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Geophysics

Structural Model of the Frontal Part of the Eastern Achara-Trialeti Fold-and-Thrust Belt: the Results of Seismic Profile Interpretation

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(Presented by Academy Member Tamaz Chelidze)

The structural model of the frontal part of the eastern Achara-Trialeti fold-and-thrust belt (v. Dzegvi and surrounding area) using interpretations of seismic profile is presented here. The seismic profile reveals the presence of upper and lower structural complexes. The seismic profile shows that the structures mainly are represented by north- and south-vergent thrusts, north-vergent duplex and structural wedge. The upper structural complex is represented by a shallow triangle zone and the triangle tip is located in middle Miocene deposits. The lower structural complex is represented by a structural wedge and the wedge tip is located in the Upper Cretaceous strata. On the basis of the interpreted seismic profile a structural cross-section has been constructed through the frontal part of the Achara-Trialeti fold-and-thrust belt. The seismic profile and structural cross-section show that the Armazi anticline is a fault-propagation fold developed above the thrust sheet. *© 2020 Bull. Georg. Natl. Acad. Sci.*

Achara-Trialeti fold-and-thrust belt, seismic reflection profile, triangle zone, thrust-sheet

In this paper we present the structural model of the frontal part of the eastern Achara-Trialeti fold-and-thrust belt (ATFTB) using new seismic reflection profile. The ATFTB is located in the frontal part of the Lesser Caucasus (LC) orogen and was formed since the late Miocene by the ongoing continental collision of the Arabia-Eurasia plates [1]. The study area covers the frontal part of the eastern ATFTB and southern part of the Kura foreland basin (KFB) (Figs. 1, 2). Many structural models of the frontal part of the eastern ATFTB have been proposed in the literature [1-6]. These published models have been constrained by surface geological and borehole data, however the detailed structural architecture still remains unclear and controversial. The main objectives of this study are to integrate the new surface geological and seismic data and to create a structural model of frontal part of the eastern ATFTB.

is located between the eastern ATFTB and Kura foreland fold-and-thrust belt (KFFTB) [1, 13, 14].

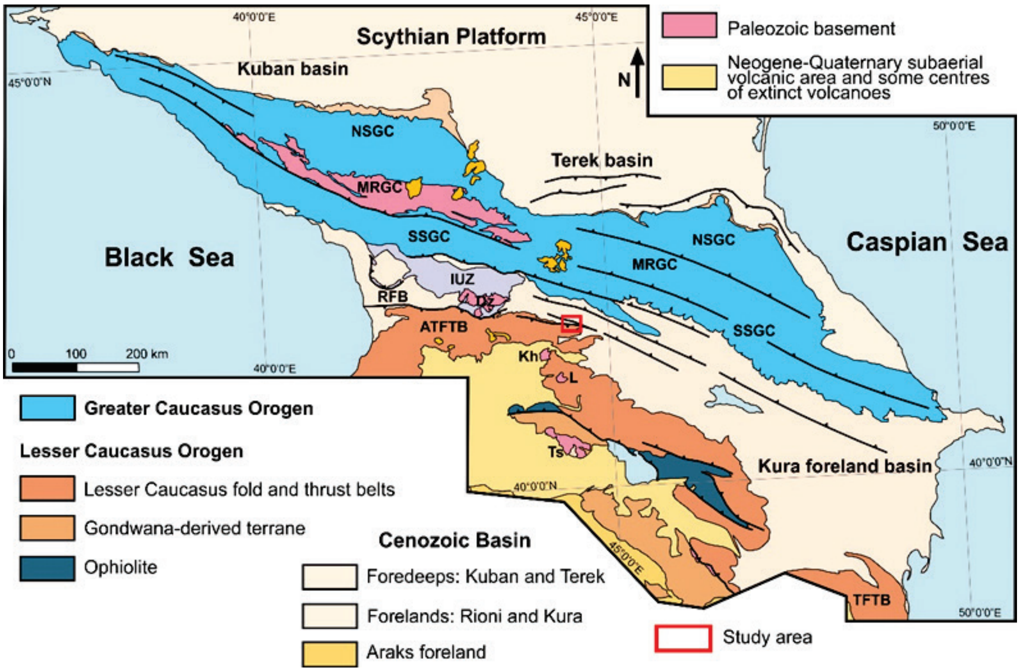

Fig. 1. Simplified tectonic map of the Caucasus [7]. Abbreviations: SSGC- Southern Slope of Greater Caucasus, MRGC-Main Range of Greater Caucasus, NSGC-Northern Slope of Greater Caucasus; RFB-Rioni foreland basin; IUZ-Imereti uplift zone; ATFTB-Achara-Trialeti fold-and-thrust belt; TFTB-Talysh fold-and-thrust belt; DZ-Dzirula; Kh-Khrami; L-Loki; Ts-Tsakhkuniats.

Geological Setting

The ATFTB extending from the Black Sea coast toward Tbilisi (360 km along strike and 65-45 km in width), eastward of Tbilisi submerges under Neogene Kura molasses [8]. The ATFTB (Fig. 1) is located in the northern part of the active collisional Lesser Caucasus orogen associated with Arabia-Eurasia convergence and has a long, complex tectonic evolution history that continues to the present day [8-12]. According to Sosson et al. [6] Achara-Trialeti is a thick-skinned fold-and-thrust belt and extensional basin inversion was caused by the reactivation of normal faults of Paleocene-Eocene age during the post-Maykopian (Oligocene-Lower Miocene) period. Our study (v. Dzegvi and surrounding area) is focused on the frontal part of the eastern ATFTB (Figs. 1, 2). KFB

The structure within the study area is represented by W-E trending fold and north- and south-vergent reverse-fault and thrust [2-5]. The Armazi anticline is an asymmetric fold composed of Cretaceous-Paleogene strata. The south- and north-vergent thrusts is developed North of the Armazi anticline [2-5]. The frontal structure of the zone which extends from Gori to Mtskheta is characterized by a well-developed frontal (north-dipping) monocline involving the stratigraphy down to Lower Miocene [1]. The sedimentary succession of the frontal part of the eastern ATFTB and southern part of KFB is represented by commonly more than 7 km thick Jurassic, Cretaceous, Paleogene and Neogene deep marine, shallow marine and thick continental strata. During the Cretaceous and Paleogene, the Achara-Trialeti extensional basin was filled with approximately

3500-4000 m thick sediments [15]. Syn-orogenic sediments are represented by 1500-2000 m thick Middle-Upper Miocene shallow marine and thick continental deposits [14].

field mapping, (2) interpretation of the seismic profile, and (3) construction of the structural cross-section. Fault-related folding and wedge thrust folding theories were used in the interpretation of

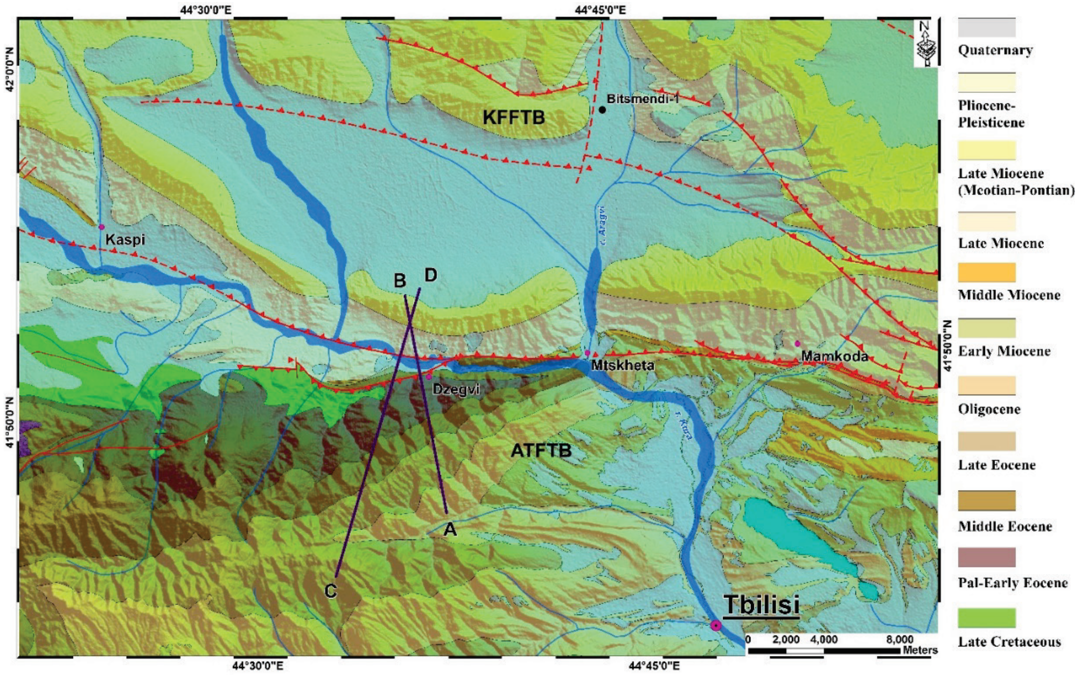

Fig. 2. Geological map of the study area, modified from D. Papava [4]. Abbreviations: ATFTB- Achara-Trialeti fold-and-thrust belt; KFFTB- Kura foreland fold-and-thrust belt.

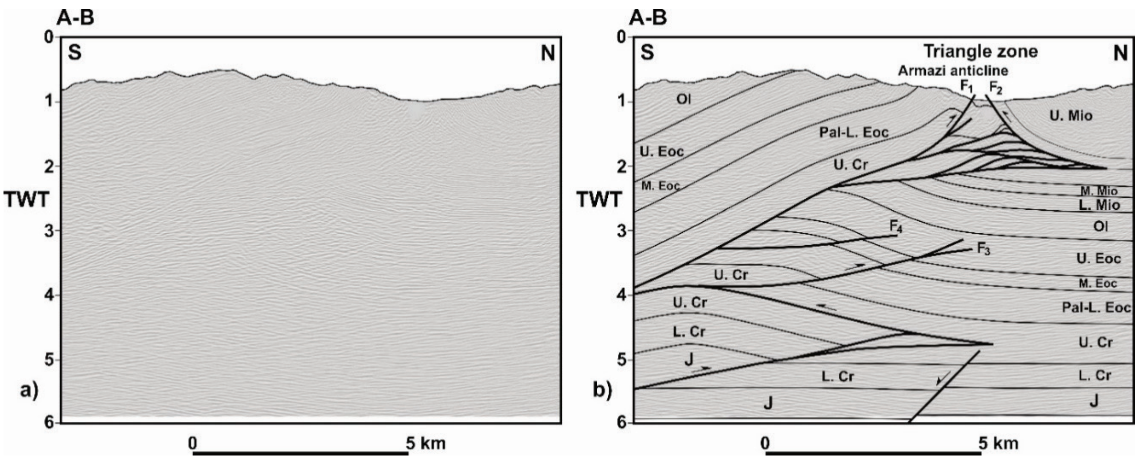

Fig. 3. (a) Uninterpreted and (b) interpreted seismic reflection profiles (A-B). Location is shown in Fig. 2. Abbreviations: J – Jurassic; L. Cr – Lower Cretaceous; U. Cr – Upper Cretaceous; Pal-L. Eoc – Paleocene-Lower Eocene; M. Eoc – Middle Eocene; U. Eoc – U. Eoc; Ol – Oligocene; L. Mio – Lower Miocene; M. Mio – Middle Miocene; U. Mio – Upper Miocene.

Methods and Results

In order to construct the structural model following methods were used: (1) 1:50.000 scale geological

the seismic reflection profile and construction of the structural cross-section [16, 17]. For the interpretation of the seismic profile and construction of the structural cross-section we used surface geological information obtained from 1:50.000 scale geological map [4] and our personal field data (Fig. 2).

To illustrate the structural model of the frontal part of the eastern ATFTB we present the new interpreted time migrated seismic image along the profile A-B and structural cross-section (C-D) (Figs. 3a,b & 4). The location of the seismic reflection profile and structural cross-section is shown in Fig. 2. The seismic reflection profile A-B shows that the structures mainly are represented by north- and south-vergent thrusts (F_1, F_2), north-vergent duplex and structural wedge. It is divided by the upper and lower structural complexes (Fig. 3b). The upper structural complex is represented by a shallow triangle zone which includes a north-vergent Armazi fault-related fold (F_1), north-vergent duplex, and south-vergent passive-backthrust (F_2) at the deformation front. The north-vergent thrust (F_1) is composed of upper Cretaceous and Paleogene strata. The passive-backthrust is represented by upper Miocene (Sarmatian and Meotian-Pontian) deposits. The lower structural complex is represented by a structural wedge and is made up of lower-upper Cretaceous-Jurassic strata. Two north-vergent blind thrusts (F_3, F_4) are developed above the structural wedge (Fig. 3b). On the basis of the interpreted seismic profile a structural cross-section has been constructed (Fig. 4).

Discussion

Structural cross section constructed from field and subsurface data (Fig. 3b) shows the N-directed displacement of thrusts and thrust-wedge (or structural wedge) along two detachment horizons (Fig. 4). Within the triangle zone the duplex sequence comprises Cretaceous-Neogene strata that were formed due to passive-roof duplex style of deformation. The southern part of the Kura foreland basin is represented by upper Miocene strata that were deformed and uplifted by passive-back thrusting at the triangle zone. The kinematic evolution of the south-vergent backthrust is related to the northward propagating duplex and triangle tip is located in middle Miocene (Fig. 4). Lower structural complex which is composed by Jurassic-Cretaceous strata is represented by blind structural wedge and wedge tip is located in upper Cretaceous strata (Fig. 4).

The interpreted seismic profile and structural cross-section have revealed that Armazi anticline is a breakthrough fault-propagation fold developed above the thrust sheet (Figs. 3 b, 4). The imbricated structure below the Armazi anticline is characterized by break-backward thrusting. Pre-existing fault-bend folds were cut by the younger thrust ramp along the points **c** and **f** (Fig. 4). Finally, the Armazi breakthrough fault-propagation fold was developed along the second new ramp (points **f** and **h**) (Fig. 4). We have named the F_1 (Fig. 3b) fault the Dzegvi thrust-sheet. The overall displacement along the Dzegvi thrust-sheet trajectory (**a**, **b**, **c**, **d**, **e**, **f**, **g**, **h, i**) is about 9000 m.

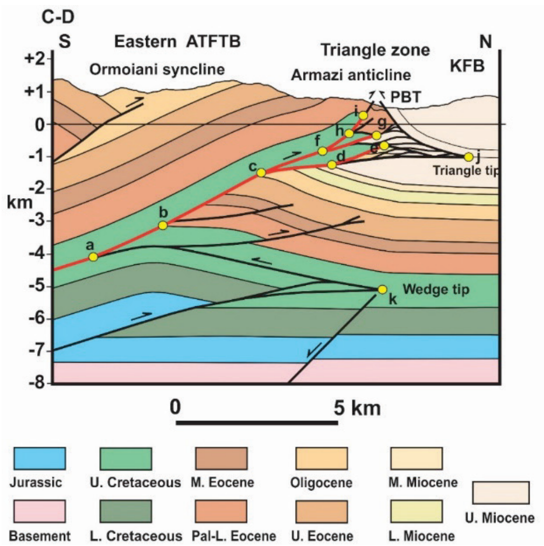

Fig. 4. Structural cross-section (C-D). Location is shown in Fig. 2. Abbreviations: ATFTB- Achara-Trialeti fold-and-thrust belt; KFB- Kura foreland basin; PBT-Passive-backthrust.

Two detachment levels within the lower part of Jurassic and upper Cretaceous section support a thin-skinned style of shortening. Within the frontal part of the eastern ATFTB shortening affected the about 7 km thick Jurassic-Neogene volcano-sedimentary strata above the Variscan basement (Fig. 4). According to thin- and thick-skinned tectonics theory, the introduced model is similar to the basement-involved thin-skinned fold-and-thrust belt model [18].

Conclusions

Results obtained through the interpretation of the seismic profile and structural cross-section, allow us to assume:

- The frontal part of the eastern ATFTB is represented by upper and lower structural complexes;
- Two detachment levels within the lower part of Jurassic and upper Cretaceous section could be distinguished;
- The upper structural complex is represented by a shallow triangle zone which includes a north-vergent Armazi fault-related fold, north-vergent duplex, and south-vergent passive-backthrust at the mountain front. The triangle tip is located in middle Miocene deposits;
- The Armazi anticline is developed above thrust-sheet breakthrough fault-propagation fold. The imbricate structure below the Armazi anticline is characterized by the break-backward thrusting. The displacement of the thrust sheet is about 9000 m.
- The lower structural complex is represented by a structural wedge and the wedge tip is located in the Upper Cretaceous strata.

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გეოფიზიკა

აღმოსავლეთ აჭარა-თრიალეთის ნაოჭა-შეცოცებითი სარტყლის ფრონტული ნაწილის სტრუქტურული მოდელი: სეისმური პროფილის ინტერპრეტაციის შედეგები

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(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

წარმოდგენილია აღმოსავლეთ აჭარა-თრიალეთის ნაოჭა-შეცოცებითი სარტყლის ფრონტული ნაწილის (სოფ. ძეგვი და მისი მოსაზღვრე ტერიტორიები) სტრუქტურული მოდელი სეისმური პროფილის ინტერპრეტაციის გამოყენებით. სეისმური პროფილი გვიჩვენებს ზედა და ქვედა სტრუქტურული კომპლექსების არსებობას. სეისმური პროფილიდან ჩანს, რომ სტრუქტურები ძირითადად წარმოდგენილია ჩრდილო და სამხრეთ-ვერგენტული შეცოცებებით, ჩრდილო-ვერგენტული დუპლექსებით და სტრუქტურული სოლით. ზედა სტრუქტურული კომპლექსი წარმოდგენილია სამკუთხა ზონით და მისი დაბოლოება განლაგებულია მიოცენურ ნალექებში. ქვედა სტრუქტურული კომპლექსი წარმოდგენილია სტრუქტურული სოლით და მისი დაბოლოება განლაგებულია ზედა ცარცულ ნალექებში. ინტერპრეტირებულ სეისმურ პროფილებზე დაყრდნობით აგებულია აჭარა-თრიალეთის ნაოჭა-შეცოცებით სარტყელზე გამავალი სტრუქტურული ჭრილი. სეისმური პროფილი და სტრუქტურული ჭრილი გვიჩვენებს, რომ არმაზის ანტიკლინი არის რღვევა-გავრცელებადი ნაოჭი და განვითარებულია ტექტონიკური ზეწრის თავზე.

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