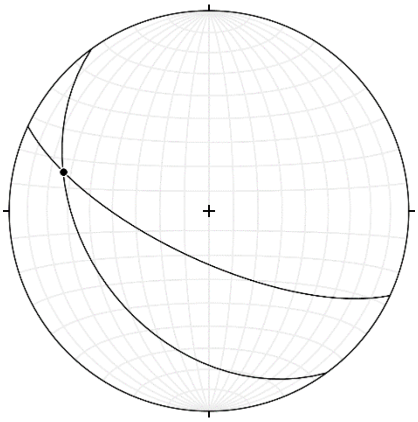
- Bedding: B1 234/37, B2 229/2
- Cleavage: C1/fault 200/62, C2 205/70
- Fold hinge/axial plane: 144/0, 234/20 (a)(syncline) (of the apparent drag fold to the left, if it were a normal fault):
- Intersection lineations: 272/31 (b), 285/25 (c)



(a)



(b)



(c)

18.11

GPS: 44.06593, 18.10473

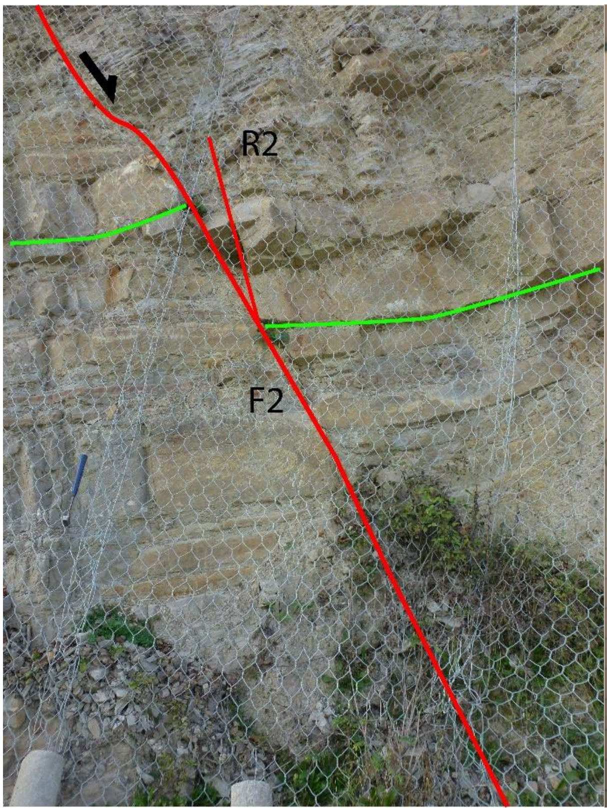
Location: Highway section, middle part of the section.

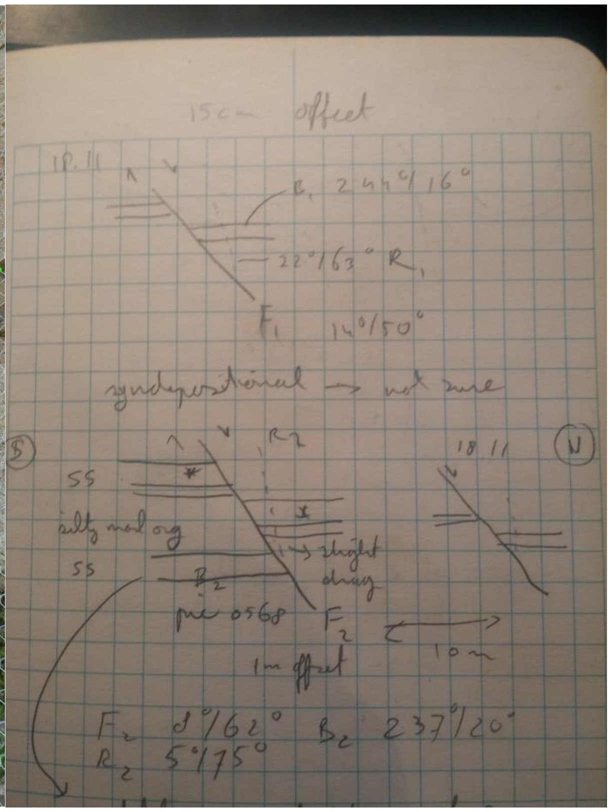
Lithology: Medium/coarse sandstones (20-40cm) alternated with thin beds of silty marls. In the bottom of the sandstone layers apparent granite pebbles are present.

Formation (age): 2M2, right on the border with M2,3

Other observations: Metal wire mesh for scale, 10cm per vertical honeycomb. Is the plane a fault or cleavage, drag does not make sense if it was a fault. Therefore we assume it to be strong cleavage that maybe accommodated a little movement.

Pictures/sketches:





Measurements:

- Bedding: B1 244/16, B2 237/20
- Faults: F1 14/50 (apparent normal 15cm offset), R1 22/63 (possibly syndepositional but cannot say for sure), F2 8/62 (apparent normal 1 m offset), R2 5/75 (slight drag visible on right side of the fault but not measureable)

18.12

GPS: 44.0658, 18.10464

Location: Highway section, middle part of the section.

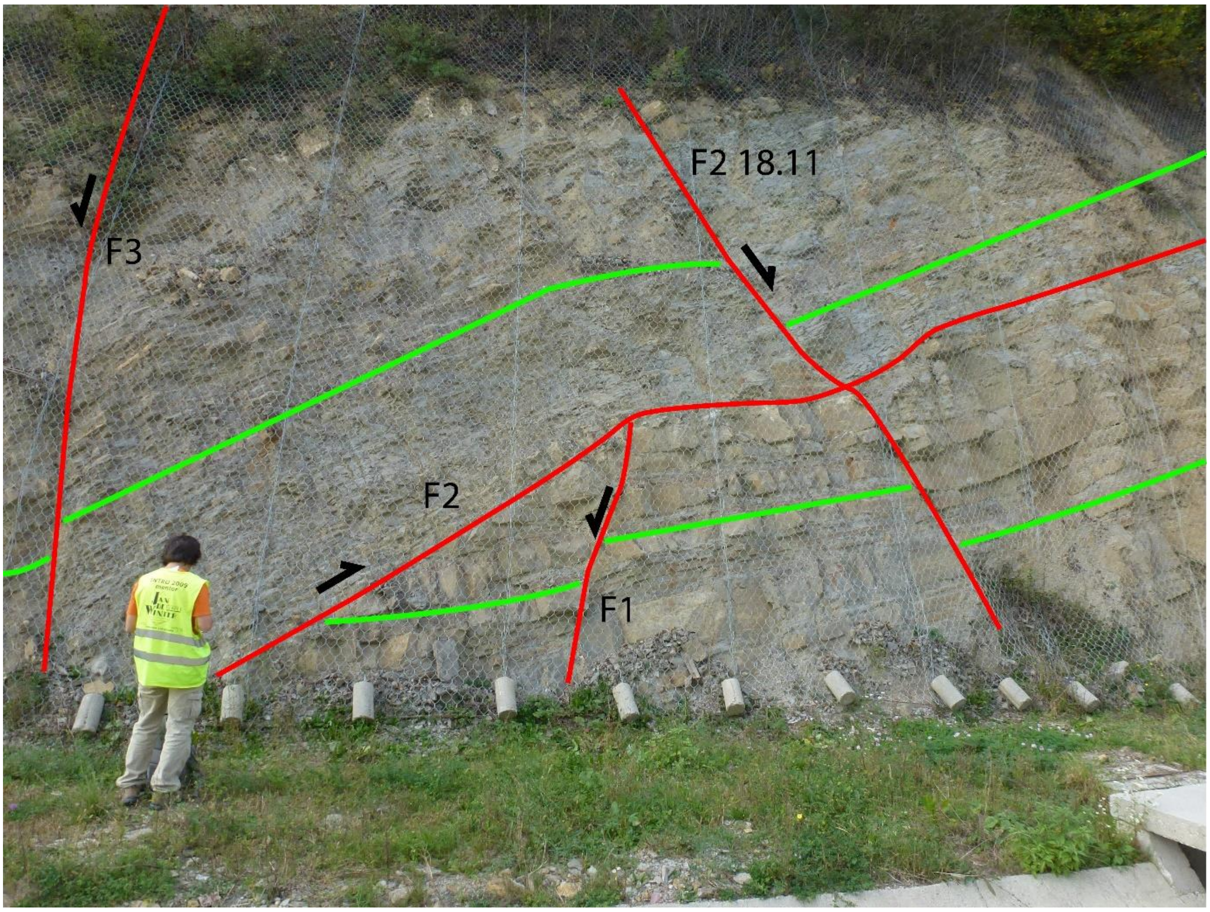
Lithology: Thinner sandbeds (3-15cm), fine towards top, coarse at the base (clear fining upwards (or amalgamated)) interbedded with more silty marls. Organic matter shows wavy and planar lamination in the sandstone beds and this organic matter is also present in the marls in large amounts.

Formation (age): 2M2, M2,3 right on the border with M2,3

Other observations: Clear offset, but the amount is difficult to establish due to very homogenous lithology in the outcrop.

Are the faults from different fault sets? F3 is more oblique. F1 is cut by F2, F2 from 18.11 cuts F2 of 8.12. Very close to "thrust" on geological map.

Pictures/sketches:



Measurements:

- Bedding: B1 245/25, B2 208/36 (fault parallel bedding)
- Faults: F1 186/85 (apparent normal 30cm offset), R1 356/60, F2 208/36 (apparent reverse offset hard to judge), F3 150/81 (apparent normal 35cm offset)

18.13

GPS: 44.06528, 18.10455

Location: Highway section, middle part of the section.

Lithology: Very heterogenous lithology, starts from top: 2m package of sandbeds (2-3mm) in a marly silt dominated lithology (1), 1 m more sandstone dominated package with some marly silt interbeds, 1m of cobble-boulder conglomerate, sub-well rounded but poorly sorted (containing the granite pebbles seen earlier), a coal layer, and finally a package of sandstones (10-20cm) interbedded with some marly silts (2). The bottom sandstone beds show pebble lag and are clearly fining upwards.

To the left of the fault the lithology changes, 20m of dark grey marls with black stripes (5cm), interbedded with some (10-20cm) coarse sand/pebble conglomerate layers, some layers become very reddish due to weathering (see figure (3))., and 1 cm fine sandstone layers, and below this a 1m bed of pebble/cobble conglomerate, porrly sorted and sub-rounded/angular, below which lies a 6m package of marly silt with thicker fine/medium sandstone layers (2-3cm) looking like rhytmites.

Formation (age): 2M2, M2,3 right on the border.

Other observations: Clear offset, but the amount is difficult to establish due to very homogenous lithology in the outcrop.

Are the faults from different fault sets? F3 is more oblique. F1 is cut by F2, F2 from 18.11 cuts F2 of 8.12.

Pictures/sketches:



(LEFT TOP) Lithology (1), (RIGHT TOP) Lithology (2) pebble lag, (LEFT BOTTOM) Lithology, reddish weathering (3).

Measurements:

- Bedding: 244/20
- Faults: F1 129/73 (apparent normal 4cm offset)

18.14/15/16

GPS: 44.0651, 18.10467 (18.14) & 44.06482, 18.10455 (18.15) & 44.06446, 18.10424 (18.16)

Location: Highway section, middle part of the section before the valley splitting the outcrop.

Lithology:

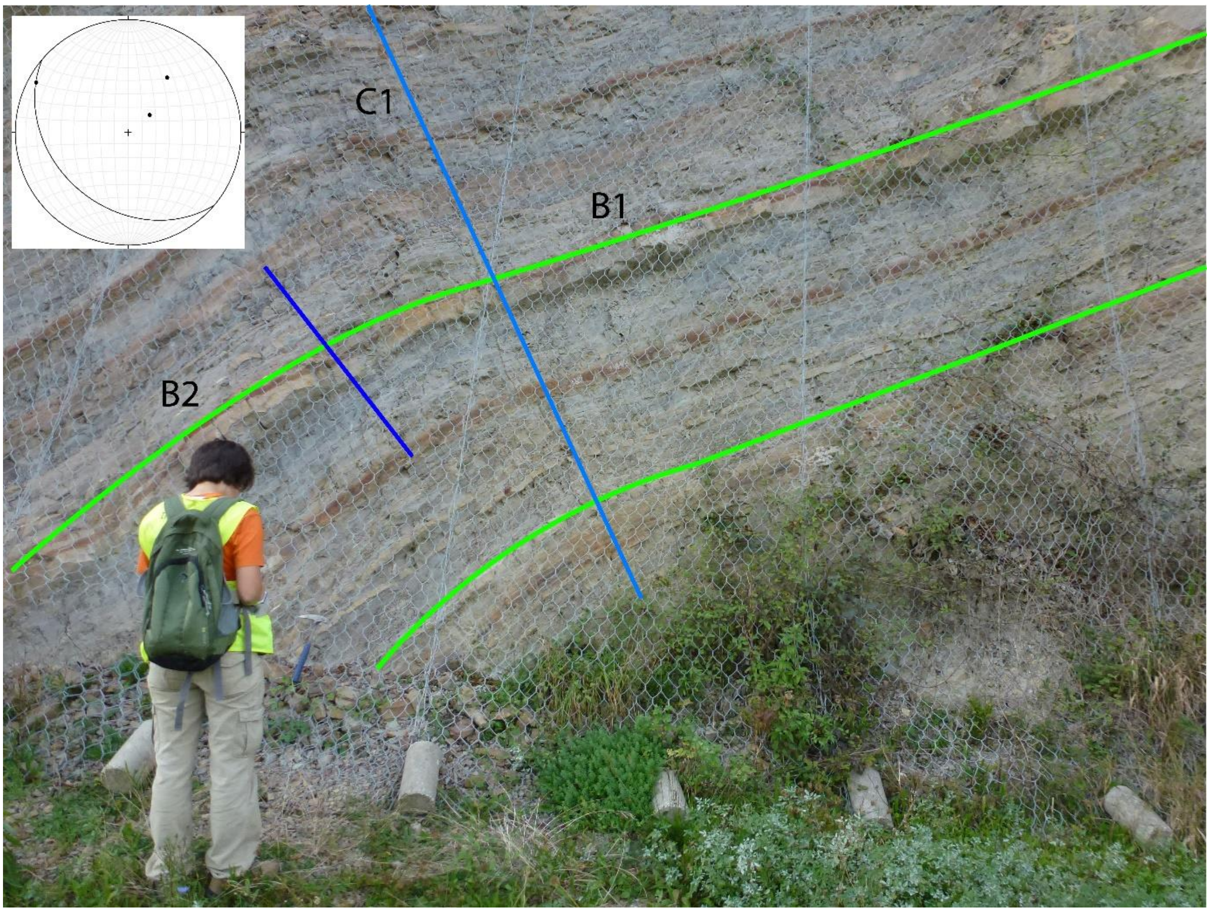
- 18.14: 20m of dark grey marls with black stripes (5cm), interbedded with some (10-20cm) coarse sand/pebble conglomerate layers, some layers become very reddish due to weathering (see figure (3))., and 1 cm fine sandstone layers, and below this a 1m bed of pebble/cobble conglomerate, porrly sorted and sub-rounded/angular, below which lies a 6m package of marly silt with thicker fine/medium sandstone layers (2-3cm) looking like rhytmites.

- 18.15: Sandstones and debrites (badly sorted cobble conglomerate) and silty marls, silty marls interbedded by channel sandstones and planar sandstone beds. Thick grey silty marl, interbedded by 20cm medium/coarse planar sandstone with pebble layers.
- 18.16: Repeating pattern of: Cobble conglomerates, clast supported, sub-rounded, medium sorting, to chaotic coarse sandstones containing some pebbles, to medium-coarse sandstones with aligned pebble layers. All surfaces are planar except for the cobbles with sometimes show an erosional surface in the underlying beds. Towards the south (upwards lithology wise) the layers become coarser.

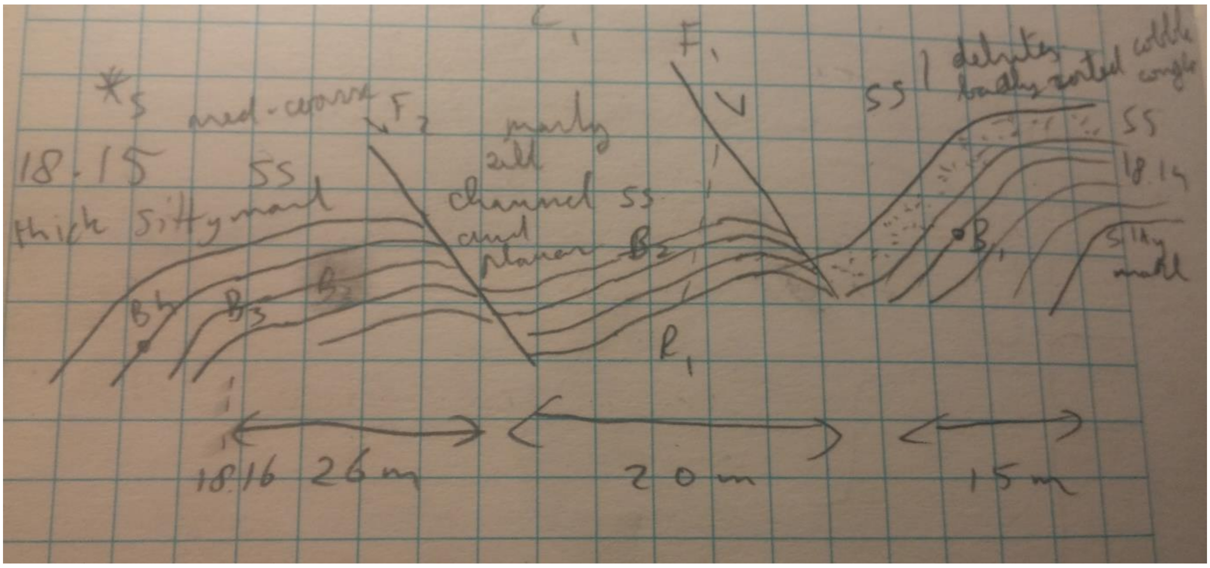
Formation (age): 2M2, M2,3 right on the border.

Other observations: Fold hinges/axial planes for 18.14 and 18.15 very similar.

Pictures/sketches:



18.14

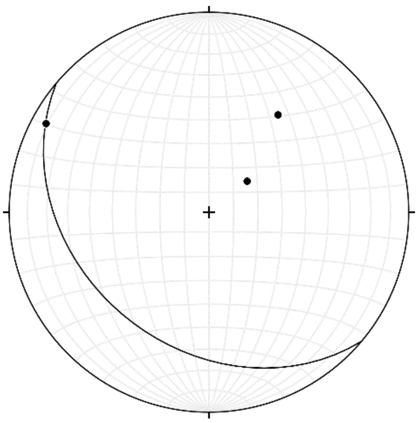


18.15

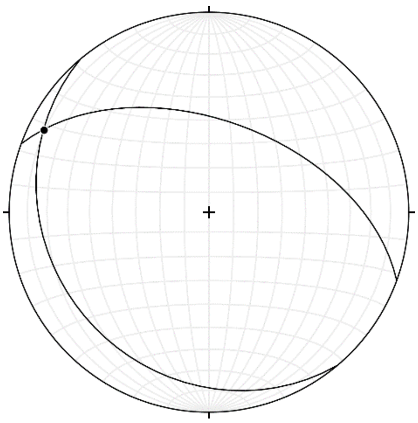
PICTURES NEVENA 3448-51 18.16

Measurements:

- 18.14
  - Bedding: B1 230/20, B2 215/50
  - Cleavage: C1 20/52
  - Fold hinge/axial plane: 299/8, 220/34 (a)(anticline)
  - Intersection lineation: 297/8 (b)

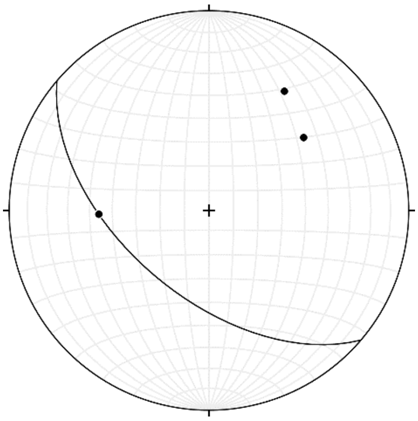


(a)



(b)

- 18.15
  - Bedding: B1 222/48, B2 228/18, B3 232/50, B4 212/60
  - Fault: F1 12/60 (apparent normal), R1 252/75, F2 15/55 (apparent normal)
  - Fold hinge/axial plane: 268/44, 221/55



- 18.16
  - Bedding: B1 206/42

18.17/18

GPS: 44.06415, 18.10471 (18.17) & 44.06392, 18.10373 (18.18)

Location: Highway section, middle part of the section towards the valley splitting the southern part of the section.

Lithology:

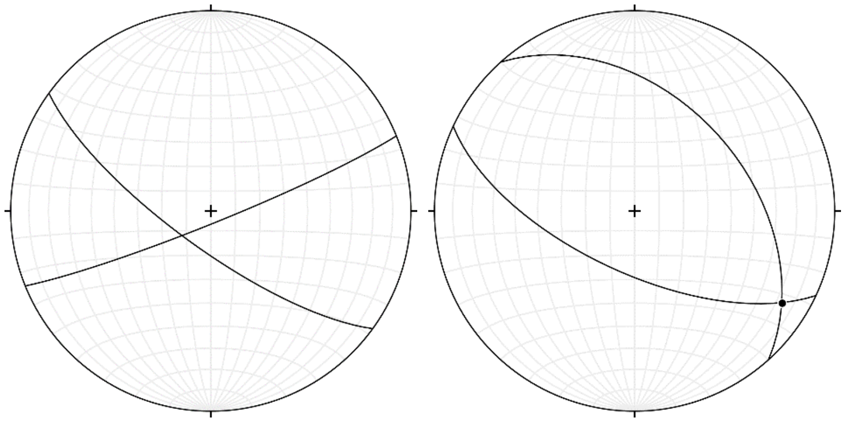
- 18.17: Coarse intervals visible at the northern stops of this section disappear and we are left with silty marls, and a random coarse sandstone bed with larger clast in it up to cobble size.
- 18.18: A grey silty marl interval interbedded with a few coarser beds: clast supported pebble-boulder conglomerate, poorly sorted and a fine/medium sandstone beds with pebble channels inside, overall planar though.

Formation (age): M2,3 right on the border with 2M2.

Measurements:

- 18.17
  - Bedding: B1 216/75
  - Cleavage: C1 158/85
  - Intersection lineation: 230/75 (a)

- 18.18
  - Bedding: B1 206/65
  - Cleavage: C1 48/43
  - Intersection lineation: 122/15 (b)



(a) *(b)*

18.19

GPS: 44.06347, 18.10369

Location: Highway section, middle part of the section just before the valley splitting the outcrop.

Lithology: Fine/medium sandstone with marly matrix and pebble channels inside, but overall planar, similar to the 18.18 lithology but a little coarser.

Formation (age): M2,3 right on the border with 2M2.

Other observations: GPS not accurate

Measurements:

- Bedding: B1 216/60

18.20

GPS: NO GPS but likely close to 44.06347, 18.10369 but at bit more to the south

Location: Highway section, middle part of the section just before the valley splitting the outcrop.

Lithology: Fine grained siltstone mixed with larger (upto pebble size clasts) and really thinly bedded marly silt without clastics to the S.

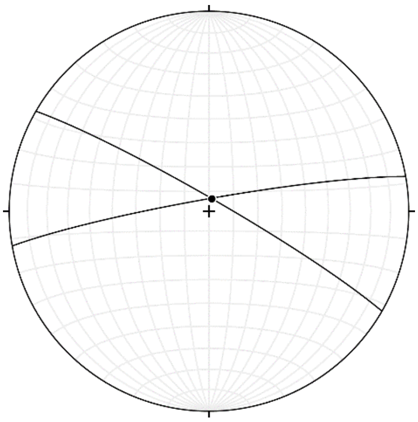
Formation (age): M2,3 right on the border with 2M2.

Other observations: GPS not accurate

Pictures/sketches:

Measurements:

- Bedding: B1 30/85, B2 36/88
- Cleavage: C1 350/85
- Intersection lineation: 10/85



18.21

GPS: NO GPS but likely close to 44.06347, 18.10369 but at bit more to the south

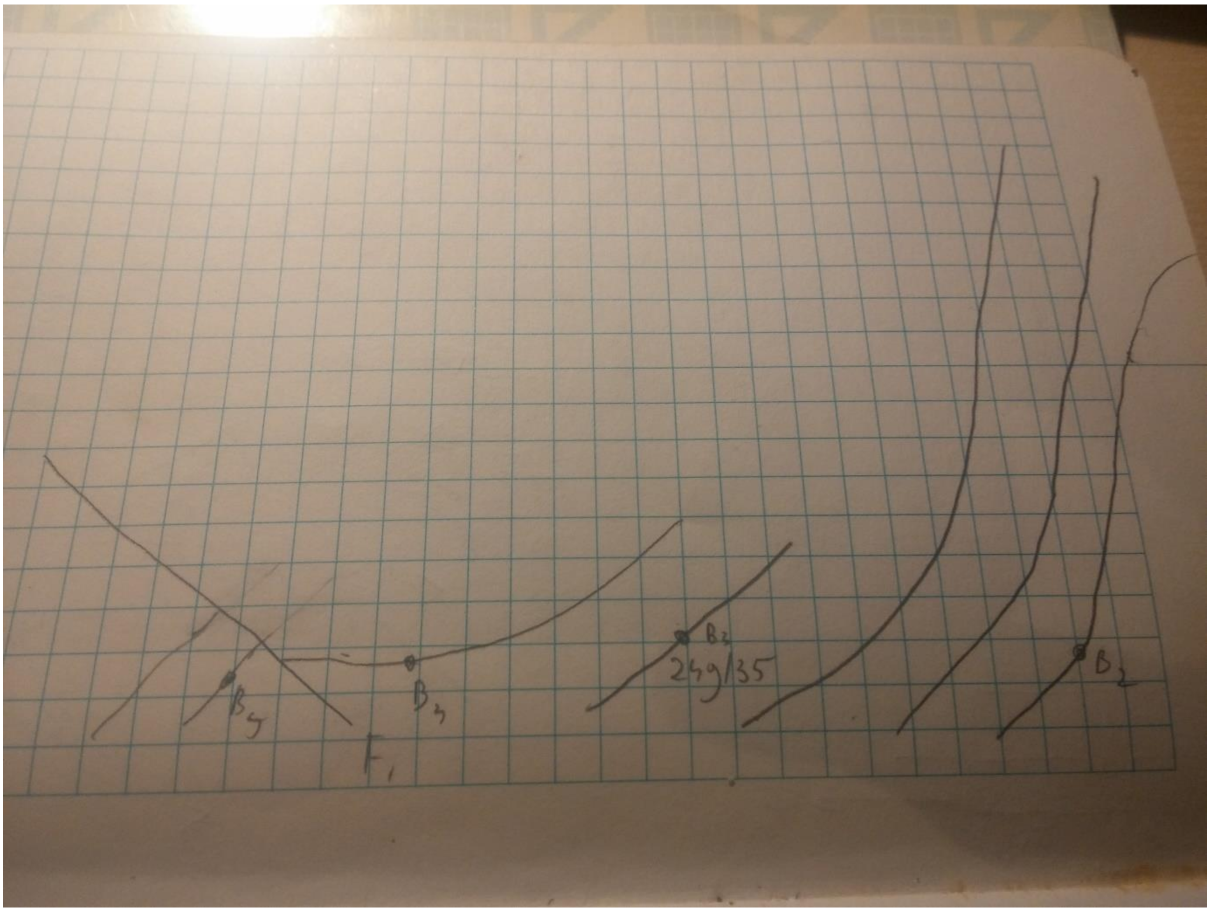
Location: Highway section, middle part of the section just after the valley splitting the outcrop.

Lithology: Parallel wavy laminated grey marly silt interbedded by 10 cm fine/medium sandbeds.

Formation (age): M2,3 right on the border with 2M2.

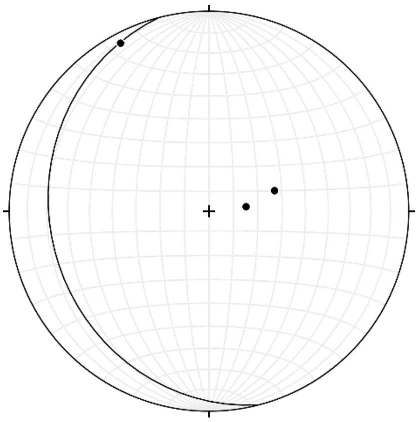
Other observations: GPS not accurate

Pictures/sketches:

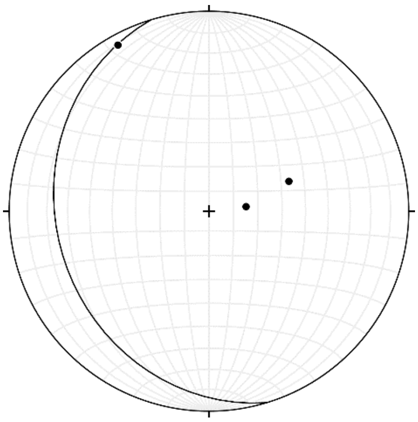


Measurements:

- Bedding: B1 227/77, B2 252/28, B3 249/35, B4 262/15, B5 206/55
- Fault: 8/33 (apparent normal)
- Fold hinges/axial planes: 332/5, 256/21 (syncline)(a), 331/5, 253/25 syncline(b)



(a)



(b)

19.1

GPS: same as 19.2, 44.05174, 18.12

Location: Dobrinje, in the higher lying village.

Lithology: Silty marl with fine-medium sandbeds (5-20cm)

Formation (age): M2,3

Other observations: 12.21 to the NE

Measurements:

- Bedding: 190/60

19.2

GPS: 44.05174, 18.12

Location: Dobrinje, in the higher lying village.

Lithology: Silty marl with fine-medium sandbeds (5-20cm)

Formation (age): M2,3

Other observations: 12.21 to the NE

Measurements:

- Bedding: 200/70

19.3

GPS: 44.0519, 18.12023

Location: Dobrinje, road into the hills with all the pastures

Lithology: Silty marl with fine-medium sandbeds (5-20cm)

Formation (age): M2,3

Other observations: 12.21 to the NE, overall trend of last stops is bedding of roughly 200/70

Measurements:

- Bedding: 206/75

19.4

GPS: 44.05216, 18.1209 & 44.05269, 18.12332 (19.4a) & 44.05303, 18.12273 (19.4b)

Location: Dobrinje, road into the hills with all the pastures

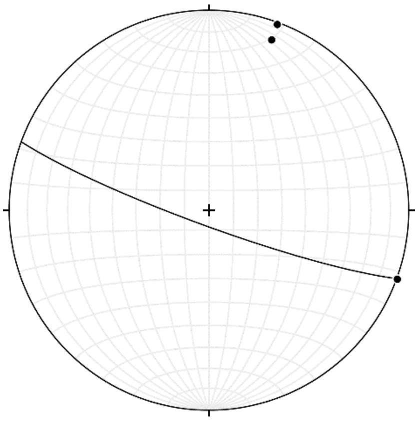
Lithology: Silty marl with fine-medium sandbeds (5-20cm)

Formation (age): M2,3

Other observations: 12.21 to the NE, overall trend of last stops is bedding of roughly 200/70

Measurements:

- Bedding: 210/56, 200/89 (19.4a), 200/80 (19.4b)
- Fold hinge/axial plane: 110/0, 200/84 (anticline)



19.5

GPS: 44.05331, 18.1241

Location: Dobrinje, road into the hills with all the pastures

Lithology: Dominant silty marls with 5-20cm thick fine/medium sandbeds and some thin conglomerate beds, matrix supported, sub-rounded pebbles.

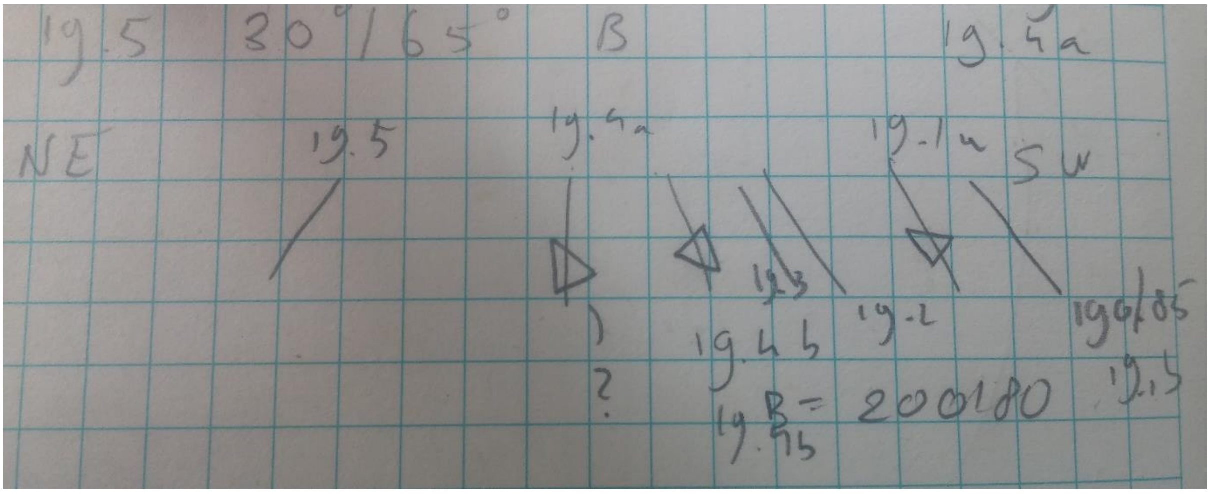
Formation (age): M2,3

Other observations: 12.21 to the NE, overall trend of last stops is bedding of roughly 200/70

Measurements:

- Bedding: 30/65

❖ **Overview sketch of 19.1-5**



19.6

GPS: 44.04849, 18.12327

Location: Dobrinje, in the pasture along the road to Buzici, with the farmer and his grandson on his tractor.

Lithology: Dominant silty marls with 5-10cm thick fine/medium sandbeds.

Formation (age): M2,3

Other observations: A splay of the main fault runs through this area.

Measurements:

- Bedding: 10/85

19.7

GPS: 44.049, 18.12577

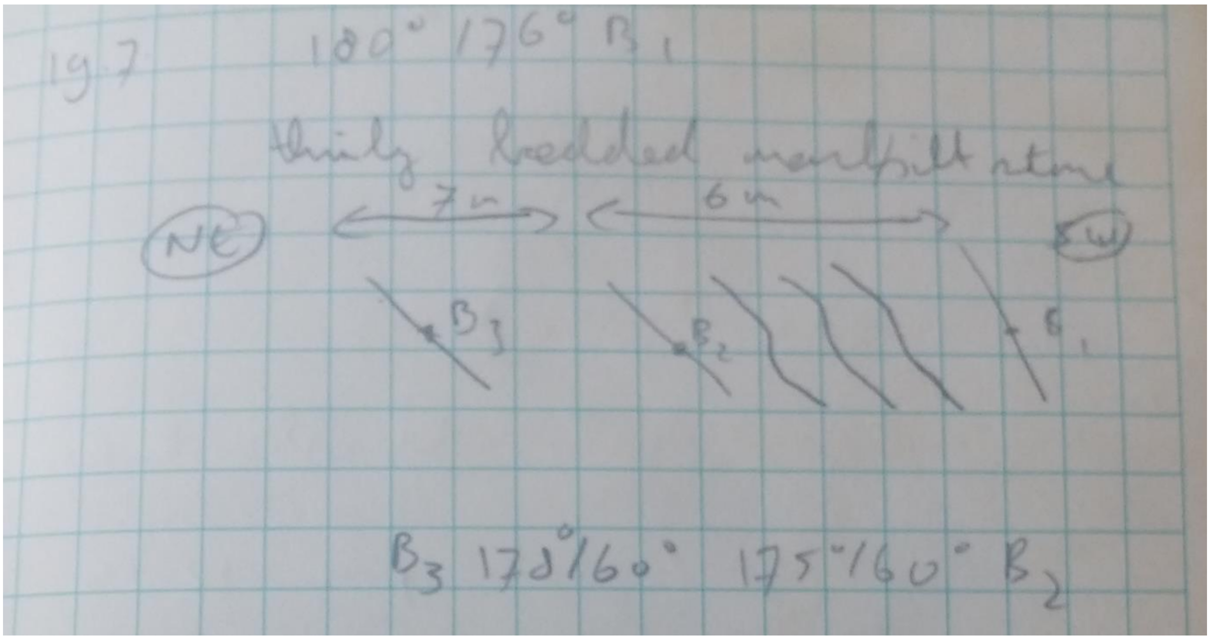
Location: Dobrinje, in the pasture along the road to Buzici, with the farmer and his grandson on his tractor.

Lithology: Dominant silty marls with some siltstones (1-5cm).

Formation (age): M2,3

Other observations: A splay of the main fault runs through this area. Z-shapes visible NE-SW direction.

Pictures/sketches:



Measurements:

- Bedding: B1 180/76, B2 175/60, B3 178/60

19.8/9

GPS: 44.04939, 18.1246 (19.8) & 44.04911, 18.12398

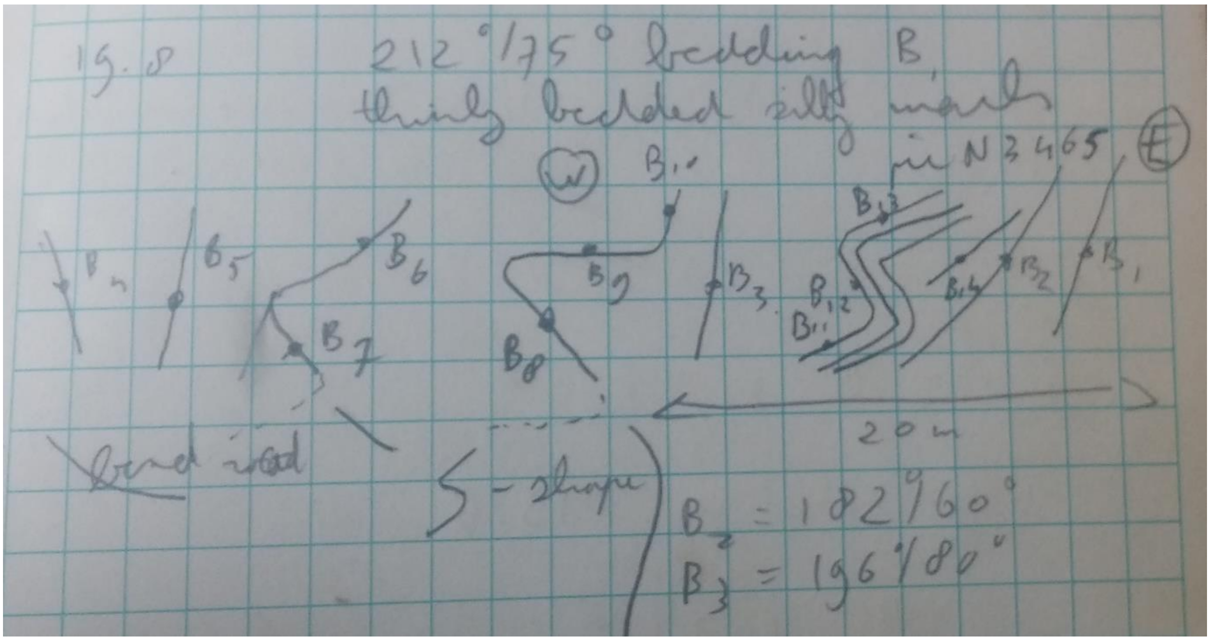
Location: Dobrinje, the top part of the pasture along the road to Buzici, with the farmer and his grandson on his tractor. Untill the mine warning signs where we stopped.

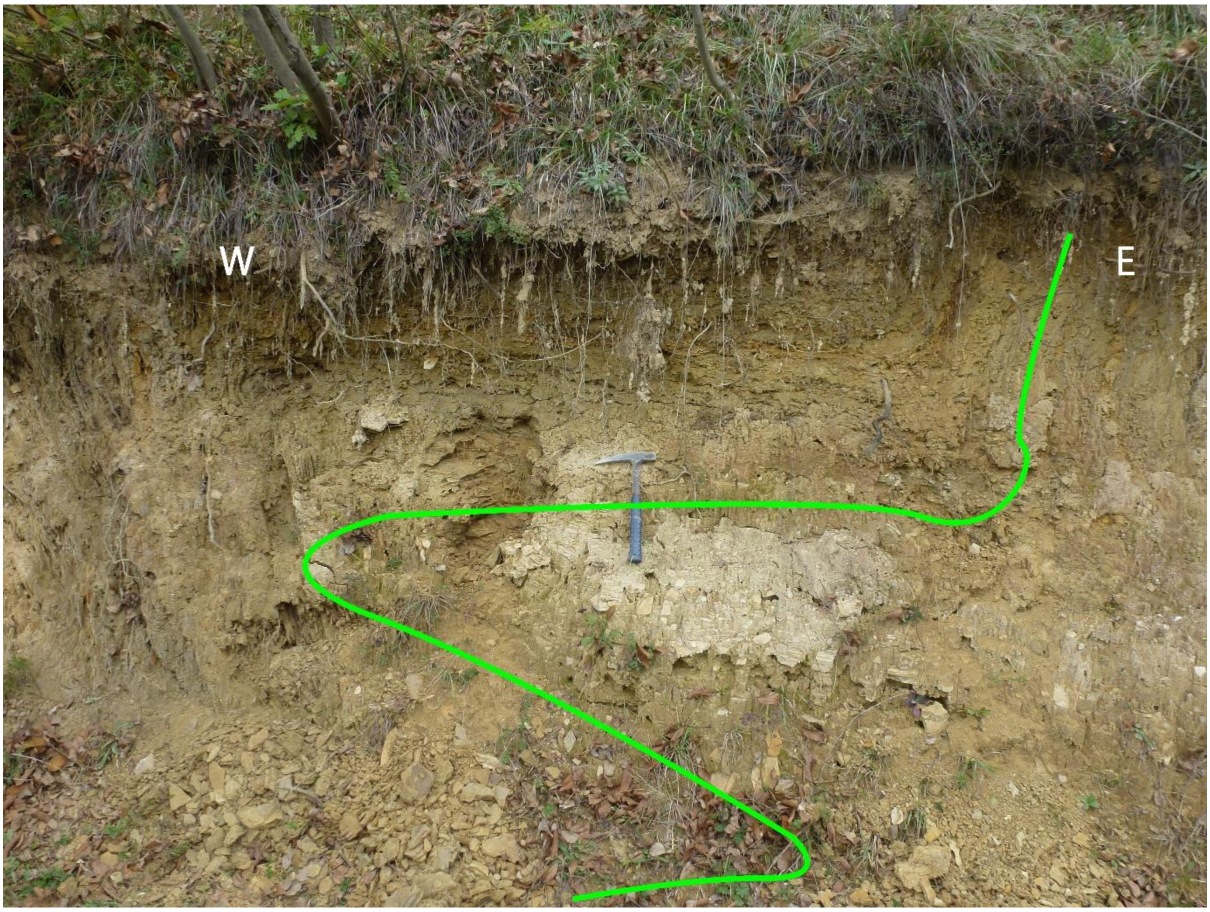
Lithology: Dominant thinly bedded silty marls with very few more resistant siltstones (1-5cm).

Formation (age): M2,3

Other observations: A splay of the main fault runs through this area.

Pictures/sketches:

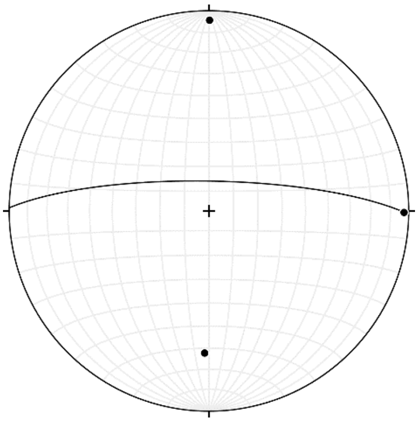




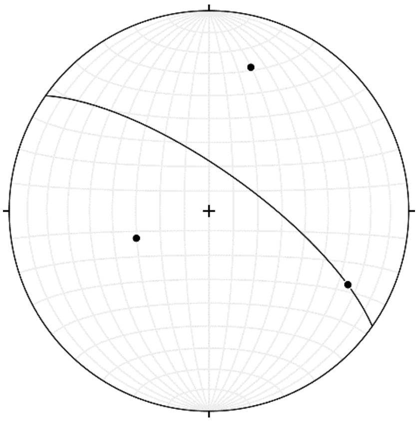
S-shape W-E

Measurements:

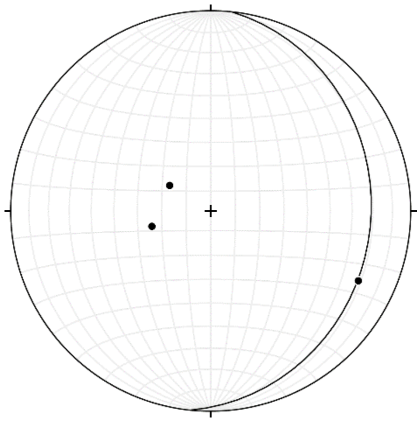
- Bedding: B1 212/75, B2 182/60, B3 196/80, B4 2/60, B5 180/85, B6 196/64, B7 32/70, B8 25/76, B9 122/20, B10 212/74, B11 191/35, B12 18/74, B13 195/60, B14 179/45
- Fold hinges/axial planes: 90/3, 1/78 (syncline)(a), 118/23, 35/73 (anticline)(b), 115/20, 96/21 (anticline)(c), 107/4, 195/71 (anticline)(d), 107/4, 197/83 (syncline)(e)



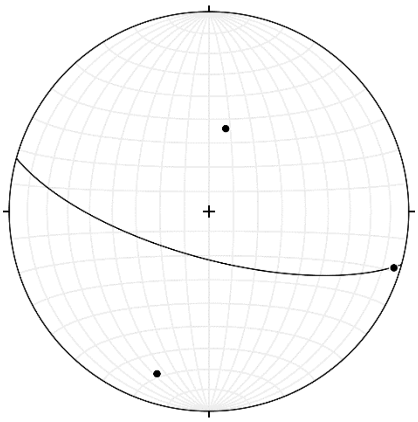
(a)



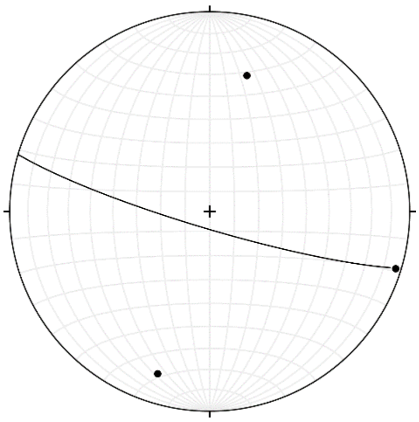
(b)



(c)



(d)



(e)

19.10

GPS: 44.04948, 18.12363

Location: Dobrinje, in the pasture along the road to Buzici, with the farmer and his grandson on his tractor.

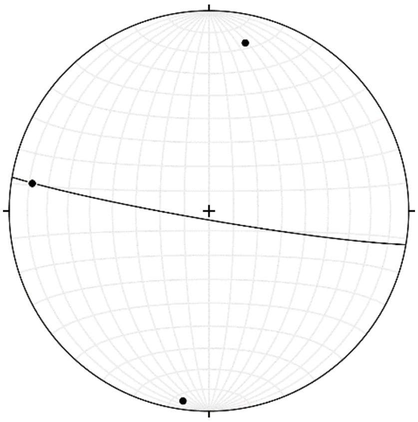
Lithology: Dominant silty marls with some siltstones (1-5cm).

Formation (age): M2,3

Other observations: A splay of the main fault runs through this area. Z-shapes visible NE-SW direction.

Measurements:

- Bedding: B1 8/85
- Fold hinge/axial plane: 279/11, 190/86 (syncline)



19.11

GPS: 44.04998, 18.1246

Location: Dobrinje, in the pasture along the road to Buzici, with the farmer and his grandson on his tractor.

Lithology: Dominant silty marls with some siltstones (1-5cm).

Formation (age): M2,3

Other observations: A splay of the main fault runs through this area. Z-shapes visible NE-SW direction.

Measurements:

- Bedding: B1 192/75

19.12

GPS: 44.01139, 18.16898

Location: East of the town of Mulici, section where you had to climb over the railway tracks.

Lithology: Silty marls with fine/medium sandstone beds (5-20cm).

Formation (age): Quarternary river deposits on map but still M2,3

Pictures/sketches:

Measurements:

- Bedding: B1 324/35

19.13

GPS: 44.03314, 18.18641

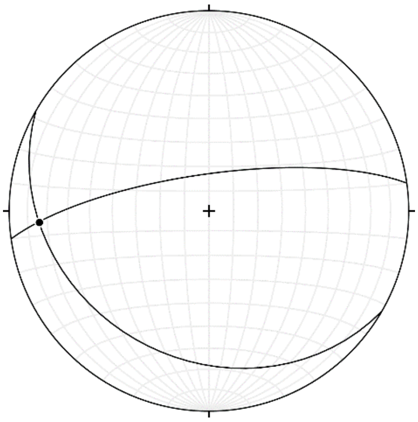
Location: Just before the town of Smrsnica.

Lithology: Thick megabed medium sandstone with some pebble channel towards the top (1m wide), multistory amalgamated body (total stratgraphic thickness 6m), on top lies a package of marly silts and fine sandstone beds with ostracods (5-20cm).

Formation (age): Quarternary river deposits on map but still M2,3

Measurements:

- Bedding: B1 210/27, B2 197/15
- Cleavage C1 352/75
- Intersection lineation: 266/16



19.14

GPS: 44.04148, 18.18311

Location: Just before the town of Smrsnica, the waterbasin and gravejard.

Lithology: Marly silts interbedded with fine/medium sandstones (5-10cm)

Formation (age): 2M2, squished inbetween 2Ol,M and 2M2

Measurements:

- Bedding: B1 348/10

19.15

GPS: 44.04512, 18.1793

Location: Above the town of Smrsnica.

Lithology: Marly silts interbedded with fine/medium sandstones (5-10cm)

Formation (age): 2M2, squished inbetween 2Ol,M and 2M2

Measurements:

- Bedding: B1 190/65

19.16

GPS: 44.04599, 18.17847

Location: Above the town of Smrsnica.

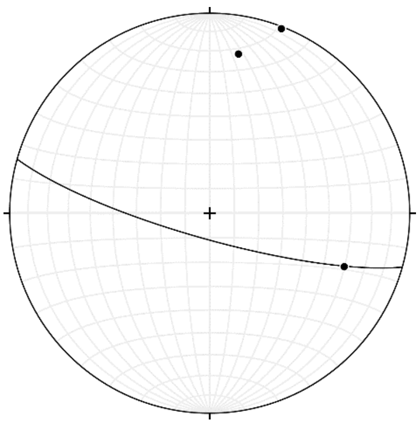
Lithology: Megabeds with pebble channels.

Formation (age): 2M2, close to thrust contact with 2Ol,M.

Other observations: Right at the thrust contact where the Oligocene is thrusted over this Miocene package.

Measurements:

- Bedding: B1 190/70, B2 201/89
- Fold hinge/axial plane: 112/29, 196/79



19.17

GPS: 44.04597, 18.17882

Location: Above the town of Smrsnica.

Lithology: Megabeds with pebble channels.

Formation (age): 2M2, close to thrust contact with 2Ol,M.

Other observations: Right at the thrust contact where the Oligocene is thrusted over this Miocene package.

Measurements:

- Bedding: B1 165/SV

19.18

GPS: 44.04553, 18.1705 (19.18bottom) & 44.04632, 18.172 (19.18top)

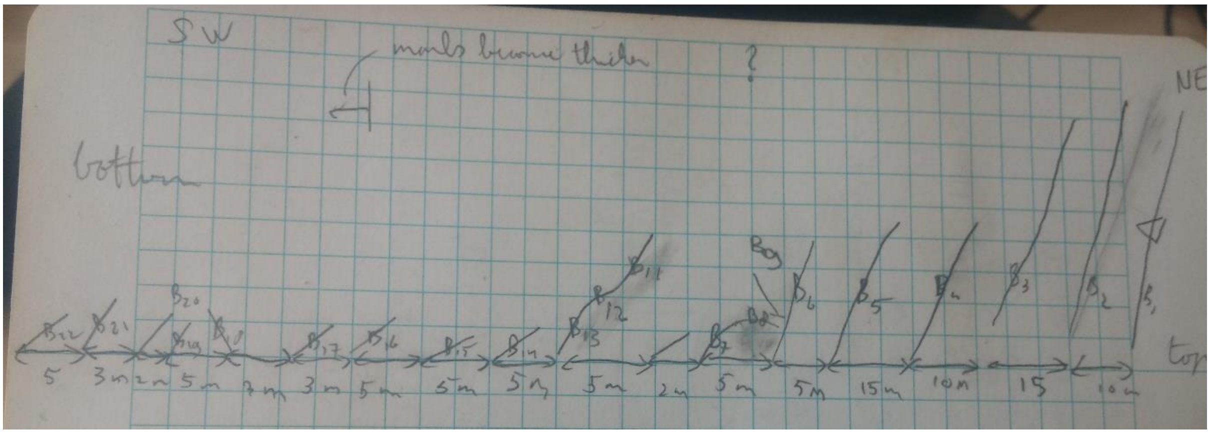
Location: Above the town of Porijecani, next to the goat/cow farm up to the "military practice zone". Where we took measurements mainly in the carved out road by runoff.

Lithology: Grey organic rich silty marl interbedded with fine/medium sandstone (5-15cm)

Formation (age): 2M2, close to thrust contact with 2Ol,M.

Other observation: Marls become thicker towards the bottom (SW).

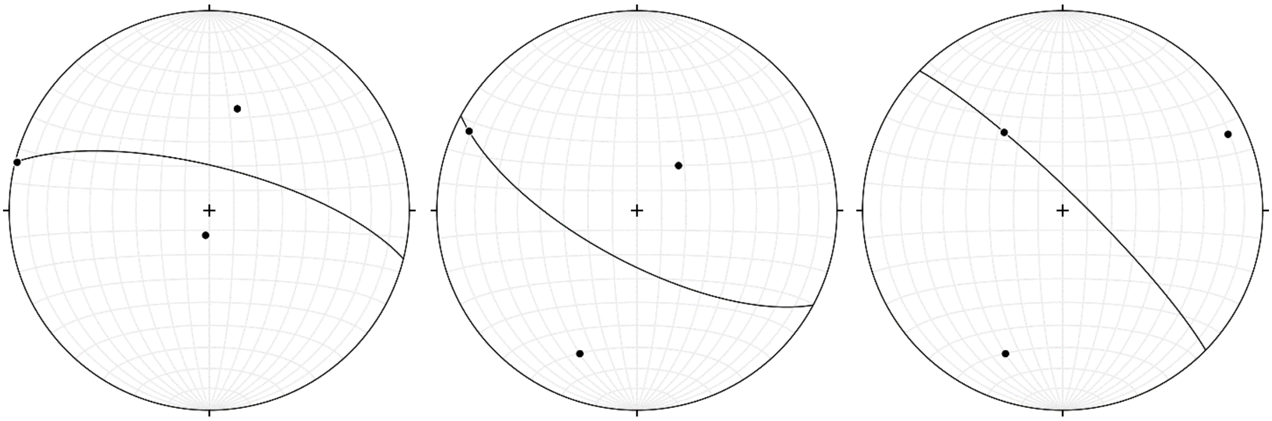
Pictures/sketches:



Measurements:

- Bedding: B1 201/56, B2 198/54, B3 212/62, B4 212/55, B5 202/51, B6 220/60, B7 195/44, B8 10/10, B9 236/3, B10 232/20, B11 230/32, B12 195/30, B13 200/45, B14 192/21, B15 260/35, B16 250/5, B17 222/25, B18 22/66, B19 245/80, B20 240/70, B21 222/55, B22 232/25

- Fold hinges/axial planes: 284/1, 14/72 (anticline)(a), 295/8, 208/69 (syncline)(b), 323/49, 44/83 (anticline)(c)



(a) (b) (c)

19.19

GPS: no GPS

Location:

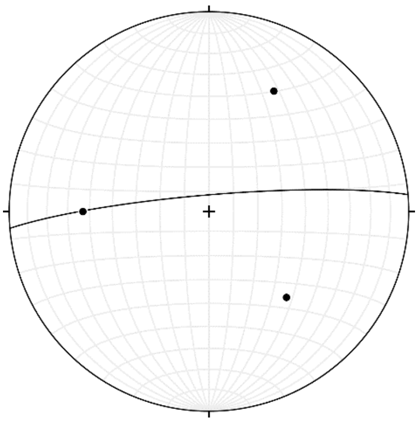
Lithology: Grey organic rich silty marl interbedded with fine/medium sandstone (5-15cm)

Formation (age): 2M2, close to thrust contact with 2Ol,M.

Other observation: Chevron type fault bend fold.

Measurements:

- Bedding: B1 318/48, B2 208/58
- Fold hinge/axial plane: 270/37, 355/83



19.20

GPS: no GPS

Location:

Lithology: Dominantly grey silty marls, with very rare fine sandstone beds (5-10cm), the marls contain a lot of organic material and dispersed plant remains and shell casts, below the package lies a coal layer (10cm)

Formation (age): 2M2, close to thrust contact with 2Ol,M.

Measurements:

- Bedding: B1 258/25

19.21

GPS: 44.11567, 18.20243

Location: Close to Kraljevska Sutjeska, road to Tesevo

Lithology: Limestones, boundstone typical oligocene type, heavily brecciated in places.

Formation (age): On the border of 2Ol,M and K2 (Ugar)

Measurements:

- Bedding: B1 210/20

19.22

GPS: 44.11541, 18.19942

Location: Close to Kraljevska Sutjeska, just after the small village with bars to the right of the “good” road.

Lithology: Crystallized/metamorphosed limestones (Ugar)

Formation (age): On the border of 2Ol,M and K2 (Ugar)

Measurements:

- Bedding: B1 40/40
- Cleavage: 11/85
- Intersection lineation: 99/24
- Fault: 64/85 (sinistral, strike-slip), ss lineation 332/20

COAL MINE VRTLISTE

GPS: UTM34 02676464, 4891344

Location: In the Vrtliste coal mine

Lithology: Crystallized/metamorphosed limestones (Ugar)

Formation (age): M1,2

Other observations: Red clay surface cuts everything.

Measurements:

- Fault: 260/SV (possibly 2 degrees dip to the south)(Strike-slip, sense unclear)

20.1-5

GPS: 44.06868, 18.10616

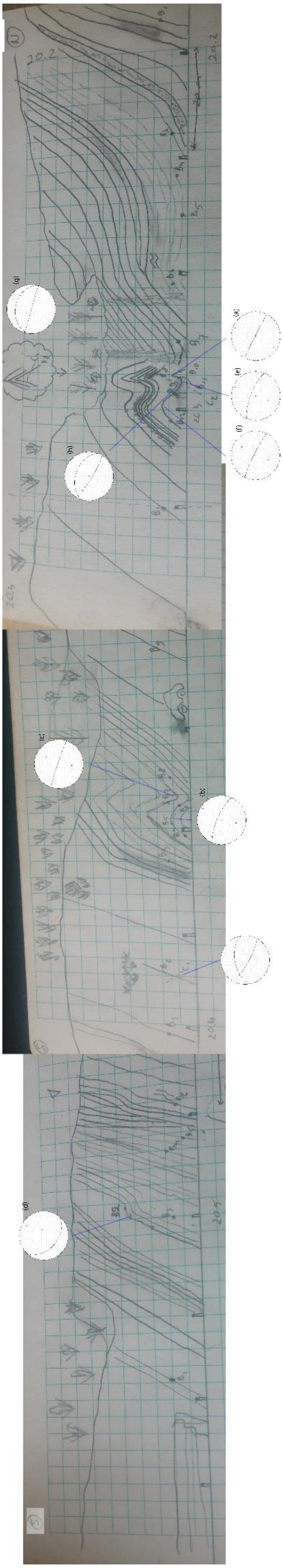
Location: Start of 2nd part of the highway section (the one past the termoelektrana plant)

Lithology:

- **20.1:** Brecciated lithology with “Lasva” sandstones, limestones with the same crusts as in Ol,M2 but more lithified and a collection of pebbles inbetween the different block.

Formation (age): 2M2 close to the border with M2,3

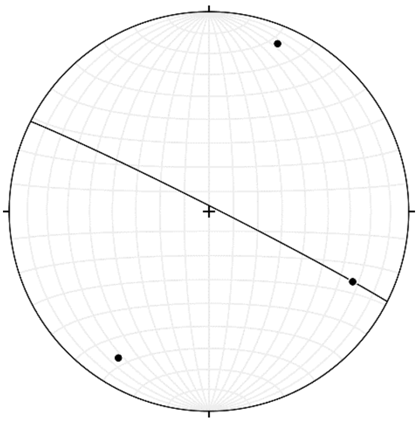
Pictures/sketches:



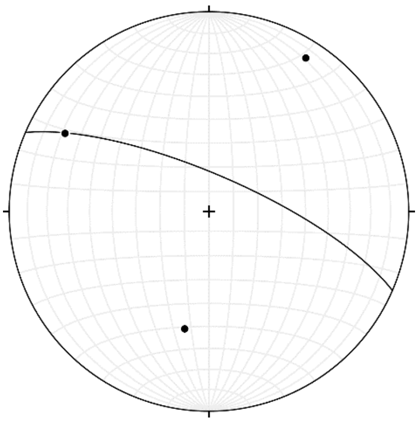
Measurements:

20.2-5

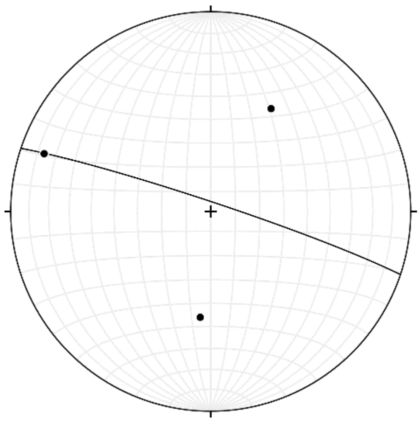
- Bedding: (20.2/3) B1 184/45, B2 210/70, B3 257/30, B4 258/18, B5 288/10, B6 208/55, B7 228/35, B8 196/89, B9 11/35, B10 20/45, B11 32/75, B12 212/55 (20.3/4) B1 200/70, B2 209/78, B3 212/75, B4 212/80, B5 196/26 (196/10 (layer parallel slip)), B6 12/50, B7 6/44, B8 210/50, B9 220/70 (20.4/5) B1 200/75, B2 252/20, B3 210/70, B4 208/80, B5 199/88, B6 222/86
- Cleavage: C1 11/35, C2 212/80, (20.3/4) C1 349/55
- Fold hinges/axial planes: 116/21, 27/88 (anticline)(a), 299/19, 23/75 (anticline)(b), 289/13, 18/86 (syncline)(c), 294/15, 221/43 (anticline)(d) 292/2, 21/73 (syncline)(e), 297/7, 26/85 (syncline)(f)
- Intersection lineation: 286/3 (C1 B8)(g), 300/10 (C2 B9)(h), 290/36 (C1 20.3/4 B2)(i)



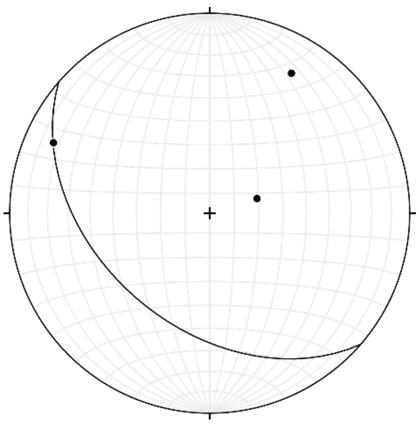
(a)



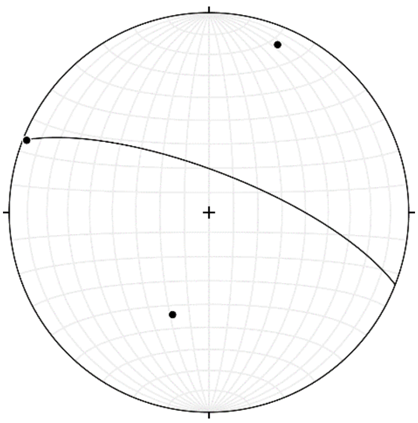
(b)



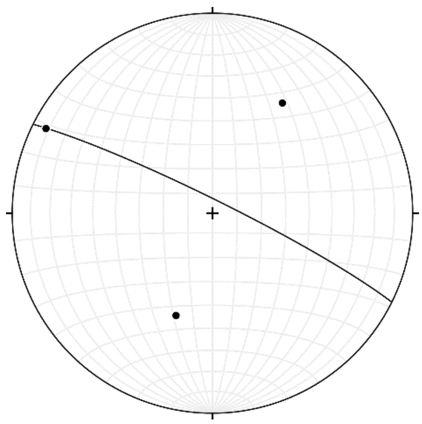
(c)



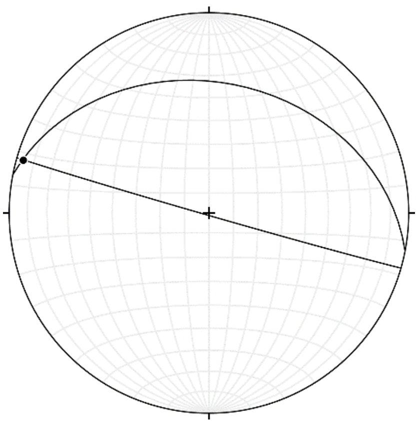
(d)



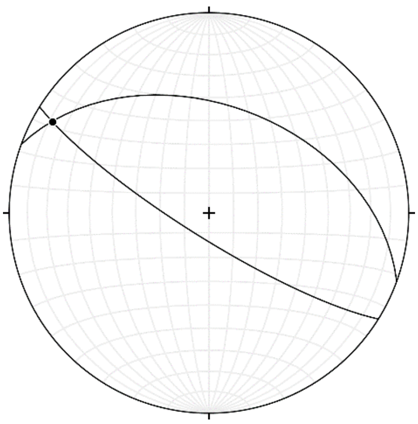
(e)



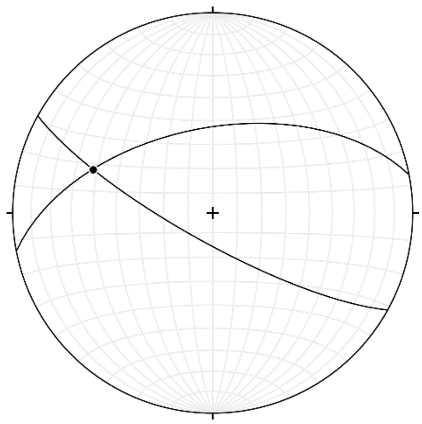
(f)



(g)



(h)



(i)

20.6

GPS: 44.06106, 18.08748

Location: Close to Seoca

Lithology: Grey silty marl interbedded with fine/medium sandstone (5-10cm)

Formation (age): M2,3

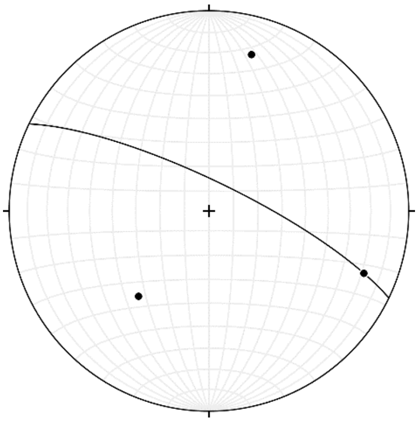
Other observation: Inbetween two "splays" of the main fault on map. Fining downwards so maybe an overturned syncline? Or amalgamated beds which were interpreted wrongly as a coarsening up sequence.

Pictures/sketches:

N3495

Measurements:

- Bedding: B1 40/46, B2 195/70, B3 216/70
- Fold hinge/axial plane: 112/18, 26/78 (~anticline)



20.7

GPS: 44.05875, 18.09029

Location: Close to Seoca

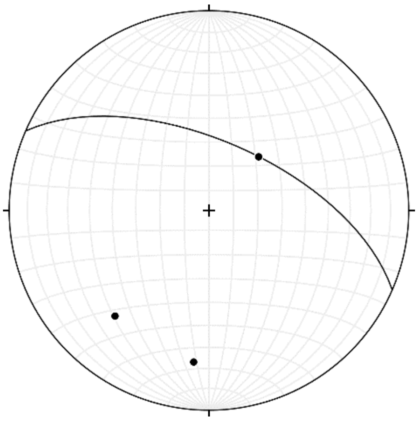
Lithology: Grey silty marl interbedded with fine/medium sandstone (5-10cm)

Formation (age): M2,3

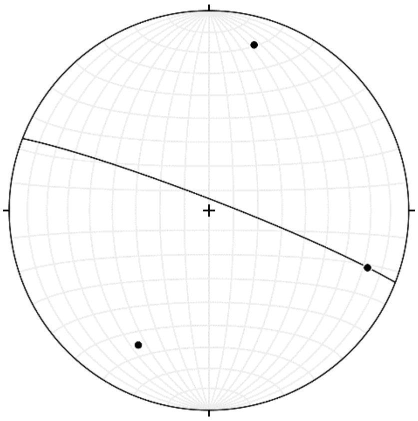
Other observations: Inbetween two "splays" of the main fault on map. Fining downwards so maybe an overturned syncline?

Measurements:

- Bedding: B1 6/65, B2 42/60, B3 28/65, B4 195/75
- Fold hinges/axial planes: 42/60, 23/61 (anticline)(a), 110/17, 21/86 (anticline)(b)



(a)



(b)

20.8

GPS: 44.05703, 18.09064

Location: In the village of Seoca

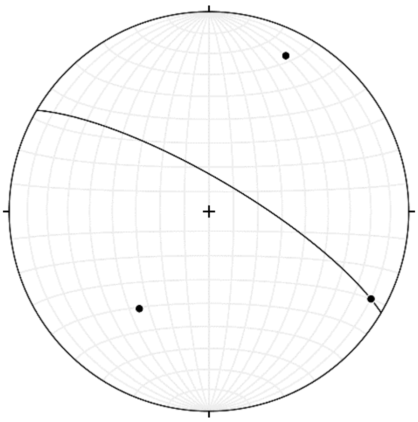
Lithology: Grey silty marl interbedded with fine to coarse sandstone (5-25cm), the thicker the beds the less planar and more channelized they become.

Formation (age): M2,3

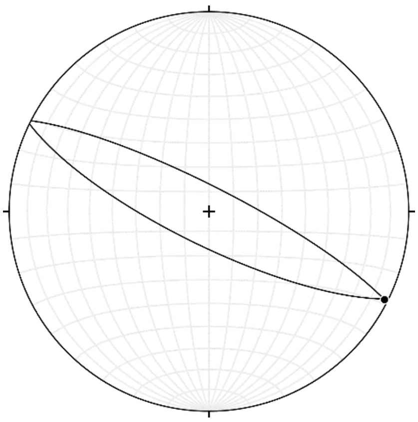
Other observations: Inbetween two "splays" of the main fault on map. Fining downwards so maybe an overturned syncline? Or amalgamated beds which were interpreted wrongly as a coarsening up sequence.

Measurements:

- Bedding: B1 36/50, B2 206/76
- Cleavage: C1 27/80
- Fold hinge/axial plane: 118/9, 30/77 (syncline fining upward on both sides)(a)
- Intersection lineation: 117/2 (b)



(a)



(b)

20.9

GPS: 44.04715, 18.1146 (strange point, more likely on the road to Koprivnica)

Location: At the southern most highway bridge over the Lasva river west of Dobrinje.

Lithology: Grey silty marl interbedded with fine/medium (5-10cm)

Formation (age): Quarternary of map but M2,3

Measurements:

- Bedding: B1 192/67

20.10

GPS: 44.10676, 18.09596

Location: Road to Koprivnica

Lithology: Grey silty marl interbedded with fine to coarse sandstone (5-25cm), the thicker the beds the less planar and more channelized they become.

Formation (age): M2,3

Other observations: Seems to be a thrust structure in the marl similar to what we have seen before, but lithology seems to be less consolidated and therefore it is harder to judge. B8 is probably thrust parallel.

Measurements:

- Bedding: B1 266/16, B2 267/31, B3 256/50, B4 260/45, B5 214/5, B6 212/30, B7 192/18, B8 212/30
- Fault: 212/30 (Bedding parallel to B8)(apparent reverse)

20.11

GPS: 44.10548, 18.09504

Location: Road to Koprivnica

Lithology: Brownish silty marl interbedded with fine to medium sandstone (5-10cm)

Formation (age): 2M2

Measurements:

- Bedding: B1 43/20, B2 16/41, B2A 20/40, B3 356/55
- Fault: 2/41, ss lineation 34/48

20.12

GPS: 44.09912, 18.09101

Location: South of Koprivnica, lunchspot

Lithology: Dominant grey silty marl occasionally interbedded with fine sandstone (5cm max).

Formation (age): 2M2

Measurements:

- Bedding: B1 153/16

20.13

GPS: 44.1008, 18.09056

Location: In the meadows above/west of Koprivnica.

Lithology: Grey silty marl occasionally interbedded with fine sandstone (5cm max).

Formation (age): 2M2

Measurements:

- Bedding: B1 152/9

20.14

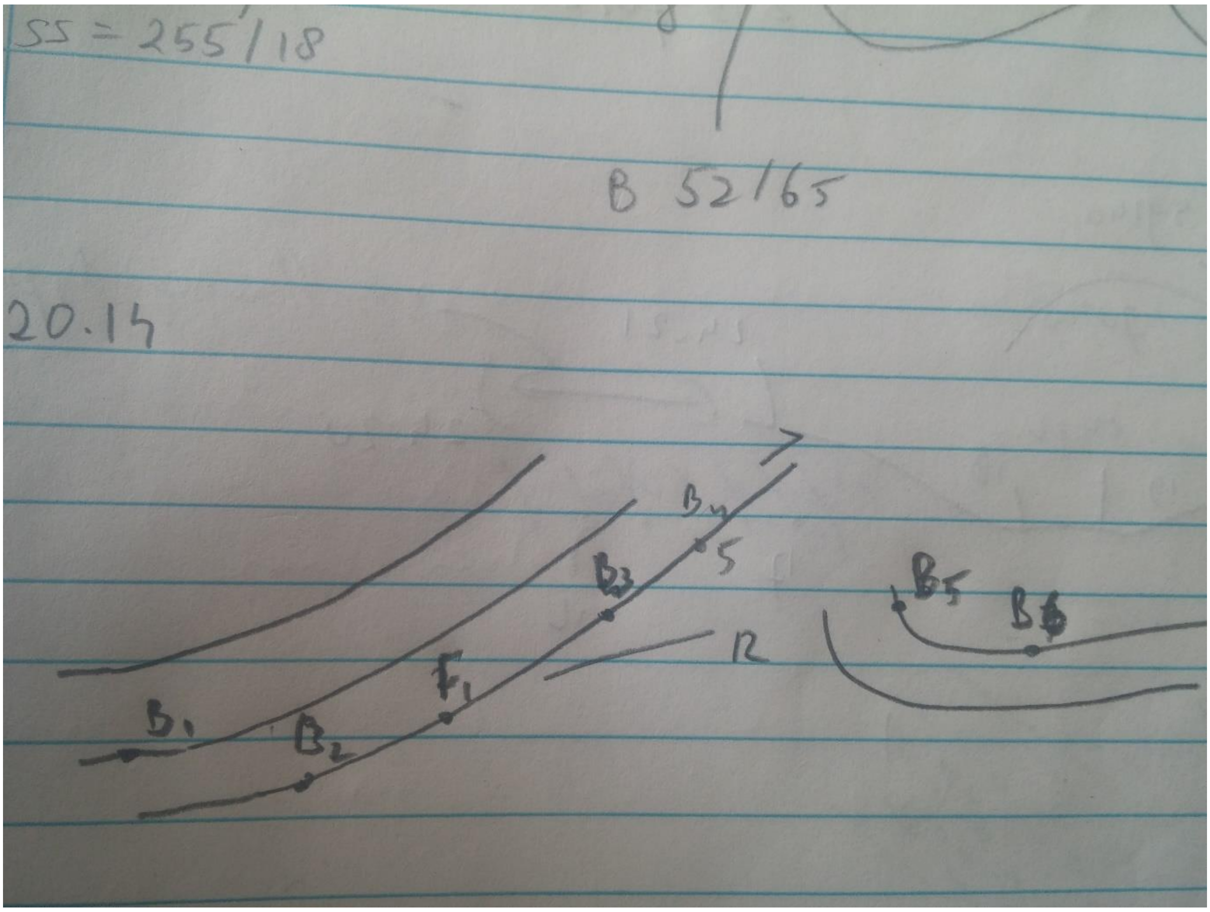
GPS: 44.10442, 18.09397

Location: High road to Koprivnica

Lithology: Brown silty marl occasionally interbedded with fine sandstone (5cm max).

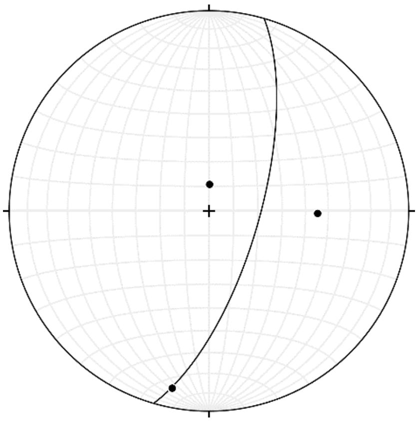
Formation (age): 2M2

Pictures/sketches:



Measurements:

- Bedding: B1 105/12, B2 73/5, B3 70/18, B4 72/25, B5 271/45, B6 180/11
- Fault: 74/62, riedel 87/44
- Fold hinge/axial plane: 192/11, 106/69 [B5,B6](drag/footwall syncline)



20.15-17

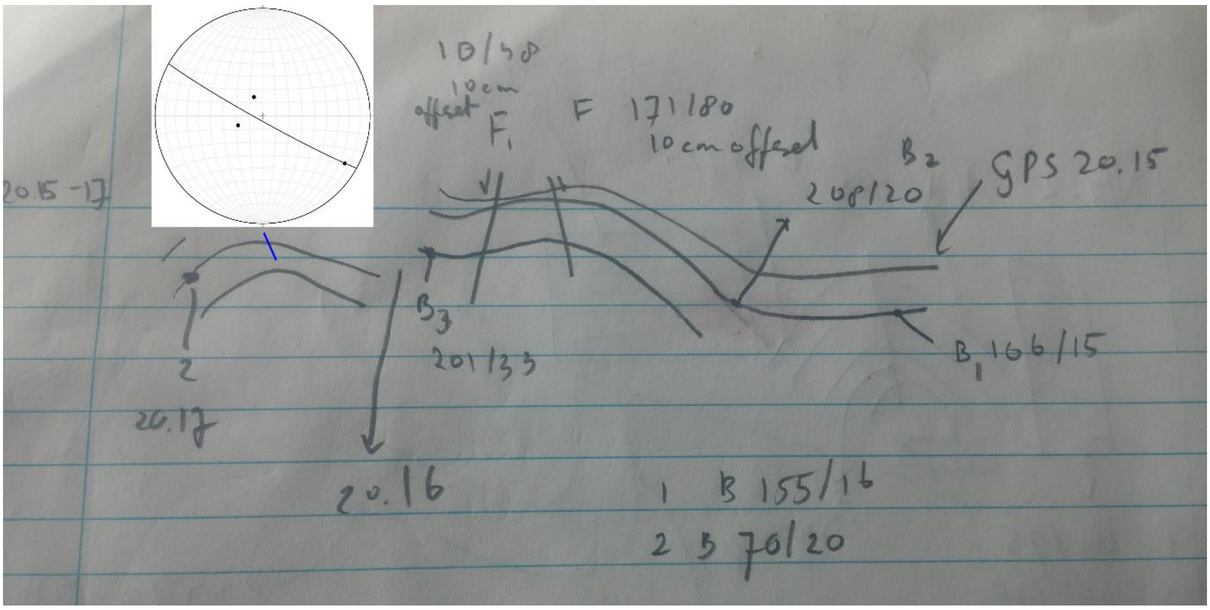
GPS: 44.10461, 18.09433 & 44.1049, 18.09448 (20.16) & 44.10537, 18.09468 (20.17)

Location: High road to Koprivnica

Lithology: Brown silty marl occasionally interbedded with fine sandstone (5cm max).

Formation (age): 2M2

Pictures/sketches:



Measurements:

- Bedding: B1 106/15, B2 208/20, B3 201/33, B4 70/20, B5 155/16
- Faults: F1 10/48 (apparent normal, 10cm offset), F2 171/80 (apparent normal, 10cm offset)
- Fold hinge/axial plane: 120/13, 209/86 [B4,B5](anticline)

20.18

GPS: no GPS but likely close to 44.10537, 18.09468 (20.17)

Location: High road to Koprivnica

Lithology: Brown silty marl occasionally interbedded with fine sandstone (5cm max).

Formation (age): 2M2

Measurements:

- Bedding: B1 74/70, B2 59/40, B3 70/20

21.1

GPS: 44.13977, 18.00491

Location: On the hill above Biljesevo above the highway (before fuel ran out).

Lithology:

Formation (age): 2M2

Measurements:

- Bedding: B1 216/20

21.2

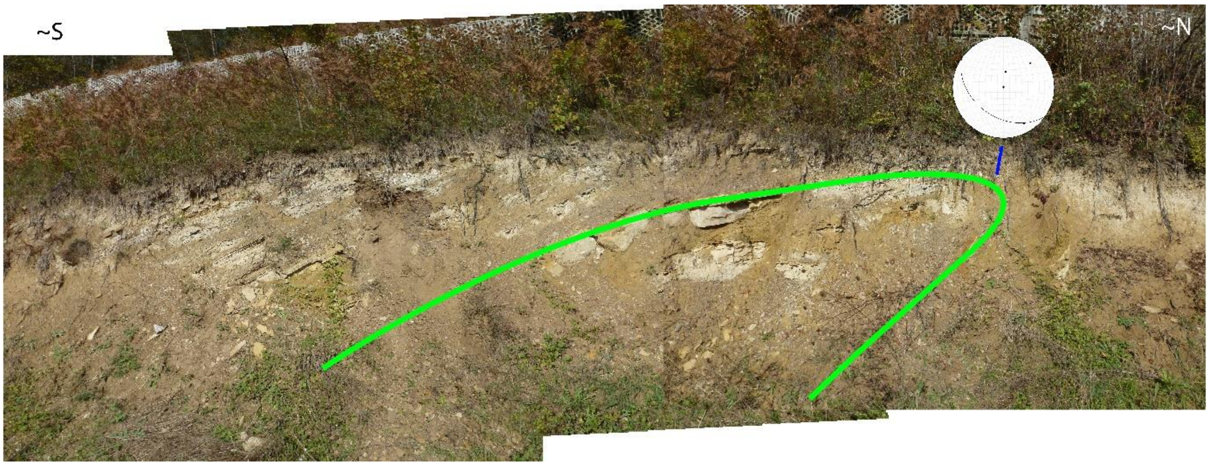
GPS: 44.13574, 17.99755

Location: In the town of Biljesevo right above the highway (landslide road town, before fuel ran out).

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by thin sandstones (1-5cm)

Formation (age): 2M2

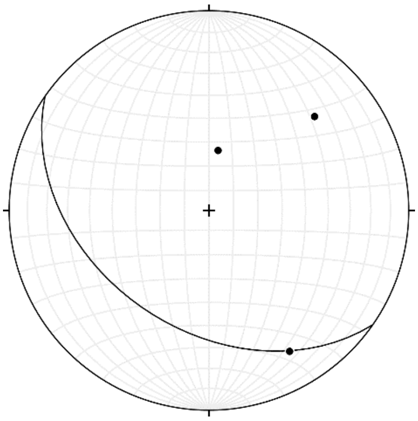
Pictures/sketches:



Measurements:

- Bedding: B1 187/33, B2 196/35, B3 188/25, B4 182/17, B5 228/60
- Fault: 10/63 (apparent normal)

- Fold hinge/axial plane: 150/20, 215/41 [B3,B5](anticline)



21.3

GPS: 44.13599, 17.99775

Location: In the town of Biljesevo, right above the highway (landslide road town, before fuel ran out).

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by thin sandstones (1-5cm)

Formation (age): 2M2

Measurements:

- Bedding: B1 225/16

21.4

GPS: 44.13664, 17.99567

Location: Between the town of Biljesevo, and Gornji Luzani, right above the highway (landslide road town, before fuel ran out).

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by thin sandstones (1-5cm), fining upwards

Formation (age): 2M2

Measurements:

- Bedding: B1 201/15

21.5

GPS: 44.1383, 17.99415

Location: Between the town of Biljesevo, and Gornji Luzani, right above the highway (landslide road town, before fuel ran out).

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by thin sandstones (1-5cm), fining upwards

Formation (age): 2M2

Measurements:

- Bedding: B1 ~254/30

21.6

GPS: 44.12052, 17.94476

Location: Road the Dusina/Gornja Visnjica

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by sandstones with wavy appareance and erosive bases (5-30cm), fining upwards.

Formation (age): M2,3

Measurements:

- Bedding: B1 ~254/30

21.7

GPS: 44.12007, 17.94421

Location: Road the Dusina/Gornja Visnjica

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by sandstones with wavy appareance and erosive bases (5-30cm), fining upwards.

Formation (age): M2,3

Measurements:

- Bedding: B1 216/25

21.8

GPS: 44.11945, 17.94383

Location: Road the Dusina/Gornja Visnjica

Lithology: Very sandy marls interbedded by sandstone beds.

Formation (age): M2,3

Other observations: Some hinge collapse features visible.

Measurements:

- Bedding: B1 168/75

21.9

GPS: 44.1188, 17.94312

Location: Road the Dusina/Gornja Visnjica

Lithology: Very sandy marls interbedded by sandstone beds.

Formation (age): M2,3

Measurements:

- Bedding: B1 285/52

21.10

GPS: 44.11877, 17.94093

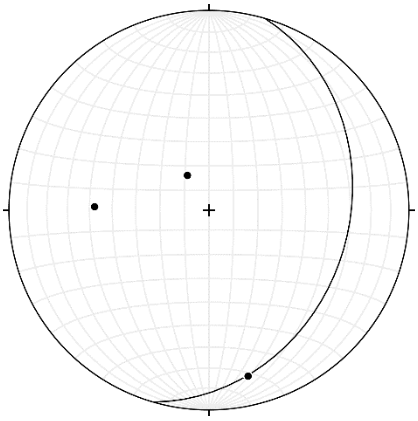
Location: Beginning of Dusina village

Lithology: Marls interbedded by fine/medium sandstone beds (2-5cm).

Formation (age): M2,3

Measurements:

- Bedding: B1 148/17, B2 120/41, B3 92/48
- Fold hinge/axial plane: 167/16, 106/31 [B1,B3](anticline)



21.11

GPS: 44.08138, 18.11962

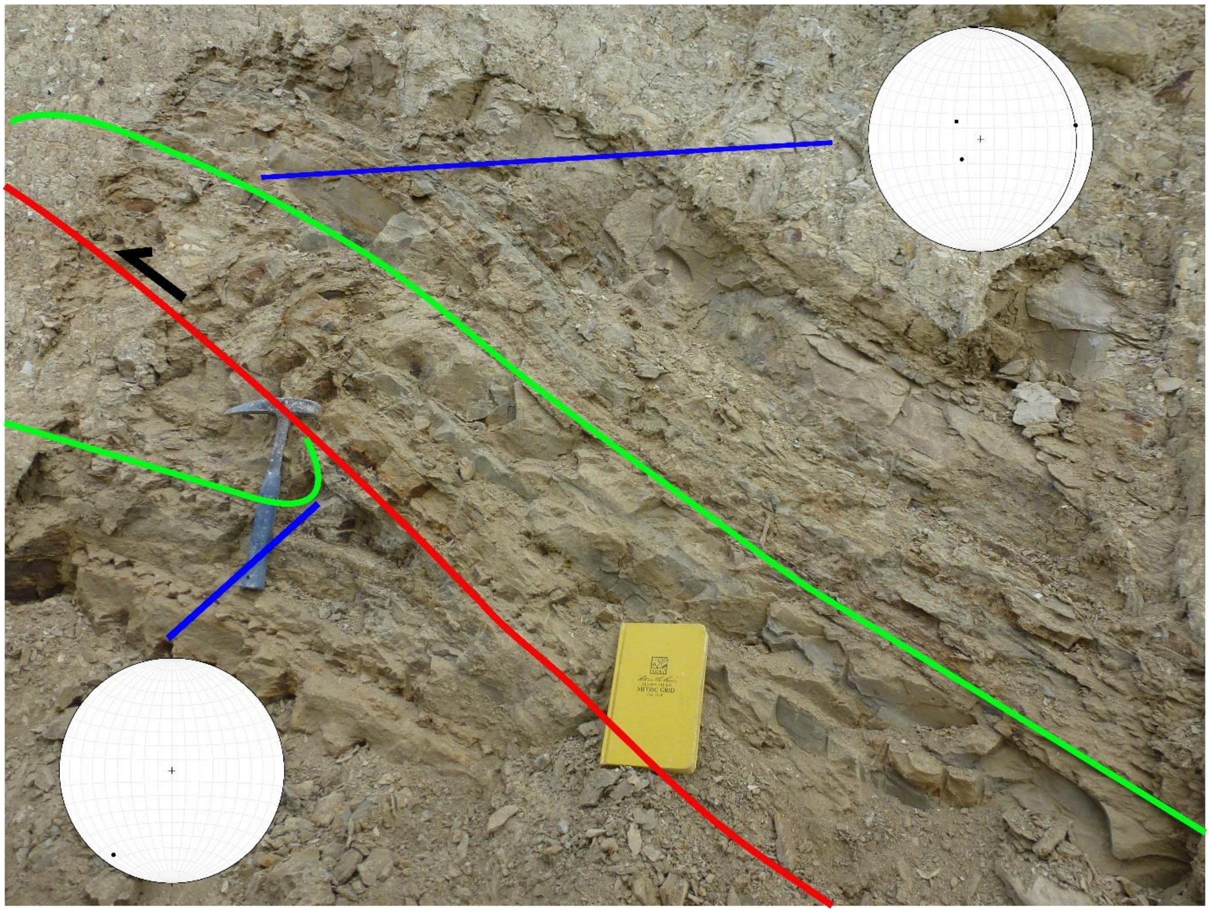
Location: Just under the termoelektranaplant dump over the first hill to the south of the back road the Dobrinje.

Lithology: Thinly bedded marls alternated with more massively bedded marls interbedded by thin sandstones (1-5cm)

Formation (age): 2M2

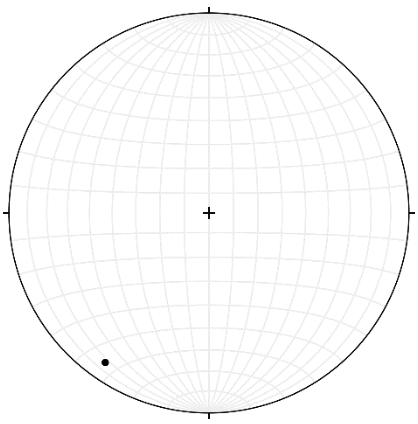
Other observations: Similar to 15.17

Pictures/sketches:

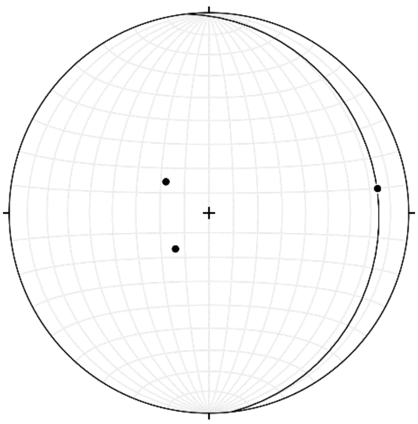


Measurements:

- Bedding: B1 44/20, B2 126/22, B3 160/13, B4 180/15, B5 235/13, B6 180/7
- Fault: 126/22 (apparent reverse, bedding parallel to B2)
- Fold hinges/axial planes: 215/10 (footwall syncline, measured directly)(a), 82/16, 84/16 (hangingwall anticline)[B1,B2](b)



(a)



(b)

21.12

GPS: 44.07929, 18.12009

Location: Just under the termoelektranaplant dump over the first hill to the south of the back road the Dobrinje.

Lithology: Marls interbedded by fine/medium sandstone beds (5cm).

Formation (age): 2M2

Measurements:

- Bedding: B1 149/13

21.13

GPS: 44.0722, 18.11998

Location: Dobrinje road close to Gora.

Lithology: Marls interbedded by fine/medium sandstone beds (5cm).

Formation (age): 2M2

Measurements:

- Bedding: B1 22/30

21.14

GPS: 44.07035, 18.12093

Location: Dobrinje road close to Gora.

Lithology: Marls interbedded by fine/medium sandstone beds (5cm).

Formation (age): 2M2

Other observations: Fining upwards

Measurements:

- Bedding: B1 18/40

21.15

GPS: 44.05095, 18.11138

Location: Just west of Dobrinje.

Lithology: Marls interbedded by fine/medium sandstone beds (5cm).

Formation (age): M2,3 on the border with 2M2

Measurements:

- Bedding: B1 18/40

21.16

GPS: 44.05799, 18.14315

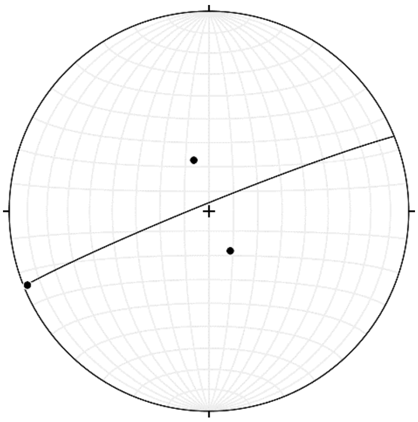
Location: In the hills above Upovac.

Lithology: Marls interbedded by fine/medium sandstone beds (5cm).

Formation (age): 2M2, At the border with 3Ol,M and M2,3

Measurements:

- Bedding: B1 163/22, B2 332/18
- Fold hinge/axis: 248/2, 338/87 (anticline)



21.17

GPS: 44.05948, 18.14313

Location: In the hills above Upovac.

Lithology: Grey silty marls

Formation (age): 2M2, At the border with 3Ol,M and M2,3

Measurements:

- Bedding: B1 318/11

21.18

GPS: 44.05622, 18.14657

Location: In the hills above Upovac.

Lithology: Grey silty marls

Formation (age): 2M2, right on the border with 3Ol,M and M2,3

Measurements:

- Bedding: B1 6/35

21.19

GPS: 44.05568, 18.14727 (B1), 44.05531, 18.1482 (B2)(Upovac), 44.1186, 18.09021 (B3), 44.12069, 18.0964 (Desetnik)(B4)

Location: In the hills above Upovac, and the last two point near Desetnik (across the highway from Kakanj).

Lithology: Grey silty marls

Formation (age): 2M2, right on the border with 3Ol,M and M2,3, Second points also 2M2

Measurements:

- Bedding: B1 3/25, B2 10/30, B3 187/40, B4 170/40

22.12

GPS: 44.04755, 18.16689

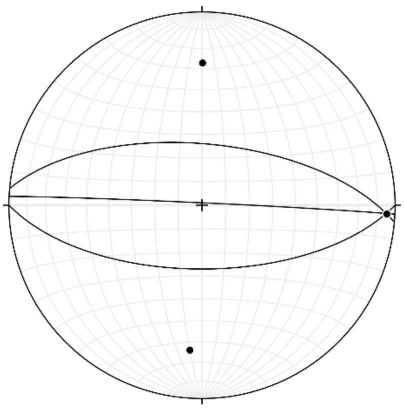
Location: Road above Porijeciani

Lithology: marl

Formation (age): M2,3

Measurements:

- Bedding: 180/63, 5/64
- Fold hinge/axial plane: 93/5, 3/89



22.25

GPS: 44.0465, 18.16863

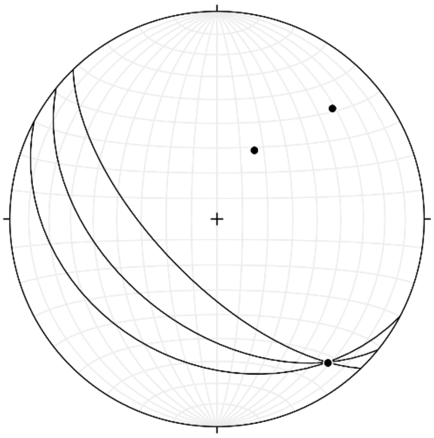
Location: Road above Porijeciani

Lithology: Thinly bedded marl

Formation (age): M2,3

Measurements:

- Bedding: 208/31, 226/66
- Fold hinge/axial plane: 142/14, 219/47



22.40

GPS: 44.1351, 18.02374

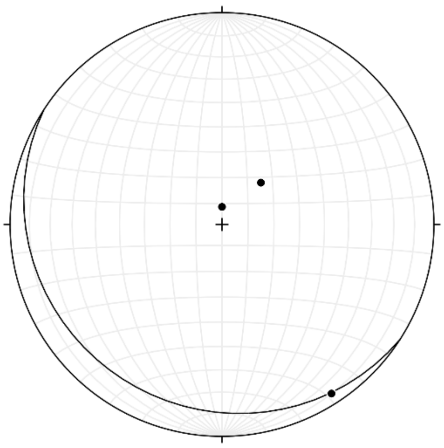
Location: East of Modrinje, N of highway

Lithology: marl

Formation (age): 2M2

Measurements:

- Bedding: 222/22, 178/7
- Fold hinge/axial plane: 147/6, 213/14



23.9

GPS: 44.1293, 18.06415

Location: East of Modrinje, S of highway

Lithology: Organic rich Oligocene on top of Miocene limestone

Formation (age): M2,3 & 3Ol,M

Measurements:

- Bedding: 95/28, 134/38

24.2

GPS: 44.02466, 18.1893

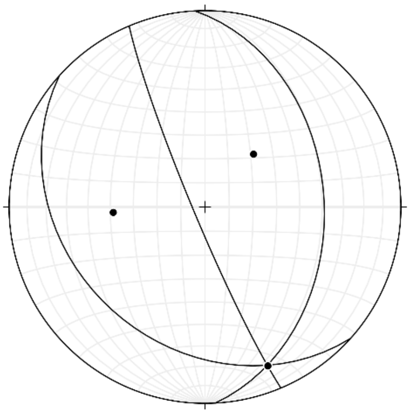
Location: Road S of Smrcnica

Lithology: Thinly bedded marls with very thin sandstones inbetween

Formation (age): M2,3

Measurements:

- Bedding: 222/30 (B1), 216/29 (B2), 210/29 (B3), 87/39 (B4), 252/35 (B5), 214/29 (B6)
- Fold hinge/axial plane: 159/14, 247/85



24.8

GPS: 44.04113, 18.18566

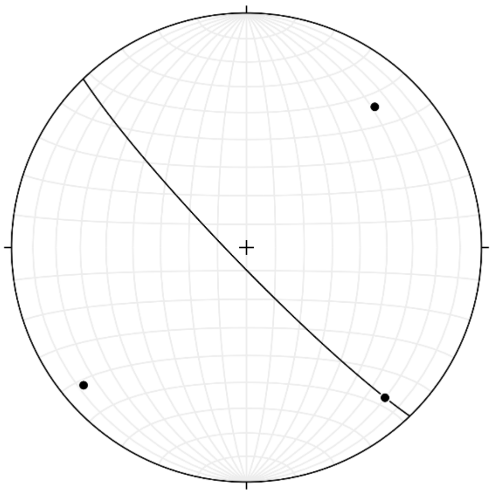
Location: N of Smrcnica

Lithology: Thinly bedded (distal) marls

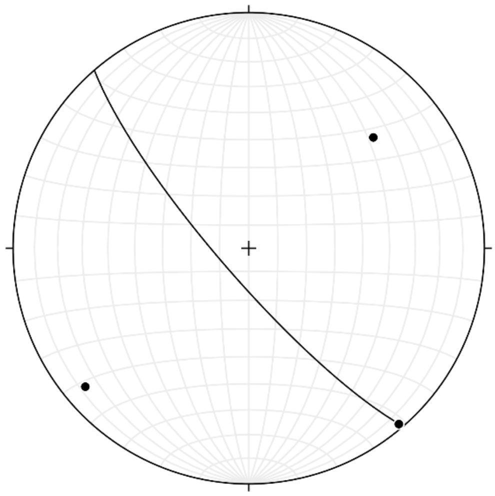
Formation (age): M2,3

Measurements:

- Bedding: 226/60 (B1), 50/80 (B2), 222/70 (B3)
- Fold hinge/axial plane: 137/15, 226/85 (a) (anticline B2,B3), 140/3, 229/80 (b) (syncline B1,B2)



(a)



(b)