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Geology

Deformation Styles of Fault-Related Folds in the Imereti Uplift Zone, Western Georgia

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(Presented by Academy Member Tamaz Chelidze)

Abstract. The external zone of the western Greater Caucasus orogen, known as the Imereti Uplift Zone, developed during the Late Alpine period in response to the convergence between the Arabian and Eurasian plates. Seismic profile interpretation allowed us to create two structural cross-sections, which help to analyze the geometry of fault-related folds associated with both thick- and thin-skinned structures. Seismic profile and structural cross-sections show that the dominant structural styles of the compressional structures are related to multiple detachments. Seismic data revealed the presence of thick-skinned fault-bend folds. Thin-skinned fault-related folds above the basement thrust are represented by imbricate fault-bend and fault-propagation folds. © *2025 Bull. Georg. Natl. Acad. Sci.*

Keywords: Imereti Uplift Zone, seismic profile, thick-skinned structure, fault-related fold, fault-propagation fold

Introduction

The geometry and kinematics of fault-related folds are essential in geological processes, such as hydrocarbon accumulation, structural evolution, and earthquake assessment [1]. Fault-related folds form hydrocarbon traps in many fold-and-thrust belts [2]. Determining the deformation structural style of fault-related folds is crucial for understanding the petroleum prospectivity of structural plays. Seismic profiles offer a unique method for enhancing our understanding of the geometry and kinematics of fault-related folds [1, 2].

The aim of the present paper is to demonstrate the deformation style of the fault-related folds. In this study, we examine fault-related folds through the interaction between shallow and deep structures using seismic profiles and two structural cross-sections from the Okriba oil-bearing area in the Imereti Uplift Zone (IUZ) (Fig. 1).

Geological setting. Our study area, the IUZ, is one of the most important oil-bearing regions in western Georgia (Fig. 1). Several studies on the stratigraphy and structure of this zone have been conducted due to the scientific interest arising from the presence of hydrocarbon deposits [4, 5].

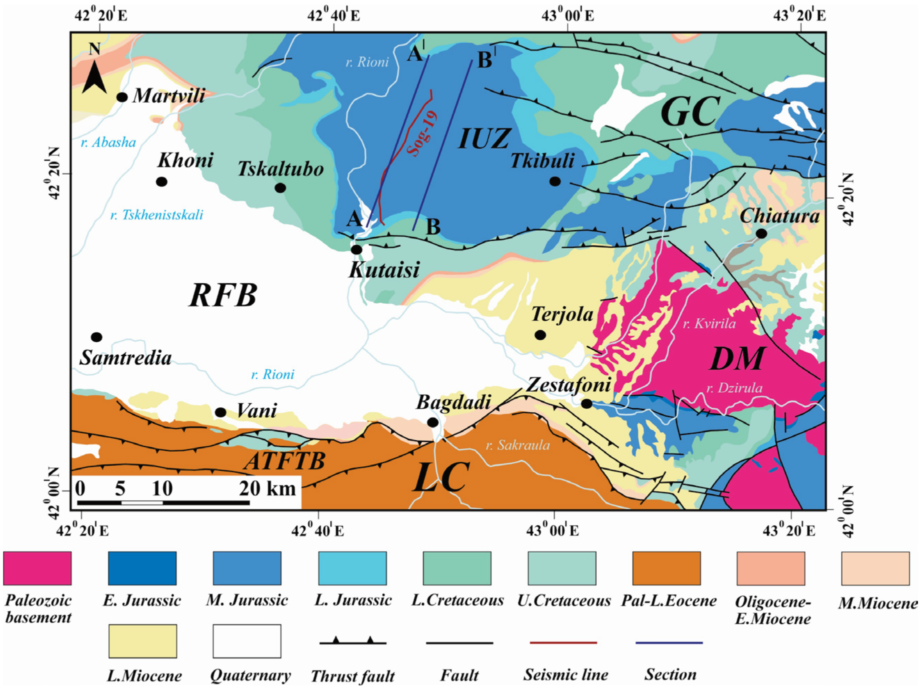

Fig. 1. Seismic profile and structural cross-section's location geological map modified from Adamia et al. [3]. Abbreviations: GC-Greater Caucasus; LC-Lesser Caucasus; RFB-Rioni foreland basin; IUZ-Imereti uplift zone; ATFTB-Achara-Trialeti fold-and-thrust belt.

The IUZ represents an external zone of the western Greater Caucasus (GC) orogen, located in the far-field zone of the Arabia-Eurasia collision system. The IUZ and Dzirula massif (DM) break a contiguous collisional foreland basin into disconnected basins, the Rioni basin to the west and the Kura basin to the east. The outcrops within the study area (Fig. 1) are dominated by the middle-upper Jurassic siliciclastic rocks, igneous intrusions, volcanic and volcaniclastic rocks, and Cretaceous mixed siliciclastic and carbonate rocks [3, 6-8]. The Jurassic-Cretaceous strata of the IUZ area are commonly > 3-4 km thick and predominantly composed of deep- and shallow-marine rocks [3, 6, 7]. The pre-Mesozoic basement of the IUZ comprises Hercynian granitic-metamorphic rocks in its core, overlain by Devonian to Carboniferous phyllites. Most of the pre-Mesozoic basement is intruded by granitoids and covered with Lower and Middle Jurassic strata [3, 5, 8].

The anticlines within IUZ formed during the inversion of the GC back-arc basin [3, 7, 8]. The contractional deformation in this external sector of GC, based on the growth strata age and apatite fission-track data from the surrounding Rioni and Kura foreland basins began in the Middle Miocene [9-12]. The present-day seismic activity of IUZ, unevenly distributed along the deformation front, clusters along the south-vergent thrust faults across onshore Georgia and exhibits especially strong earthquake activity, recorded by both historical and instrumental data, with dominantly compressional fault plane solutions [13, 14].

Data and Method

Subsurface data mainly include near seismic profile (Sog-19 – post-stack depth-migrated) and two structural cross-sections (A-AI, B-BI) across the IUZ (Figs. 2-4). Our field measurements and observations facilitated the construction of the geometry of the structures. Fault-related folding and wedge thrust folding theories [1] were used in the interpretation of the seismic profile (Sog-19) (Fig. 2. A, B) and construction of the two structural

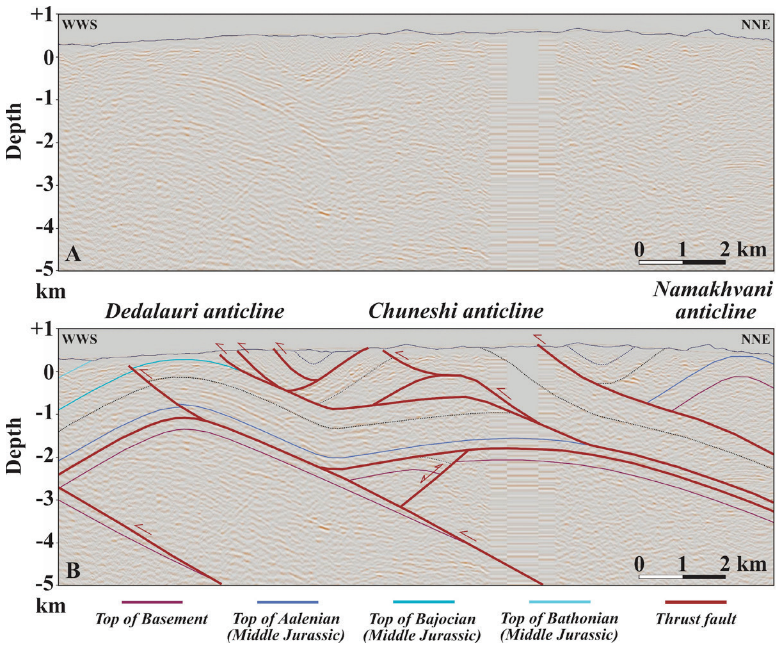

Fig. 2. (A) Uninterpreted and (B) interpreted seismic profile Sog-19. The location is shown in Fig. 1.

cross-sections (A-AI, B-BI) (Figs. 3, 4). For the interpretation of the seismic profile and construction of two structural cross-sections the Move software was used.

Results

The post-stack depth-migrated seismic profile (Sog-19) reveals both surface and subsurface structures along the IUZ. Using the seismic data, we identify fault-related folds in IUZ formed due to the interaction between thick and thin-skinned structures (Fig. 2). The following structural cross-sections (A-AI and B-BI) provide a detailed characterization of thesse structures based on the seismic profile interpretation (Figs. 3, 4).

Seismic profile and structural cross-sections show that the dominant structural styles of the compressional structures are related to multiple detachments. Thick-skinned structures comprise fault-bend folds moving into the sedimentary cover, mainly along lower Jurassic shales, which form basement wedges that transfer the deformation to the south. Major basement-involved thrusts produce first-order thick-skinned fault-bend folds, which move southward creating second-order fault-related folds in the sedimentary cover (Figs. 2-4). Preexisting basement-involved extensional faults inverted during compressive deformation produced basement-cored uplifts that transferred thick-skinned shortening southward onto the thin-skinned structures detached above the basement. The Chuneshi anticline is represented by an imbricate fault-bend fold developed along a flat-ramp detachment. The morphology of the Dedalauri anticline allows us to interpret it as a fault-propagation fold detached above the early Jurassic shales (Figs. 3, 4). The formation of compressional structures is related to piggyback thrust sequences.

In summary, we suggest that the deformation structural style of the IUZ is characterized by thick-skinned fault-related folds, thin-skinned fault-propagation, and imbricate fault-bend folds. Our work suggests that upper crustal shortening is a primary factor in the topographic uplift and crustal thickening of the IUZ. The proposed structural model indicates a relationship between thick- and thin-skinned structures developed during Late Alpine times. The structural style offers a promising geological setting for potential structural traps

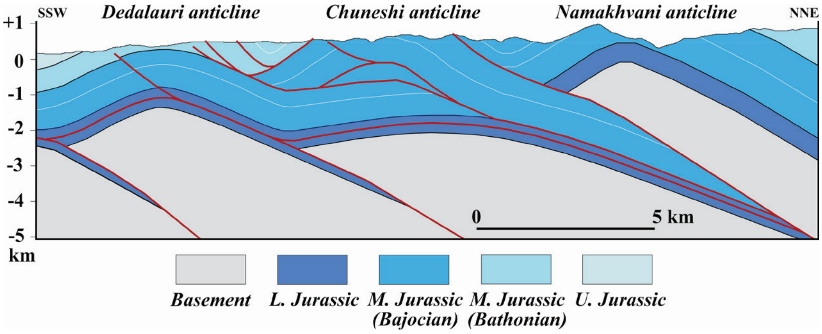

Fig. 3. Structural cross-section A-AI. The location is shown in Fig. 2.

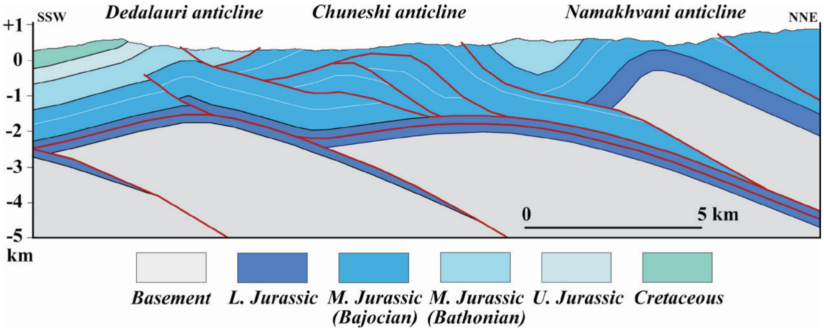

Fig. 4. Structural cross-section B-BI. The location is shown in Fig. 2.

in the IUZ. The major structural trends are formed by fault-bend and fault-propagation folds. The potential productive reservoirs of the study area are of the Middle Jurassic (Aalenian and Bajocian) age. In the future, we hope that a petroleum industry will drill a well in this zone taking into account the results of our research, and that it will turn out to be productive.

Conclusion

The IUZ was formed due to the interaction between thick and thin-skinned structures. In the IUZ dominant structural styles of the compressional structures are related to multiple detachments. From the SSW to the NNE, the seismic profile and structural cross-sections show: (1) basement-involved thrust faults or thick-skinned fault-bend folds, and (2) thin-skinned fault-related folds represented by fault-propagation and imbricate fault-bend folds. A fault-propagation fold built on a detachment level situated in the Early Jurassic shales. Imbricate fault-bend folds formed over two detachment levels which are connected to a ramp of a dip towards the NNE indicating a displacement to the SSW.

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გეოლოგია

რღვევებთან დაკავშირებული ნაოჭების დეფორმაციის სტილი იმერეთის აზევების ზონაში, დასავლეთ საქართველო

ვ. ალანია*, მ. ა. იუკლერი**, კ. აბესაძე**, ზ. გალდავა**, დ. გახარია**, მ. ქურციკიძე**

** ივანე ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტი, მ. ნოდიას გეოფიზიკის ინსტიტუტი, საქართველო*
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(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

დასავლეთ კავკასიონის ოროგენის გარე ზონა, რომელიც ცნობილია იმერეთის აზევების ზონის სახელით, განვითარდა გვიან ალპურ პერიოდში არაბეთისა და ევრაზიის ფილაქნების კონვერგენციის შედეგად. სეისმური პროფილის ინტერპრეტაციამ მოგვცა საშუალება შეგვექმნა ორი სტრუქტურული ჭრილი, რომელიც დაგვეხმარა სქელ და თხელზეწრულ სტრუქტურებთან დაკავშირებული ნაოჭების გეომეტრიის ანალიზში. სეისმური პროფილი და სტრუქტურული ჭრილები აჩვენებს, რომ კუმშვითი სტრუქტურების დომინანტური სტრუქტურული სტილი დაკავშირებულია მრავალრიცხოვან მოწყვეტის ზედაპირებთან. სეისმურმა მონაცემებმა გამოავლინა სქელზეწრული რღვევა-გაღუნული ნაოჭების არსებობა. თხელზეწრულ რღვევებთან დაკავშირებული ნაოჭები განვითარებული ფუნდამენტის შეცოცებების თავზე წარმოდგენილია ქერცლოვანი რღვევა-გაღუნული და რღვევა-გავრცელებადი ნაოჭებით.

REFERENCES

1. Shaw J. H., Connors C. D., Suppe J. (2005) Seismic interpretation of contractional fault-related folds. *AAPG Studies in Geology,* 53. Denver, USA.
2. McClay K. (2011) Introduction to thrust fault-related folding. *Thrust fault-related folding: AAPG Memoir*, 1-19.
3. Adamia Sh., Sadradze N., Alania V., Talakhadze G., Khmaladze K. (2020) Geology of lithosphere of the Georgia, deep structure, geodynamics and evolution. Diagrama Press, Tbilisi State University.
4. Vakhania D. (2008) General overview of gas and oil saturation of sedimentary cover of the west zone of the sinking Transcaucasian intermountain region against the background of oil and gas generation problems. *Georgian Oil and Gas*, **22:** 87-107.
5. Tari G., Vakhania D., Tatishvili G., Mikeladze V., Gogritchiani K., Vacharadze S., Mayer J., Sheya C., Siedl W., Banon J., Sanchez J.T. (2018) Stratigraphy, structure and petroleum exploration play types of the Rioni Basin, Georgia. *Geological Society, London, Special Publications*, **464:** 403-438.
6. Beridze M. (1983) Geosynclinal sedimentary lithogenesis as exemplified by early Mesozoic formations of the Greater Caucasus. Metsniereba, Tbilisi.
7. Vincent S., Somin M., Carter A., Vezzoli G., Fox M., Vautravers B. (2020) Testing models of Cenozoic exhumation in the western Greater Caucasus. *Tectonics,* **39:** e2018TC005,451.
8. Banks C. J., Robinson A. G., Williams M. P. (1997) Structure and regional tectonics of the Achara-Trialeti fold-belt and the adjacent Rioni and Karli foreland basins, Republic of Georgia. *Regional and Petroleum Geology of the Black Sea and Surrounding Region,* 331-346.
9. Tibaldi A., Alania V., Bonali F. L., Enukidze O., Tsereteli N., Kvavadze N., Varazanashvili O. (2017) Active inversion tectonics, simple shear folding and back-thrusting at Rioni Basin, Georgia. *Journal of Structural Geology*, **96:** 35-53.
10. Alania V., Chabukiani A., Chagelishvili R., Enukidze O., Gogrichiani K., Razmadze A., Tsereteli N. (2017) Growth structures, piggyback basins and growth strata of Georgian part of Kura foreland fold and thrust belt: implication for Late Alpine kinematic evolution. *Geol. Soc. Lond. Spec. Publications* **428**: 171-185.
11. Alania V., Melikadze G., Pace P., Fórizs I., Beridze T., Enukidze O., Giorgadze, A., Razmadze, A. (2022) Deformation structural style of the Rioni foreland fold-and-thrust belt, western Greater Caucasus: Insight from the balanced cross-section. *Frontiers in Earth Science*, **10:** 10968386.
12. Gusmeo T., Cavazza C., Alania V., Enukidze O., Zattin M., Corrado S. (2021) Structural inversion of back-arc basins-The Neogene Adjara-Trialeti fold-and-thrust belt (SW Georgia) as a far-field effect of the Arabia-Eurasia collision. *Tectonophysics,* **803:** 228702.
13. Adamia Sh., Alania V., Chabukiani A., Maisuradze G., Kuloshvili S. (2004) Seismic source zone models of recent earthquakes of Georgia. *Proceedings of the 5th International Symposium on Eastern Mediterranean Geology*, 545-551.
14. Tsereteli N., Tibaldi A., Alania V., Gventsadse A., Enukidze O., Varazanashvili O., Müller B. I. R. (2016) Active tectonics of central-western Caucasus, Georgia. *Tectonophysics,* **691:** 328-344.

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