Geophysics

Preliminary Structural Interpretation of a Seismic Profile across the Frontal Sector of the Eastern Achara-Trialeti Fold-and-Thrust Belt

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This paper presents a new structural model for the frontal part of the eastern Achara-Trialeti fold-and-thrust belt based on the interpretation of a seismic reflection profile across the retro-wedge of the Lesser Caucasus orogen. The structural details from the interpreted seismic reflection profile provide new data on the deep structure of the frontal part of the eastern Achara-Trialeti fold-and-thrust belt. The seismic reflection profile crosses, from south to north, the Varketili anticline, the Ormoiani syncline, and a south-directed imbricate thrust system. Seismic interpretation is constrained by surface geology, exploration wells, and application of theoretical models on fault-related folding. Seismic reflection data interpretation reveals the interaction between south- and north-vergent fold-thrust structures and north-vergent duplexes at depth. The duplexes are well imaged on the seismic profile and constituted by a lower and an upper duplex system. The lower duplex involves the Cretaceous-Middle Eocene sequence, whereas the upper duplex affects the Upper Eocene strata. *© 2021 Bull. Georg. Natl. Acad. Sci.*

Achara-Trialeti fold-and-thrust belt, seismic reflection profile, duplex

The structural interpretation of the deep architecture of the frontal sector of the eastern Achara-Trialeti fold-and-thrust belt (ATFTB) has significantly changed following the interpretation of progressively new seismic data [1-3]. A robust reconstruction of the subsurface derived only from surface geology and borehole data is fairly hard to obtain [4, 5], consequently the reliability of such models is doubtful. It should be mentioned that previous studies for particular sectors of the eastern

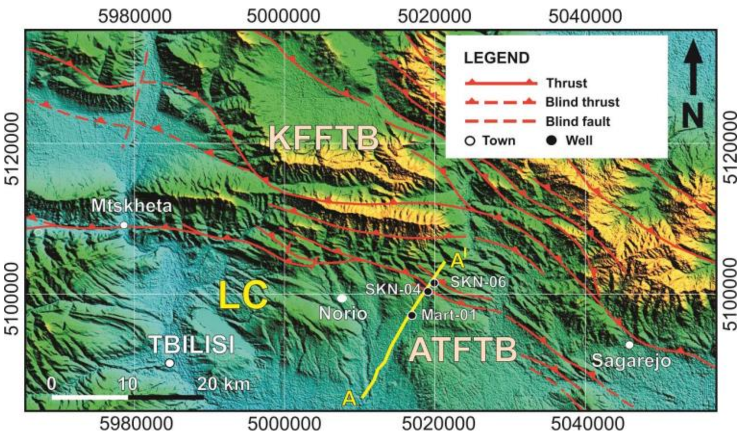

Fig. 1. Study area and simplified structural map of frontal part of the eastern ATFTB and KFB. The red color indicates the main thrusts, mapped based on our interpretation and on already published maps and cross sections [3, 6]. Yellow color line is seismic profile A-A^{I}. Abbreviations: LC-Lesser Caucasus; KFFTB-Kura foreland fold-and-thrust belt; ATFTB-Achara-Trialeti fold-and-thrust belt.

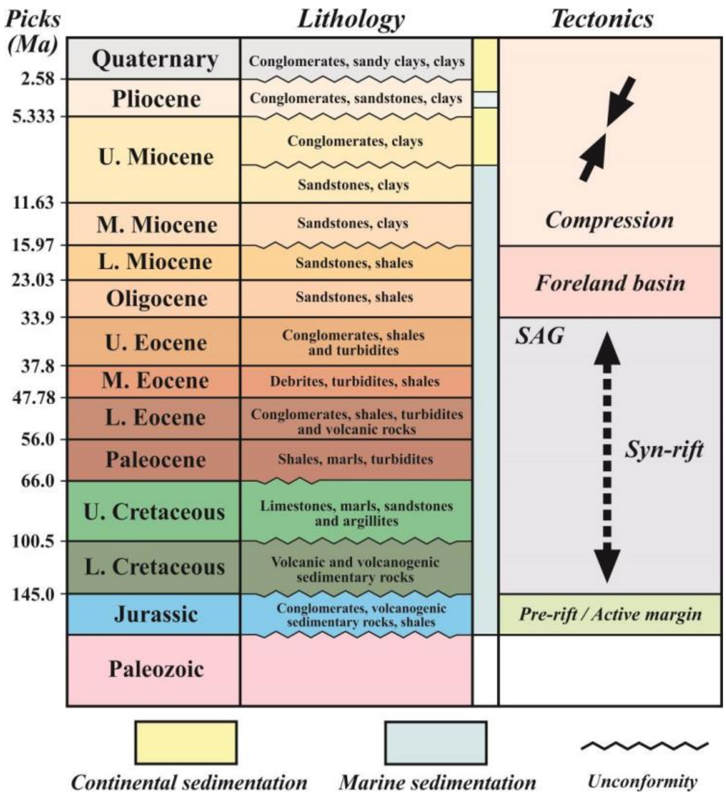

Fig. 2. Tectono-stratigraphic chart of the study area [3].

ATFTB, such as the subsidence zone, were mainly based on well data [6]. Conversely, several new seismic reflection profiles are now available for areas in the northern part of eastern ATFTB. In this particular segment, the deep structure of the Norio-Satskhenisi oil field is the target object of our investigation (Fig. 1). The main aim of our research was to study the deep structure of the area via interpretation of a seismic profile by applying conceptual models related to the theory of fault-related folding [4, 5].

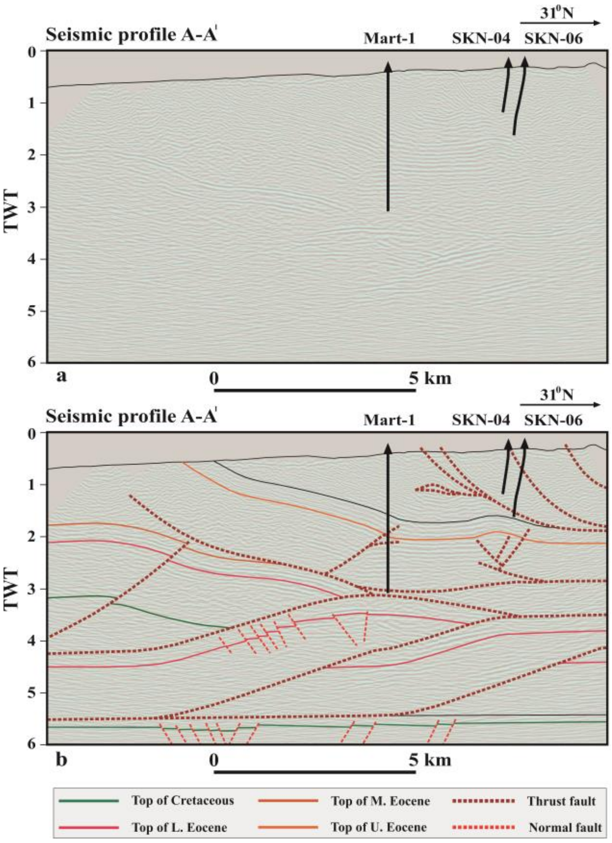

Fig. 3. (a) Uninterpreted and (b) interpreted seismic reflection profile A-A[I]. Location is shown in Figure 1.

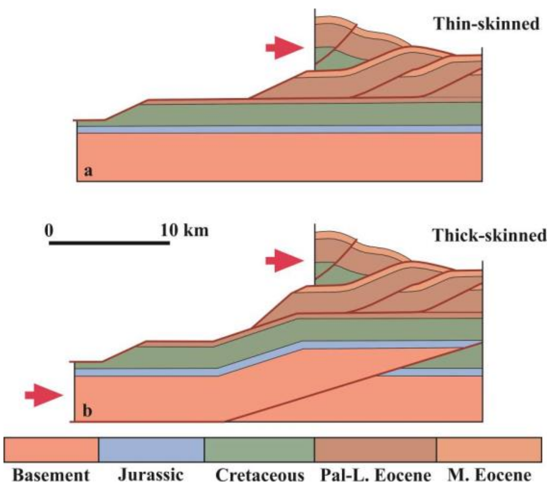

Fig. 4. Structural model for the frontal part of the eastern ATFTB. (a) Thin-skinned model. (b) Thick-skinned model.

of the ATFTB is affected by northward thrusting of the Lesser Caucasus basement wedge(s) [1, 3, 7].

The ATFTB is located in the retro-wedge of the Lesser Caucasus orogen. The present-day geometry The collision between the Arabian and Eurasian plates caused inversion of sub-parallel extensional basins and intensive deformation within the Lesser Caucasus during late Alpine times [1, 3]. The ATFTB lies to the south of the Kura foreland basin (KFB) and extends in the west-east direction. Our study, which has been carried out integrating seismic reflection profile interpretation with published data, is located in central Georgia along the frontal part of the eastern ATFTB. The location of the 2D seismic reflection profile (A-A^I) is shown in Figure 1.

The structural trend in the eastern ATFTB consists of north and south-vergent folds, reverse faults, and thrusts [1, 6-12]. The stratigraphy of the study area records the evolution from the extensional Achara-Trialeti rift basin to its closure and inversion in the compressional context of the Arabia-Eurasia collision zone (Fig. 2). The sedimentary succession of the frontal part of the eastern ATFTB is commonly represented by more than 7 km thick pre-rift (Jurassic), syn-rift (Cretaceous-Upper Eocene), post-rift/foreland (Oligocene-Lower Miocene) and syn-orogenic (Middle Miocene-Pliocene) strata [3]. The contractional deformation in the eastern ATFTB, which was mostly concentrated in the frontal part of the eastern ATFTB at the border with the KFB, has commonly been attributed to the Upper Miocene-Pleistocene [1, 7]. Recent apatite fission-track and (U-Th)/He data have refined its age of inception, which occurred in the Middle Miocene [10, 11]. Recent GPS and earthquakes data indicate that the ATFTB is tectonically active [13-15].

The 2D seismic reflection profile A-A^I crosses from south to north the Varketili anticline, the Ormoiani syncline, and the south-directed imbricate thrust system (Fig. 1). Seismic interpretation is constrained by surface geology, exploration wells, and application of fault-related folding models [4]. The 2D time migrated seismic profile A-A^I indicates that the fold-and-thrust belt front is characterized by the interaction between the shallow south-directed thrust system and deeper south- and north-directed duplexes (Fig. 3). The duplexes are well imaged on the seismic profile and are constituted by two vertically stacked lower and upper duplex systems (Fig. 3). The lower duplex system affects the Cretaceous-Middle Eocene strata whilst the upper duplex system involves the Upper Eocene strata. Our interpretation suggests that several detachment faults controlled the deformation of the frontal part of the eastern ATFTB. A basal detachment fault is localized within the Lower Eocene shales, and a shallow detachment fault lies within the Upper Miocene strata (Fig. 3). At surface, the collision zone (or initial collision zone) between the Lesser and Greater Caucasus orogens shows south-vergent imbricated thrust-fold structures. The south-directed imbricate thrusts involve Maikopian and Upper Miocene deposits. The seismic profile (A-A^I) interpretation also reveals the occurrence of inherited normal faults, which have not been reactivated, within the contractional structures [16] and below the detachment. Reactivation of other normal faults through positive inversion [17] occurred during compression (Fig. 3). The structural details from the interpreted seismic reflection profile A-A^I provide a new perspective on the deep structure of the frontal part of the eastern ATFTB. In this work, based on the integration of field and 2D seismic data, we suggest that the deep structure of the frontal eastern Achara-Trialeti fold-and-thrust belt is characterized by north and south-vergent thrusts and north-vergent duplex systems. In Figure 4 we introduce two possible models for the deep structure of our study area: (1) in the first model the structure of the thrust front of the eastern ATFTB is thin-skinned, with structures developed over a mostly undeformed basement; (2) in the second model it is thick-skinned, with the basement involved in the deformation [18]. Moreover, the possibility that precursor deep-rooted faults may be involved in and control the structural evolution [17, 19] cannot excluded.

Duplexes and thrust-related folds in fold-and-thrust belts commonly form important structural hydrocarbon traps [4]. The definition of plausible structural models and the thorough comprehension of the structural architecture and kinematic development are essential for successful exploration of oil and gas resources. The main reservoir rocks in eastern Georgia are represented by Middle Eocene volcaniclastic turbidite sandstones [12, 20]. In this regard, the study area, and especially the sectors where lower duplexes and thrust-related folds are developed, are extremely important for subsurface exploration.

The new results presented in this study on the structural architecture of the frontal part of the eastern ATFTB certainly need to be integrated with further structural studies, balanced and reconstructed cross-sections and forward kinematic modelling.

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გეოფიზიკა

აღმოსავლეთ აჭარა-თრიალეთის ნაოჭა-შეცოცებითი სარტყლის ფრონტულ სექტორზე გამავალი სეისმური პროფილის წინასწარი სტრუქტურული ინტერპრეტაცია

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(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

სტატიაში წარმოდგენილია აღმოსავლეთ აჭარა-თრიალეთის ნაოჭა-შეცოცებითი სარტყლის ფრონტული ნაწილის სტრუქტურული მოდელი, რომელიც დაფუძნებულია მცირე კავკასიონის ოროგენის რეტრო-სოლის გასწვრივ მდებარე სეისმური პროფილის ინტერპრეტაციაზე. ინტერპრეტირებული სეისმური პროფილის სტრუქტურული დეტალები იძლევა ახალ მონაცემებს აღმოსავლეთ აჭარა-თრიალეთის ნაოჭა-შეცოცებითი სარტყლის ფრონტული ნაწილის სიღრმული აგებულების შესახებ. სეისმური პროფილი სამხრეთიდან ჩრდილოეთის მიმართულებით კვეთს ვარკეთილის ანტიკლინს, ორმოიანის სინკლინს და სამხრეთ-ვერგენტულ ქერცლოვან შეცოცებებს. სეისმური ინტერპრეტაცია შესრულებულია ზედაპირული გეოლოგიის, ბურღილების მონაცემების და რღვევებთან დაკავშირებული ნაოჭების თეორიული მოდელების გამოყენებით. არეკვლილი სეისმური მონაცემები გვიჩვენებს სამხრეთ და ჩრდილოეთ-ვერგენტული ნაოჭა-შეცოცებითი სტრუქტურების და სიღრმეში ჩრდილოეთ-ვერგენტული დუპლექსების ურთიერთდამოკიდებულებას. დუპლექსები კარგად არის გამოსახული სეისმურ პროფილზე და წარმოდგენილია ქვედა და ზედა დუპლექსების სისტემით. ქვედა დუპლექსები მოიცავს ცარცი-შუა ეოცენის, ხოლო ზედა დუპლექსები - ზედა ეოცენის ქანებს.

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