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Tectono-thermal evolution of central Transcaucasia: Thermal modelling, seismic interpretation, and lowtemperature thermochronology of the eastern Adjara-Trialeti and western Kura sedimentary basins (Georgia)

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1	Tectono-thermal evolution of central Transcaucasia: Thermal modelling, seismic
2	interpretation, and low-temperature thermochronology of the eastern Adjara-Trialeti
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4	
5	Gusmeo Thomas ^a , Schito Andrea ^b , Corrado Sveva ^c , Alania Victor ^d , Enukidze Onise ^d ,
6	Massimiliano Zattin ^e , Pace Paolo ^{f,g} , Cavazza William ^a
7	
8	^a Department of Biological, Geological and Environmental Sciences, University of Bologna, Bologna,
9	Italy
10	^b Department of Geology and Geophysics, School of Geosciences, University of Aberdeen, Aberdeen
11	AB24 3 UE, UK
12	° Department of Sciences, Geological Sciences Section, Roma Tre University, Rome, Italy
13	^d M. Nodia Institute of Geophysics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
14	^e Department of Geosciences, University of Padua, Padua, Italy
15	^f Department of Engineering and Geology, "G. d'Annunzio" University of Chieti-Pescara, Chieti,
16	Italy
17	^g PACE Geoscience, Chieti, Italy
18	
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20	Abstract:
21	
22	Structural interference along the boundaries of adjacent tectonic domains generates complex
23	subsidence and exhumation patterns. In this paper we study a key segment of the convergence
24	zone between the interfering south-verging Greater Caucasus and north-verging Lesser
25	Caucasus retro-wedge. The study area comprises the along-strike transition between the

26 Paleogene Adjara-Trialeti back-arc basin and the Oligocene-Neogene Kura foreland basin of

27 eastern Georgia. During the Neogene, despite their difference in age and subsidence 28 mechanisms, both basins have been progressively inverted to various extent within the overall 29 context of the Arabia-Eurasia continental collision. Thermal modelling of borehole data from 30 the Adjara-Trialeti basin allowed to reconstruct two phases of rapid subsidence, late Paleocene-31 Early Eocene and Middle-Late Eocene, respectively correlated to flexural loading by the Lesser 32 Caucasus retro-wedge and continental rifting. Integration of thermal modelling, apatite fission-33 track statistical inverse modelling, and seismic interpretation detected a third subsidence phase 34 in the Early Miocene, possibly related to strike-slip tectonics. Thermal maturity data dictate 35 that 1.0-1.3 km of the Adjara-Trialeti sedimentary succession has been eroded since the onset 36 of structural inversion in the mid-Miocene. The burial history of the western Kura Basin 37 outlines intermittent and asymmetrical episodes of flexural subsidence from the Oligocene to 38 the Late Miocene, due to competing loading by the Lesser Caucasus, the Adjara-Trialeti fold-39 and-thrust belt and the Greater Caucasus. Finally, during latest Miocene times southward 40 propagation of deformation from the Greater Caucasus induced an additional tectonic loading 41 (1.3-1.8 km) due to the emplacement of thin-skinned thrust sheets, mostly eroded during the 42 Plio-Quaternary.

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Keywords: Transcaucasus, Kura Basin, thermal maturity, thermal modelling, fission-track
thermochronology, structural interference

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48 **1. Introduction**

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50 Tectonic and thermal reconstruction of sedimentary basins evolution during subsidence and 51 structural inversion traditionally refers to clear-cut end-members and ideal models

52 characterised by relatively simple evolutionary patterns, or identify discrete and uniform 53 domains that are then studied more or less independently. Such simplifications can hardly be 54 applied to the boundary zones between adjacent structural domains, where interfering tectonic 55 and subsidence motifs produce complicated temporal-spatial patterns. This is exemplified by 56 the structurally complex Transcaucasian region of central Georgia, an area dominated by the 57 contrasting and partially superposed effects of extension- and compression-driven subsidence, 58 as well as by the structural interference between two oppositely-verging orogenic belts.

59 The southern Caucasian region is constituted by the Greater and Lesser Caucasus and the 60 intervening Rioni-Kura foreland basins (Fig. 1). This area absorbs a considerable amount 61 (about 15-20%) of the strain associated with the Arabia-Eurasia collision (Reilinger et al., 62 2006), as testified by GPS vectors indicating an anticlockwise motion relative to stable Eurasia, 63 with northward motion increasing from about 2 mm/yr in the Rioni Basin close to the Black 64 Sea coast to 12 mm/yr in the Kura Basin close to the Caspian Sea coast (Forte et al., 2013; 65 Reilinger et al., 2006). Most deformation in the Caucasian region is accommodated in the 66 domain comprised between the Greater and the Lesser Caucasus (named Transcaucasus; 67 Karakhanyan et al., 2013; Sokhadze et al., 2018).

68 Transcaucasia (i.e. the region south of the Greater Caucasus) connects the world-class Caspian Basin petroleum province to the east and the underexplored easternmost Black Sea 69 70 basin to the west, where active hydrocarbon seeps on the seafloor (e.g. Pape et al., 2021) and 71 oil shows in deep-water wells indicate the presence of at least one active petroleum system in 72 the offshore of easternmost Turkey (see Tari et al., 2018, for a review). The oceanographic 73 connection between the Caspian and Black seas closed in the early Late Miocene due to 74 convergence of the facing structural fronts of the south-verging Greater Caucasus and north-75 verging retro-wedge of the Lesser Caucasus orogenic prism, which incorporated the Adjara-Trialeti FTB (Alania et al., 2021a; Banks et al., 1997; Gusmeo et al., 2021; Nemčok et al., 76

2013; Tari et al., 2021). Such a convergence is considered a far-field effect of the collision
between the Eurasian and Arabian plates along the Bitlis-Zagros suture zone, several hundred
kilometres to the south (Alavi, 1994; Cavazza et al., 2018; Dewey et al., 1986; Jolivet &
Faccenna, 2000; Okay et al., 2010). This deformation has affected a large swath of the Eurasian
hinterland, inducing reactivation of older structures (including structural inversion of preexisting sedimentary basins) and diffuse strike-slip deformation (Albino et al., 2014; Cavazza
et al., 2019).

84 The aim of this work is to provide quantitative constraints on the burial/exhumation history 85 of the eastern portion of the Georgian Transcaucasus, a tectonically complex area featuring the 86 structural interference between two tectonic domains characterised by different pre-87 deformation history, deformation timing, exhumation degree, and structural styles. These units are: (i) the E-W-trending Adjara-Trialeti fold-and-thrust belt (FTB), a former rift basin now in 88 89 the retro-wedge of the Lesser Caucasus, and (ii) the western Kura flexural foreland basin, 90 characterised by distinct subsidence pulses and then deformed by the southward advancing 91 Greater Caucasus frontal structures (Figs. 1 and 2). The geological complexity of the along-92 strike transition from the Adjara-Trialeti to the Kura inverted basins (Fig. 2) has favoured 93 multiple, often contrasting interpretations regarding the structural layout and the tectonic 94 evolution of the eastern termination of the Adjara-Trialeti FTB, where it plunges eastwards and 95 is covered by south-verging thrusts deforming the Kura Basin (Alania et al., 2021a; Gusmeo et 96 al., 2021; Pupp et al., 2018; Tari et al., 2021).

97 The study area is ideal to investigate the initial phases of collision between two converging 98 orogenic belts: the south-verging Greater Caucasus pro-wedge and the mostly north-verging 99 Adjara-Trialeti FTB (Alania et al., 2021a; Banks et al., 1997; Gusmeo et al., 2021; Nemčok et 100 al., 2013). Tectonic convergence determined progressive exhumation of the intervening Kura Basin sedimentary fill. In this context, the retro-wedge of the Lesser Caucasus may also have
played an important role (Alania et al., 2021a; Gusmeo et al., 2021).

103 During the last few decades, a growing academic and industrial interest has provided 104 structural data and burial models on the western Kura basin (Adamia et al., 1992; Boote et al., 105 2018; Nemčok et al., 2013; Patton, 1993; Pupp et al., 2018; Robinson et al., 1997; Sachsenhofer 106 et al., 2018, 2021). Recent thermochronologic work has determined the structural inversion of 107 the Adjara-Trialeti FTB as mid-Miocene (Gusmeo et al., 2021). Corrado et al. (2021) obtained 108 thermal maturity data on sedimentary successions across the southern Greater Caucasus - Kura 109 - Adjara-Trialeti system. Building on such datasets, in this paper we integrate new 110 multidisciplinary data in the transitional area between the eastern Adjara-Trialeti inverted rift 111 basin and the thin-skinned western Kura Basin in order to provide quantitative constraints on 112 the burial/exhumation history of the eastern Georgian Transcaucasus. The dataset includes (i) 113 low-temperature thermochronologic inverse models, (ii) thermal models of well data, and (iii) 114 a composite geological cross-section of the transition zone built upon the interpretation of three 115 unpublished seismic reflection profiles.

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- 118 **2. Geological background**
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The study area covers the region where the north-verging Adjara-Trialeti FTB plunges eastward and is covered by the deformed sedimentary rocks of the western Kura Basin (eastern Georgia). In this work we analyse six of the several wells drilled for hydrocarbon exploration (Patton, 1993; Sachsenhofer et al., 2021), three in the Adjara-Trialeti FTB and three in the Kura Basin (Figs. 1 and 2). 125 The Adjara-Trialeti FTB (Figs. 1 and 2) is a W-E-trending orogenic belt formed as a result 126 of the structural inversion of a former back-arc rift basin developed on the upper (Eurasian) 127 plate of the northern Neotethys subduction zone (Adamia et al., 1981, 2011; Alania et al., 2018; 128 Banks et al., 1997; Barrier et al., 2018; Gusmeo et al., 2021; Lordkipanidze et al., 1989; 129 Nemčok et al., 2013). The pre-rift sedimentary succession features Aptian-Cenomanian 130 volcanic and volcaniclastic rocks, covered by Turonian-to-Early Paleocene limestones and 131 marls (Adamia et al., 1981, 2011; Banks et al., 1997; Yılmaz et al., 2000, 2014). Extension 132 started in the Paleocene, together with the deposition of a thick succession of terrigenous 133 turbidites (the Paleocene-Eocene Borjomi Flysch). The main phase of rifting occurred in the 134 Middle Eocene, characterized by the emplacement of submarine volcanic rocks and shallow 135 mafic-to-intermediate intrusions (Adamia et al., 2011; Banks et al., 1997; Okrostsvaridze et al., 136 2018; Yılmaz et al., 2000, 2014). In the Late Eocene, mostly epiclastic turbidites with minor 137 marls were deposited in the eastern sector of the Adjara-Trialeti basin. In Oligocene-Early 138 Miocene times shales, siltstones and fine-grained sandstones were deposited in a mainly 139 anoxic/disoxic environment (Pupp et al., 2018; Sachsenhofer et al., 2018, 2021), interbedded with fine-grained terrigenous turbidites. The post-rift phase lasted from the Oligocene to the 140 141 Early Miocene and was followed by structural inversion since Middle Miocene times (Gusmeo 142 et al., 2021). Despite having an independent origin, the Adjara-Trialeti FTB was then 143 incorporated in the retro-wedge of the Lesser Caucasus (Alania et al., 2021a).

The domain comprised between the Greater Caucasus and the Lesser Caucasus (Transcaucasia) is constituted by an intermontane depression extending from the Black Sea to the Caspian Sea (Fig. 1). The depression is divided by the Dzirula Massif, a polymetamorphic basement salient which separates the Kura and Rioni flexural foreland basins (Adamia et al., 2010, 2011; Alania et al., 2017; Banks et al., 1997; Nemčok et al., 2013; Rolland et al., 2011). The two basins - mostly filled by Oligocene-to-Recent sediments - plunge to the east and west, respectively, and developed as a flexural response to both the Greater Caucasus to the north
and the Lesser Caucasus to the south (Adamia et al., 2010; Banks et al., 1997; Nemčok et al.,
2013).

In the Kura Basin (Figs. 1 and 2) Oligocene-Lower Miocene clastic (shales, siltstones and fine-grained sandstones) and evaporitic rocks were deposited in the anoxic-dysoxic environment of the Paratethys, and are locally known as the Maikop series (Pupp et al., 2018; Sachsenhofer et al., 2018). Their thickness can reach up to 2.5-3.5 km in the Georgian sector of the Kura Basin (Adamia et al., 2010).

158 During Middle to early Late Miocene times (Chokrakian-Sarmatian) further 1.5-2.2 km of 159 shales and fine-grained siliciclastics (sandstones), intercalated in the uppermost sections with 160 mainly calcareous units (mudstones, marls and oolitic limestones and locally with coarse-161 grained rocks), were deposited within the Kura Basin (Adamia et al., 2010; Alania et al., 2017). 162 Since the Late Sarmatian (Tortonian) ongoing convergence between the Greater and Lesser 163 Caucasus forced the final uplift of the Dzirula Massif and the Kura Basin started plunging 164 towards the Caspian Sea, as demonstrated by the progressive marine regression within the basin 165 from west to east (Adamia et al., 2010; Alania et al., 2017; Barrier et al., 2018; Nemčok et al., 166 2013; Shatilova et al., 2020). At the same time, within the Kura Basin began the widespread deposition of coarse-grained clastic deposits, eroded from the adjacent orogenic belts. 167

168 Continental conditions prevailed from the Late Sarmatian to the present, interrupted only in 169 the Akchagylian-Apsheronian (Late Pliocene-Early Pleistocene) by a short-lived shallow 170 marine transgression, probably in response to the rapid growth and advancement of the Greater 171 Caucasus and the ensuing subsidence in the foreland area (Adamia et al., 2010; Avdeev and 172 Niemi, 2011; Nemčok et al., 2013; Sukhishvili et al., 2020; Trikhunkov et al., 2021).

173 Continuous convergence between the Greater and Lesser Caucasus caused incremental174 deformation of the Kura foreland basin. Thick-skinned deformation occurred in the Sarmatian

175 followed by thin-skinned deformation from the Late Sarmatian-Meotian (Nemčok et al., 2013). 176 In the final stages of convergence, the Greater Caucasus deformation propagated into the northern Kura Basin forming the Kura south-vergent thin-skinned foreland FTB (Kakheti 177 178 ridge, Fig. 2), developed since the Middle Miocene, with peak deformation in the Late Miocene-Pliocene (Alania et al., 2017). A Late Pliocene-Pleistocene acceleration of uplift has 179 also been pointed out in this belt (Sukhishvili et al., 2020), probably linked with coeval 180 181 enhanced uplift in the Greater Caucasus and subsequent propagation of deformation. The 182 Kakheti ridge and the Adjara-Trialeti structures interfere in the Tbilisi area, creating an 183 outstanding example of incipient collision between two facing orogenic belts (Alania et al., 184 2021a) (Figs. 1 and 2).

185 The study area is tectonically active. GPS vectors in the eastern Adjara-Trialeti FTB are 186 N/NNE-oriented and indicate velocities in the order of 4-6 mm/yr, decreasing to the north in the Kura Basin to 2-4 mm/yr (Reilinger et al., 2006; Sokhadze et al., 2018). Historical 187 188 earthquakes in the study area are of moderate intensity, with the last major event recorded in 189 2002 in the surroundings of Tbilisi (Fig. 2) yielding a magnitude of 4.5 (Tibaldi et al., 2019). 190 Present-day heat flow is ca. 50 mW/m² in the eastern Adjara-Trialeti FTB and ca. 40-45 mW/m² in the western Kura Basin (Melikadze et al., 2015; Sangin et al., 2018; Yükler et al., 191 2000), and crustal thickness ranges between \sim 45 and 50 km in the area of study (Adamia et 192 193 al., 2017; Motavalli-Anbaran et al., 2016).

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- 196 2.1 Wells stratigraphy
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The six wells analysed in this study are, from south to north, Kumisi 1, Kumisi 2 and Patardzeuli-E1 in the eastern Adjara-Trialeti FTB, and Satskhenisi 102, Satskhenisi 101 and Norio 200 in the western Kura Basin (Figs. 2 and 3).

Wells drilled in the eastern Adjara-Trialeti FTB are generally deeper (ca. 1.8 to 5 km) than the ones in western Kura Basin (ca. 1 km) and the thickest sedimentary succession (5020 m) was drilled in the Patardzeuli-E1 well (Korelskiy et al., 2019).

204 In the Adjara-Trialeti FTB, the oldest rocks were drilled in the Kumisi 1 well and are Late 205 Cretaceous volcanics and volcaniclastics followed by limestones and marls (Fig. 3). The 206 Paleocene section has similar thickness (ca. 250 m) in both Patardzeuli-E1 and Kumisi 1 wells, 207 but in Patardzeuli-E1 it is entirely made of limestones, whereas in Kumisi 1 it is composed of 208 marls at the base, followed by shales and siltstones. The Early Eocene section is thicker in 209 Patardzeuli-E1 (ca. 1800 m) than in Kumisi 1 (ca. 730 m). In Patardzeuli-E1 the lower portion 210 of the Early Eocene section is mostly characterised by limestones and marls, passing to mostly fine-grained siliciclastic rocks in the upper part; in Kumisi 1 it is made of alternating sandstones 211 212 and shales (flysch facies). The Middle Eocene is found in all three wells drilled in the eastern 213 Adjara-Trialeti FTB, and it is thicker in Patardzeuli-E1 (ca. 700 m) than in Kumisi 1 and 2 (ca. 214 250 m). It is mainly composed of tuffs and other volcaniclastic rocks, sporadically interbedded with sandstones and shales (Fig. 3). The thickness (700-900 m) and composition of the Late 215 216 Eocene section are similar in all three wells. The lower portion (ca. 230 m) in Kumisi 1 is 217 entirely made of shales and siltstones, whereas the upper part (Tbilisi Suite) is composed of 218 alternating shales, sandstones, and siltstones with marls interlayers. In Patardzeuli-E1 and 219 Kumisi 2 the Late Eocene is lithologically similar to the Tbilisi Suite of Kumisi 1 (Fig. 3).

The Maikop Series is the only succession found in all six wells and it is composed of shales, siltstones, and fine-grained sandstones. The thickness of the succession ranges from ca. 550 m (Kumisi 1) to >1200 m (Satskhenisi 102). The Maikop Series is probably incomplete in all

223	wells except for Norio 200. In the Satskhenisi 101 and 102 wells the lower part of the
224	succession (representing the Lower Maikop, hence the Lower Oligocene section) is missing,
225	whereas in Kumisi 1, Kumisi 2 and Patardzeuli-E1 at least part of the uppermost section was
226	eroded away, as demonstrated by unconformable surfaces.
227	Middle Miocene rocks (Chokrakian, Karaganian and Konkian) are found almost exclusively
228	in the Norio 200 well, where they are entirely made of shales and siltstones. The same well is
229	topped by Sarmatian (late Middle-early Late Miocene) shales and siltstones, with frequent
230	alternations of sandstones and conglomerates in the uppermost portion. Chokrakian shales are
231	found also in the Satskhenisi 101well (Fig. 3).
232	Finally, Akchagylian-Quaternary conglomerates are present in the Patardzeuli-E1 well,
233	whereas very thin Quaternary deposits constitute the top of the Kumisi 1 well (Fig. 3).
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236	3. Materials and methods
237	
238	3.1 Apatite fission-track analysis and modelling
239	
240	Fission tracks are linear radiation damages within the crystal lattice, caused by the nuclear
241	fission of radioactive isotope ²³⁸ U, which can be etched and counted with an optical microscope
242	(Donelick et al., 2005). Neutron irradiation is used to induce the decay of ²³⁵ U, generating
243	radiation damages on the surface of an external detector. Grain-by-grain determination of both
244	spontaneous and induced fission-track densities yields a single-grain age representing the
245	cooling of the grain below a closure temperature of ~100°C. Apatite grains are concentrated
246	through crushing and sieving, followed by hydrodynamic, magnetic, and heavy-liquids

247 separation. Then apatites are embedded in epoxy resin, polished, and etched in 5N HNO₃ at

20°C for 20s. The external detector method was applied: following irradiation at the Radiation
Center of Oregon State University (Donelick et al., 2005) and etching of the mica detector in
40% HF at 20°C for 45 min, spontaneous and induced fission tracks were counted under a Zeiss
Axioscope optical microscope at x1250 magnification. Central ages (Fig. 2, Table 1) were
obtained using the Radial Plotter software (Vermeesch, 2009).

253 Fission tracks in apatites have the same initial length of about 16 µm (Donelick et al., 1999; 254 Ketcham et al., 1999) but at about 60°C they start to anneal at a rate that is proportional to 255 temperature. Over geological time periods, partial annealing of fission tracks occurs at 256 temperatures between about 60 and 120°C (the Partial Annealing Zone or PAZ; Gleadow & 257 Duddy, 1981). Since track shortening is a function of the intensity and duration of heating, the 258 measurement of fission-track lengths and the numerical modelling of their frequency 259 distribution give quantitative information on the thermal evolution in the PAZ temperature 260 range. Modelling procedures find a range of cooling paths compatible with the fission-track 261 length frequency distribution (Ketcham, 2005).

262 In this work, we provide additional constraints on the thermal history of two samples 263 (TU504 and TU505) already included in the dataset of Gusmeo et al. (2021). These two 264 samples were selected because of their peculiar positions within the study area. Since only their 265 central ages were available, further mounts of apatite grains for each sample were produced, 266 etched and analysed under a Zeiss Axioscope optical microscope in order to measure enough 267 horizontally confined tracks for statistical inverse modelling. Inverse modelling of track length 268 data was performed using the HeFTy program (Ketcham, 2005), which generates a number of 269 possible T-t paths by running a Monte Carlo algorithm using fission-track lengths and ages as 270 input data. Predicted AFT data were calculated according to the Ketcham et al. (2007) 271 annealing model for fission tracks revealed by etching. Dpar values (i.e. the etch pit length) 272 were used to define the annealing kinetics. Broad T-t boxes were used for the pre- and post-

273	depositional history of the analysed samples in order to limit any user-dependent forcing on
274	the program. Details on parameters and constraints used for both models, compiled following
275	the protocol of Flowers et al. (2015), can be found in the Supplementary Materials (Tables ST6
276	and ST7).
277	
278	
279	3.2 Thermal Modelling
280	
281	3.2.1 Calibration data from Rock-Eval Pyrolysis and optical analyses
282	
283	Thermal model calibration is generally based on the assumption that thermal maturity at
284	different depths of a stratigraphic section allows to fit a maturity curve, giving an insight on
285	the maximum thermal exposure and heating regimes experienced by the sediments during
286	burial. For this purpose, vitrinite reflectance (VR _o %) data are generally used, given their high
287	sensitivity to thermal perturbations. However, when such data are absent they can be replaced
288	by other thermal maturity indicators (e.g. Tmax, biomarkers, illite % in illite-smectite mixed
289	layers, Raman and FTIR parameters) properly converted into VR _o % (see Corrado et al., 2020;
290	Schito et al., 2016).
291	Calibration data for thermal models were provided by the Georgian Oil & Gas Company.
292	They were obtained from five wells drilled for hydrocarbon exploration in the western portion
293	of the Kura Basin and in the eastern Adjara-Trialeti FTB (Fig. 2, Table 2). From south to north
294	the wells are: Kumisi 1, Kumisi 2, Patardzeuli-E1, Satskhenisi 102, Norio 200. Calibration data
295	were acquired in different laboratories and are described in industrial reports and published

296 papers: Stratochem Egypt (2014) for Kumisi 1 well; Sachsenhofer et al. (2021) for Kumisi 2,

297 Patardzeuli-E1 and Norio 200 wells; DIG (2014) for Satskhenisi 102 well. Part of the dataset
298 (relative only to the Maikop sections) was also reported by Corrado et al. (2021).

Most of the thermal maturity data derive from Rock-Eval Pyrolysis, except for the Satskhenisi 102 well where additional vitrinite reflectance measurements are available (Table 2). In detail, more than two hundred Rock-Eval Pyrolysis data and ten vitrinite reflectance measurements are available, acquired from cuttings representative of the Eocene-Early Miocene interval (Table 2, Suppl. Mat. Tables ST1, ST2, ST3, ST4, ST5). The Satskhenisi 101 well was not modelled as no thermal maturity data were available.

305 Rock-Eval Pyrolysis is the most used quantitative method for kerogen characterization. It is 306 based on the relative intensity and distribution of three peaks (S1, S2 and S3), artificially 307 generated at different lab temperatures from a whole rock specimen containing kerogen. The 308 S2 peak relates to the hydrocarbon residual potential of a source rock, whereas S1 records the 309 amount of already generated hydrocarbons. Tmax is calculated from the temperature 310 corresponding to the maximum of the S2 envelope (e.g. Behar et al., 2001) and can be used as 311 a thermal maturity indicator, at least when Total Organic Carbon (TOC) is higher than 0.5% 312 (Hunt, 1996). The TOC refers to the weight percentage (wt %) of the organic carbon present 313 in the rock (e.g. Langford and Blanc-Velleron, 1990). The Hydrogen Index (HI) is defined as 314 the ratio between the area of the S2 peak and the TOC. The most used diagram for kerogen 315 classification is the modified Van Krevelen's one, which is based on the Hydrogen Index (HI) 316 and the Oxygen Index (OI) (Abdullah et al., 2017; Tissot and Welte, 1978).

317 Pseudo-Van Krevelen diagrams (OI vs HI, Tmax vs HI, and TOC vs S2) were used to assess
318 the type of kerogen for each data (Fig. 4; Suppl. Mat. Figs. S1, S2, S3, S4, S5).

319 Vitrinite reflectance (VR_o%) measures the reflectivity under incident light of huminite-320 vitrinite group macerals that derive from upper plants (Type III kerogen). VR_o% is known to 321 be well correlated with the stages of hydrocarbon generation and is by far the most known and used thermal maturity indicator (Bertrand et al., 2010; Borrego and Cook, 2017; Corrado et al.,
2020; Dow, 1977).

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3.2.2 Modelling procedures

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328 Five wells have been modelled matching Tmax and VR_o% data with calculated maturity 329 curves at different depths using the Basin Mod 2-D software package. For models' calibration Tmax data were first converted into VR_o% values. No single equation exists for such 330 conversion, since it depends on kerogen type. According to the most recent review (Yang and 331 332 Horsfield, 2020) and considering a prevalent type III (or II/III) kerogen (Fig. 4), the onset of 333 the oil window (VR_o% = 0.55) can be set at a Tmax value of 430 °C, whereas the immature 334 stage at a Tmax value of 420 °C roughly coincides with a VR_o% value of 0.4 and the onset of 335 the wet gas stage (VR₀% = 1.3) is set at a Tmax value of 460 °C. These values are then 336 correlated by a least squared curve.

337 Tmax data can have a large spread, as outlined in the dataset presented in this study. The 338 causes of such spread are multiple and cannot be resolved with the available data. In general, data indicating higher maturity (with respect to the mean maturity trend) can be ascribed to the 339 340 presence of reworked organic matter, whereas relatively low values can be due to carryover 341 effects (i.e. presence of heavy hydrocarbons) or to high H or S content (Yang and Horsfield, 342 2020). Given the higher uncertainties (with respect to VR₀%) derived from the use of Tmax 343 data for thermal models calibration, different scenarios have been tested and framed according 344 to the geological evolution of the two studied areas: the eastern Adjara-Trialeti FTB and the western Kura Basin (Figs. 5 and 6; see below and Discussion). 345

346 Mixed lithologies were reproduced from the relative abundance of sandstones, limestones and shales as shown in Table 3 and rock decompaction follows Sclater and Christie (1980). 347 Seawater depth variations were not taken into account given that the long-term thermal 348 349 evolution of a sedimentary basin is mainly affected by sediment thickness rather than by water 350 depth (Butler, 1991). A surface temperature of 12°C and a sediment-water interface 351 temperature of 5°C were adopted, and vitrinite reflectance maturation through time was 352 modelled according to the Easy %Ro method (Burnham and Sweeney, 1989; Sweeney and 353 Burnham, 1990).

354 Present-day heat flow (HF) for the eastern Adjara-Trialeti FTB is ~ 50 mW/m² (Melikadze et al., 2010; Sangin et al., 2018; Yükler et al., 2000), and between 40 and 45 mW/m² for the 355 356 studied sector of the western Kura Basin (Kutas, 2010). Since direct constraints on the HF 357 evolution through time in the two geologic domains analysed are not available, two scenarios 358 were assumed and tested in the two domains to allow a systematic comparison. In the first 359 scenario, the HF was set at the present day value of 50 mW/m² in the Adjara-Trialeti FTB and 360 45 mW/m² in the Kura Basin (Kutas, 2010; Melikadze et al., 2015; Sangin et al., 2018; Yükler 361 et al., 2000) and kept constant through time. In the second scenario, a HF peak of around 70 mW/m^2 was assumed at about 45 Ma (i.e. during the main phase of Adjara-Trialeti rifting, see 362 Section 2), followed by a gradual decrease in HF up to the present-day value according to the 363 364 McKenzie model (McKenzie, 1978).

In all the studied wells an additional overburden was required in order to fit thermal maturity data. A sensitivity analysis was then performed, showing (for each HF scenario and each well) different maturity curves assuming different amounts of additional burial (Figs. 5 and 6). See Section 4.2.2 for further discussion on this topic and the results of the sensitivity analyses.

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Three broadly N-S trending depth-migrated seismic reflection profiles (from north to south, 373 374 lines 3004, 13 and 1401; Figs. 2 and 7) were obtained from the Georgian Oil & Gas Company. 375 Lines 3004 and 13 cross the frontal part of the eastern Adjara-Trialeti FTB and the 376 southernmost Kura Basin, passing through the location of the Norio 200 well; Line 1401 377 crosses the south-eastern Adjara-Trialeti FTB, passing through the location of the Kumisi 1 378 well and close to the Kumisi 2 well (Fig. 2). 379 Seismic interpretation is constrained by surface geology (e.g. Alania et al., 2021a; Banks et al., 1997; Nemčok et al., 2013; USSR Geological Survey, 1971), exploration wells and the 380 381 application of fault-related folding models (Butler et al., 2018; Shaw et al., 2006). Line 1401 382 was interpreted alone, whereas lines 13 and 3004 were combined and interpreted together (Fig. 383 7). Linking together the three interpreted seismic profiles a geological cross-section was then 384 built, showing the structural relationships between the eastern Adjara-Trialeti FTB and western 385 Kura Basin tectonic domains (Fig. 7). 386 387 4. Results 388 389 390 4.1 Apatite fission-track analysis and modelling 391 Analytical results of apatite fission-track analysis are reported in Table 1. The χ^2 statistical 392 393 test (Galbraith, 1981) indicates that a single population of grains is present in the analysed 394 samples. AFT central ages provide meaningful information from a geological viewpoint if the

395 sample experienced fast cooling through the PAZ but can be misleading if the sample resided

within the PAZ for a long time or experienced moderate reheating at temperatures lower than
120°C (Gleadow et al., 1986). To avoid such potential issues, more complete
thermochronological constraints were obtained through statistical modelling of fission-track
length distributions.

400 Sample TU504 is a sandstone collected north of the town of Rustavi in the eastern Adjara-401 Trialeti FTB (Fig. 2). Its depositional age, in the local Paratethyan stratigraphy, is Sakaraulian 402 (USSR Geological Survey, 1971), which corresponds to the base of the Burdigalian (Adamia 403 et al., 2010): hence an age of 20-18 Ma was assigned to this sample. Sample TU504 yielded an 404 AFT central age of 36.3 ± 2.8 Ma (Fig. 2, Table 1), older than its stratigraphic age, which 405 indicates that it was not buried enough to completely reset the AFT system. The very high $P(\chi^2)$ 406 value of 99.98% (Table 1) and the absence of dispersion (0%) (Fig. 8) indicates the presence 407 of only one population of grains. Partially to non-reset detrital samples containing a single 408 population of grains may suggest that they were fed by one thermally coherent sediment 409 source-area. The mean confined tracks length, on a total number of 83 horizontally confined 410 tracks, is $13.34 \pm 0.17 \,\mu\text{m}$ (Table 1) and the track-length frequency distribution is bimodal, 411 with two peaks centred at \sim 12 and 15 μ m (Fig. 8). Inverse modelling, integrating fission-track 412 data and stratigraphic age (Fig. 8, Table ST6), shows a phase of heating due to sedimentary 413 burial after deposition (20-15 Ma), followed by rapid cooling since 15 Ma. Although with the 414 available data we cannot be certain that the apatite grains derived from a thermally coherent 415 source, since a number of assumptions have to be verified (see a comprehensive review in Malusà and Fitzgerald, 2020), the very high $P(\chi^2)$ value, the absence of dispersion and other 416 417 independent geologic evidence (see Sections 2 and 5.2) allow us to be reasonably confident 418 regarding the inverse modelling results which suggest an Early Eocene cooling (best-fit curve; 419 Fig. 8) in the original sediment source area.

420	Sample TU505 is a middle-late Oligocene (30-23 Ma) (USSR Geological Survey, 1971)
421	sandstone (Fig. 2), collected ~15 km north of sample TU504, yielding an apatite fission-track
422	central age of 39.6 ± 3.6 Ma (Fig. 2, Table 1) which is older that its stratigraphic age, indicating
423	that burial was not enough to completely reset the AFT system. The very high $P(\chi^2)$ value of
424	97.99% (Table 1) and the absence of dispersion (0%) (Fig. 9) confirm that this sample contains
425	only one population of grains, thus suggesting a thermally coherent source. The mean confined
426	tracks length, based on 67 horizontally confined tracks, is $13.41 \pm 0.18 \ \mu m$ (Table 1) and the
427	track-length frequency distribution is bimodal, with two peaks centred at ~12 and 15 μ m (Fig.
428	9). TU505 modelling results are broadly in agreement with the ones of sample TU504. Inverse
429	modelling, integrating fission-track data and stratigraphic age, (Fig. 9, Table ST7) shows fast
430	burial/heating from about 28-25 to 20-19 Ma, followed by relatively rapid cooling since 20-19
431	Ma. Under the same assumptions explained for sample TU505 (Malusà and Fitzgerald, 2020),
432	the very high $P(\chi^2)$ value and other independent geologic evidence (see Section 5.2) allow us
433	to be reasonably confident about the best-fit t-T path in the statistical inverse modelling results
434	suggesting late Paleocene-Early Eocene rapid cooling in the original source of detritus (Fig. 9).
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437	4.2 Thermal modelling
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439	4.2.1 Calibration data
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441	Maturity data used for modelling calibration consist of Tmax and $\mathrm{VR}_{o}\%$ (only for
442	Satskhenisi 102 well) data which were provided by the Georgian Oil & Gas Company. Only

443 Tmax data from samples with TOC >0.5% were used as input data for modelling calibration.

Analytical details of calibration data are summarised in Table 2, where the minimum, maximum and average values of each parameter are reported, whereas the complete list of single analytical data is enclosed in the Supplementary Materials (Tables ST1, ST2, ST3, ST4 and ST5). Further details are reported in Corrado et al. (2021), DIG (2014), Sachsenhofer et al. (2021) and Stratochem Egypt (2014).

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- 450

4.2.2 Thermal models calibration

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In this study, Tmax data delineate a maturity trend in three out of five wells (i.e. Kumisi 1, Patardzeuli-E1 and Satskhenisi 102), whereas in Kumisi 2 and Norio 200 wells they only provide information on the thermal maturity along restricted stratigraphic sections (Late Eocene and Early Oligocene, respectively; Figs. 5 and 6; Table 2).

456 In the three wells (Kumisi 1, Kumisi 2 and Patardzeuli-E1) from the eastern Adjara-Trialeti FTB, two main constraints derive from Tmax data: the top of the Maikop section shows values 457 458 generally lower than the onset of the oil window (i.e. below 430 °C), whereas the bottom of 459 the Late Eocene section is close to the peak of oil generation (around 440 °C). The Late Eocene 460 section yields a higher degree of uncertainty, due to the high data spread in Patardzeuli-E1 well 461 and to the few data available in the Kumisi 1 well, although a better constrain on the maturity 462 level is given for this section by the clear cluster at the bottom of the Late Eocene section in 463 the Kumisi 2 well. To fit such maturity trends, depending on the assumed HF scenario (see 464 Section 3.2.2), different amounts of additional burial are required (Fig. 5). In the constant HF 465 scenario, maturity data are best fitted with 2000m of additional burial in the Kumisi 1 well and 466 1500m of additional burial in the Kumisi 2 and Patardzeuli-E1 wells (Fig. 5a, c, e). On the other hand, in the rifting HF model (the scenario with a HF peak around 45 Ma) the additional 467 468 burial required to fit thermal maturity data is of 1300m and 1000m, respectively (Fig. 5b, d, f).

Figure 10 shows the results of thermal modelling for the wells in the eastern Adjara-Trialeti
FTB (Kumisi 1, Kumisi 2 and Patardzeuli-E1), produced assuming the HF model with a peak
around 45 Ma (Fig. 10d), that is the most realistic one taking into account the geological
evolution of the Adjara-Trialeti back-arc rift basin (Adamia et al., 1981, 2011; Banks et al.,
1997). See Section 5.1.1 for further discussion on the thermal modelling results.

474 In the two wells (Norio 200 and Satskhenisi 102) from the western Kura Basin a high spread 475 characterises the Tmax data distribution. Nonetheless, a Tmax trend can be recognised along 476 the Maikopian section in the Satskhenisi 102 well; in this well, thermal maturity can be further 477 constrained by means of ten VR₀% data (Fig. 6c, d). Combining Tmax and VR₀% data in the 478 Satskhenisi 102 well, thermal maturity ranges between about 0.4 (at the top of the Maikop 479 section) to about 0.6 (at the bottom of the Maikop section) of equivalent VR_o%. Such trend can be fitted with an additional burial comprised between 800 and 2000 m assuming a constant HF 480 481 similar to the present-day value, and between 0 and 1300 m assuming the HF model with a 482 peak at around 45 Ma (Fig. 6c and d, respectively). The additional burial considered do not 483 comprise 500m of shales that we assume were deposited during the Sarmatian since they are 484 present in the nearby Norio 200 well (Fig. 3; Table 3). For what concerns the Norio 200 well, 485 the additional burial required to fit thermal maturity data varies between 1000 and 2500 m assuming a constant HF, and between 800 and 2000 m assuming the rifting model with a peak 486 487 at \sim 45 Ma (Fig. 6a, c).

Figure 11 shows the results of thermal modelling for the wells in the western Kura Basin (Norio 200 and Satskhenisi 102), produced assuming a constant HF of 45 mW/m² (Fig. 11c), which is the more realistic scenario given the flexural nature of the Kura foreland basin (Adamia et al., 2010; Nemčok et al., 2013; Patton, 1993). See Section 5.1.2 for further discussion on the thermal modelling results.

495 4.3 Structural cross-section

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The geological cross-section shown in Figure 7 was created linking together three interpreted depth-migrated seismic reflection profiles (lines 1401, 13 and 3004) provided by the Georgian Oil & Gas Company. The cross-section, oriented NE-SW, covers the eastern Adjara-Trialeti FTB and the southernmost western Kura Basin, and depicts the overall structural layout of the study area.

502 In the section, the Adjara-Trialeti FTB is characterised at depth by mostly north-verging and 503 subordinately south-verging duplex systems made of Cretaceous-Paleogene rocks, which 504 accommodate considerable shortening (Fig. 7). The Teleti and Varketili anticlines, separated 505 by a broad syncline, are fault-propagation folds developed upon south- and north-directed 506 thrusts, respectively, involving the Cretaceous-to-Eocene sequence. Structural interpretation at 507 shallow crustal levels (0-4 km) is consistent with those shown in other published cross-sections 508 and interpreted seismic lines in the study area (c.f. Alania et al., 2021a, 2021c). As seismic 509 resolution decreases at deeper levels, different models can be applied to reconstruct the 510 structural style. For example, Alania et al. (2021a, 2021b) propose an interpretation implying 511 a higher degree of shortening than Tari et al. (2021).

Previous work (Banks et al., 1997; Candaux, 2021; Gusmeo et al., 2021; Sosson et al., 2016; Tari et al., 2018) showed that the overall geometry of the Adjara-Trialeti FTB can be interpreted as the result of the structural inversion of the former extensional faults accommodating back-arc rifting, in agreement with the architecture shown in the shallowest portion of Fig. 7. The complex fault pattern at depth was formed during the progressive northward progradation of the retro-wedge of the Lesser Caucasus (Alania et al., 2021a; 518 Gusmeo et al., 2021). The Ormoiani syncline is mainly made of Maikopian (Oligocene-Early
519 Miocene) rocks, topped by thin Middle and Upper Miocene rocks.

520 Since Maikopian rocks are involved in the deformation (Fig. 7), the cross-section indicates 521 that inception of deformation postdates the Early Miocene, a timing in agreement with the 522 Middle Miocene inception of inversion of the Adjara-Trialeti FTB, based on seismic 523 interpretation (Pace et al., 2019) and low-temperature thermochronology results (Gusmeo et 524 al., 2021; this study).

525 The northern segment of the section shows a series of shallow, thin-skinned south-verging 526 thrusts involving Miocene rocks, which overlie the frontal part of the Adjara-Trialeti FTB (Fig. 527 7). In this sector, a triangle zone is formed by the interference between the north-verging 528 structures related to the Adjara-Trialeti FTB and the south-directed thrusts deforming the Kura 529 Basin. Further to the west, published seismic lines show a very similar structure in the triangle 530 zone (Alania et al., 2018, 2020, 2021a; Pace et al., 2019; Tari et al., 2021), but there the south-531 verging thrusts deforming the Kura Basin do not overthrust yet the Adjara-Trialeti FTB (Fig. 532 12). Since Upper Miocene rocks are clearly involved in the south-verging thrusts, the onset of 533 thin-skinned deformation is not older than Late Miocene (Fig. 7).

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536 5. Discussion
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538 5.1 Thermal and burial histories

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540 The integration of organic thermal indicators, thermochronology and structural data is key 541 in basin analysis and has been successfully applied in a number of studies focused on the burial 542 and erosion history of sedimentary successions (Balestra et al., 2019; Corrado et al., 2020; Di Paolo et al., 2012; Schito et al., 2018) and/or on the deformation style within an orogenic wedge
(Andreucci et al., 2014; Caricchi et al., 2015; Corrado et al., 2021; Curzi et al., 2020; Di Paolo
et al., 2012).

The overall evolution of the Adjara-Trialeti FTB and the western Kura Basin has involved different subsidence mechanisms (rifting vs. lithospheric flexure) and complex patterns of structural interference between the facing Greater Caucasus and Adjara-Trialeti fold-and-thrust belt, to the point that only an integrated approach can unravel with sufficient detail the timing and magnitude of maximum burial and exhumation, as well as the paleo-heat flows during basin evolution.

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5.1.1 Adjara-Trialeti FTB

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555 In the Adjara-Trialeti FTB low-temperature thermochronologic analyses and inverse 556 modelling of the two surface samples analysed provide an insight into the post-Oligocene 557 thermal history of the basin, while thermal models calibrated by means of wells stratigraphy 558 and thermal maturity data also constrain the oldest phases of burial. Despite the uncertainties 559 related to the high spread of Tmax well data (Fig. 5), the results suggest thermal maturity at 560 the onset and at the peak of the oil window in the Maikop and Late Eocene sections, 561 respectively. In the Patardzeuli-E1 and Kumisi 2 wells, hydrocarbon generation by Eocene and, 562 in minor account, Maikop sources has been confirmed by gas chromatography-mass 563 spectrometry (GC-MS) data (Sachsenhofer et al., 2021), strengthening the reliability of our 564 dataset. Between two HF scenarios tested in the sensitivity analysis (Fig. 5), the one involving 565 a peak of HF during Middle Eocene (around 45 Ma; Fig. 10d) back-arc rifting (Adamia et al., 1977, 1981, 2011; Okrostsvaridze et al., 2018) best suits the geological evolution of the Adjara-566 567 Trialeti Basin. Additional support to the tested HF model is provided by the high present-day heat flow in the western sector of the fold-and-thrust belt (Melikadze et al., 2015). In this area, rifting was more pronounced and arguably decreased at a slower pace, thus suggesting that also the easternmost Adjara-Trialeti Basin experienced in the past higher HF values than the present-day value of 50 mW/m².

Given that rifting did not lead to continental break-up and oceanization, HF values in the 572 Adjara-Trialeti Basin probably never exceeded 100 mW/m², as shown in typical continental 573 574 rift basins such as the Rhine Graben, Lake Tanganika, Gulf of Suez and Rio Grande Rift (Allen 575 & Allen, 2013; Ebinger et al., 1989; Evans, 1988; Friedmann & Burbank, 1995; Jackson & 576 McKenzie, 1988; Morley et al., 1990; Patton et al., 1994). Considering that our study area in 577 the easternmost Adjara-Trialeti FTB was likely a marginal portion of the basin, a value of 70 578 mW/m² can be reasonably assumed as adequate to represent the maximum HF peak during 579 rifting. Nonetheless, also higher values were tested in a trial-and-error approach, and the results 580 show significant changes only in the deeper part of the maturity curve, which increases its slope 581 and loses fit with the data.

582 Even with the HF model involving a peak around 45 Ma, an additional burial of about 1 km was still required to fit thermal maturity data (Fig. 5a, c and e). In the Kumisi 1 well such 583 584 additional burial is slightly higher (1.3 km) to compensate for the missing uppermost part of the Maikop section, which is instead present in the Kumisi 2 well. This 1.0-1.3 km of additional 585 586 burial can reasonably be attributed to a sedimentary load deposited in the Early Miocene, 587 between about 20 and 15 Ma (Table 3), i.e. after the most recent sedimentary units preserved 588 in the wells and before the cooling event accompanying erosion, that could represent the 589 persistence of marine conditions in the Adjara-Trialeti basin during Burdigalian-Langhian 590 times. Such sedimentary burial matches the fast increase of temperatures detected by statistical 591 inverse modelling of AFT data between Burdigalian and Langhian times (Figs. 8 and 9). 592 Conversely, tectonic loading at that time is unrealistic, since the nearby advancing thrusts deforming the Kura Basin were activated in the Late Miocene (Sarmatian-Pontian; Alania et
al., 2017; Nemčok et al., 2013). Finally, the thickness of the Lower Miocene section (1-2 km)
shown in the cross-section of Figure 7 supports the interpretation of such additional loading as
due to sedimentary burial.

597 Based on the assumptions described above on the thermal history (i.e. the HF model applied) 598 and the additional sedimentary burial required to fit thermal maturity data, the isotherms 599 derived from thermal modelling of the Adjara-Trialeti wells predict that maximum 600 paleotemperatures experienced by the Maikop section (Oligocene-Early Miocene) in all three 601 wells were comprised between about 90 and 110 °C (Suppl. Mat. Fig. S6). This conclusion 602 agrees with (i) statistical inverse modelling of AFT data (e.g. Figs. 8 and 9), which indicate 603 that Maikop samples from the Adjara-Trialeti FTB are partially reset and hence experienced 604 maximum paleotemperature within the Partial Annealing Zone of apatite, i.e. between 60 and 605 120 °C (this study; Gusmeo et al., 2021), and (ii) maximum paleotemperatures estimated on 606 Maikop samples from multiple thermal maturity proxies within the Adjara-Trialeti FTB 607 (Corrado et al., 2021).

608 The only other thermal model available for the study area (Pupp et al., 2018) estimates a 609 total amount of eroded section of ca. 3.5 km, different from our estimates of 1.0-1.3 km. This value results from the very low heat-flow value used as input data: Pupp et al. (2018) used a 610 constant value of 40 mW/m² to model a pseudo-well built upon surface data from the Tbilisi 611 612 area, considered as part of the Kura Basin. Based on geological and geophysical data (see for 613 example Figs. 2 and 7), the section analysed by Pupp et al. (2018) is actually part of the Adjara-614 Trialeti domain, hence the higher amount of burial derived from an underestimation of the heat 615 flow values. On the other hand, the modelling of Pupp et al. (2018), based on stratigraphy, 616 shows an increase in subsidence rates in the Early Miocene and sets the beginning of 617 exhumation of the studied section at 15 Ma, in agreement with our models (Fig. 10).

618 According to our thermal modelling results (Fig. 10), the three wells in the eastern Adjara-619 Trialeti FTB show a similar burial pattern, despite some minor differences in the thickness of equivalent stratigraphic units, in the age range of the sampled sections (e.g. Late Cretaceous-620 621 Miocene in Kumisi 1 versus Late Eocene-Miocene in Kumisi 2), and in the maximum depths 622 estimated by the models. The burial history of the Kumisi 1 and Patardzeuli-E1 wells is 623 characterised by rapid subsidence starting in the late Paleocene and continuing, with varying 624 intensity, until the mid-Miocene (Fig. 10). The Eocene-Miocene burial history of the Kumisi 2 625 well is virtually identical but this borehole did not penetrate the older chronostratigraphic units. 626 Sedimentation rates were higher during the late Paleocene-Early Eocene in the Kumisi 1 and Patardzeuli-E1 wells, and during the Middle-Late Eocene and Early Miocene in all three wells 627 628 (Fig. 10a, b and c). Timing of inception of cooling/exhumation was set at 15 Ma for all three 629 wells, based on thermochronological data on the beginning of tectonic inversion of the Adjara-630 Trialeti back-arc basin (Figs. 8 and 10; see Section 4.1; Gusmeo et al., 2021).

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632 *5.1.2 Kura Basin*

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In the western sector of the Kura Basin, the Oligocene portion of the Maikop section was sampled and studied within the Norio 200 and Satskhenisi 102 wells. Despite a large data spread, thermal maturity at the onset of the oil window is also confirmed by GC-MS data (DIG, 2014) and by the datasets reported in Corrado et al. (2021), Pupp et al. (2018) and Sachsenhofer et al. (2021).

During the Oligocene, the western sector of the Kura basin acted as a foreland basin in front
of the northward advancing Lesser Caucasus - Adjara-Trialeti system (Nemčok et al., 2013).
Given the relatively thick and rigid crust upon which the Kura foreland basin developed
(Adamia et al., 2010; Alania et al., 2017; Banks et al., 1997; Nemčok et al., 2013), it could be

643 argued that the heat flow has been relatively low throughout the entire evolution of the basin, 644 as already suggested by Corrado et al. (2021). Thus, even if for the sake of comparison the 645 scenario involving a HF peak around 45 Ma (as in the adjacent Adjara-Trialeti domain) has 646 been tested too (Fig. 6), the constant HF scenario is in our view the most appropriate to apply. 647 Based on the heat-flow map of the Black-Caspian seas region (Kutas, 2010) the present-day 648 heat-flow value in the studied sector of the western Kura Basin is around 45 mW/m², a slightly lower value than in the adjacent, relatively hotter, Adjara-Trialeti FTB. Such value agrees with 649 650 the low geothermal gradient of the area (28 °C/km; Patton, 1993), and is in the range of other 651 foreland basins worldwide (20-60 mW/m²) (Allen and Allen, 2013; Sachsenhofer, 2001; 652 Weides and Majorowicz, 2014).

653 Using a steady-state heat-flow model, both wells in the Kura Basin required an additional 654 burial after the deposition of the Sarmatian section (the latest sedimentary succession preserved 655 within the two wells) which ended at about 8 Ma in the Norio 200 well. Given the large spread 656 of Tmax data in both wells, it is not an easy task to accurately determinate the amount of 657 additional burial (Fig. 6a and c). Nevertheless, the maturity curves built assuming 1800 m and 658 1300 m of additional burial for Norio 200 and Satskhenisi 102, respectively, seem to fit at best 659 the data. Such estimations are just below the range given by Corrado et al. (2021) who, based on surface and subsurface thermal maturity data, calculated 2-3 km of Kura basin fill erosion. 660 661 It is worth noting that these values can sensibly change depending on the lithologies assumed 662 for the additional loading. In our models, we used a mixed lithology composed of shales and 663 sandstones, which is the same one characterising the Sarmatian sections (Fig. 3, Table 3) and 664 best represents the Miocene sedimentary fill of the Kura Basin.

665 Thermal modelling of the two wells from the western Kura Basin produced a broadly similar 666 subsidence pattern (Fig. 11). Relatively fast subsidence during the Oligocene was followed by 667 slower rates in the Early-Middle Miocene and very fast burial in the Late Miocene, especially after 8 Ma. This means that the additional burial required to fit thermal maturity data was
emplaced very rapidly, suggesting a tectonic origin rather than sedimentary burial: the most
probable cause of such tectonic loading is the emplacement of south-verging thrusts (Figs. 1,
2, 7 and 12) related to southward propagation of deformation from the Greater Caucasus.

Since precise constraints on the beginning of cooling/exhumation in this sector are not 672 673 available, such timing was tentatively set at 6 Ma, i.e. after the most recent deposits within the 674 Norio 200 well (8 Ma; Fig. 11, Table 3). However, after several simulations (with such timing 675 varying between 7 and 3 Ma), we found that differences in the timing of inception of erosion 676 did not affect significatively the results. A latest Miocene-Early Pliocene age of inception of 677 erosion/cooling is also in agreement with the Late Miocene age of the youngest rock units 678 within the thrust sheets imaged in the seismic lines across the southern Kura basin (e.g. Fig. 7) 679 and with previous estimates on the inception of deformation in the Kura Basin (Alania et al., 680 2017; Nemčok et al., 2013).

According to modelling results, the base of the Oligocene section in both wells experienced
 maximum paleotemperatures in excess of 80 °C (Fig. 11).

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685 5.2 Tectonic implications

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The integration of our new AFT inverse modelling and thermal modelling results constrains the burial/exhumation history of the structurally complex transition zone between two adjacent geologic domains, the Adjara-Trialeti FTB to the south and the Kura Basin to the north, which differ in age, origin, subsidence mechanisms and evolution.

691 A rift model best describes the HF evolution in the eastern Adjara-Trialeti back-arc basin,

692 with a peak at ca. 70mW/m^2 around 45 Ma followed by gradual reduction down to the present-

693 day value of 50 mW/m² (Fig. 10d). Applying such HF model, the Adjara-Trialeti basin 694 experienced continuous subsidence from the Paleocene to the middle Miocene, punctuated by 695 three main pulses of increased subsidence (Fig. 10). High subsidence rates were first registered 696 in the Kumisi 1 and Patardzeuli-E1 wells in the late Paleocene-Early Eocene. During this time 697 a thick succession, including the terrigenous turbidites of the Borjomi Flysch (Adamia et al., 698 2011; Banks et al., 1997; Yılmaz et al., 2000, 2014), was deposited in the Adjara-Trialeti basin 699 in the northern foreland of the Erzinçan-Sevan-Akera orogen, which was experiencing a 700 gradient of increasing flexural subsidence from west to east (Gusmeo et al., 2021), as confirmed 701 by the progressive eastward thickening of the Borjomi Flysch (Gamkrelidze, 1949; Yılmaz et 702 al., 2000). Interpreting the pre-depositional history of detrital samples as derived from inverse 703 modelling must be done with great care, because of the intrinsic assumptions that are hardly 704 verifiable (Malusà and Fitzgerald, 2020). Nevertheless, our thermochronologic inverse 705 modelling results (Gusmeo et al., 2021; this study) are supported by very high chi-square values 706 (close to 100%) and describe a thermal history (i.e. fast cooling/exhumation of the sediment 707 source area during Paleocene-Eocene times; Figs. 8 and 9) that is compatible with the 708 reconstructed geologic evolution of the region during that time span, when the Northern 709 Neotethys finally closed along the Izmir-Ankara-Erzinçan-Sevan-Akera suture zone due to the oblique collision between the Anatolide-Tauride terrane and the southern Eurasian margin 710 711 (Barrier et al., 2018; Rolland et al., 2019; Sosson et al., 2010; Stampfli and Hochard, 2009). 712 As a result, the building-up of the Lesser Caucasus (e.g. Barrier et al., 2018; Okay and Tüysüz, 713 1999; Sosson et al., 2010) was most likely the source of the sediments deposited in the Adjara-714 Trialeti basin, that was forming under lithospheric flexure due to loading by the Lesser 715 Caucasus retro-wedge (Gamkrelidze, 1949; Gusmeo et al., 2021). During the final stages of 716 closure of the Northern Neotethys, slab roll-back brought, in the Lutetian, to the main phase of 717 continental rifting within the Adjara-Trialeti basin, as testified by the intrusion of plutonic/hypabyssal bodies and by the deposition of volcanic and volcaniclastic rocks (Adamia et al., 2011; Gamkrelidze et al., 2019; Okrostsvaridze et al., 2018). The second phase of increased subsidence rate (Middle-Late Eocene) is likely a consequence of such continental rifting. Furthermore, the presence of volcanic and plutonic rocks, most abundant in the western sector of the basin towards the Black Sea coast, corroborates the hypothesis of high heat-flow at that time (Fig. 10).

724 The third phase of fast burial (Early Miocene), previously unrecognised, is evident in the 725 thermal models (Fig. 10) and confirmed by the fast heating phase outlined by inverse modelling 726 of AFT data (Figs. 8 and 9). At this time the area was characterized by the convergence between 727 the Greater and Lesser Caucasus (Nemčok et al., 2013). We propose that strike-slip tectonics 728 could have caused such a subsidence pulse just before the uplift of the area, based on (i) 729 paleomagnetic and structural data (Avagyan et al., 2005; Meijers et al., 2015; Rolland, 2017) 730 suggesting oroclinal bending accompanied by strike-slip deformation in the Lesser 731 Caucasus/Transcaucasus during the Cenozoic; (ii) present-day GPS vectors indicating 732 anticlockwise rotation of the Arabian Plate and in the Kura Basin (Forte et al., 2014; Reilinger 733 et al., 2006); (iii) earthquake focal mechanisms suggesting transpression/transtension in the 734 eastern Transcaucasus (Ismail-Zadeh et al., 2020; Sokhadze et al., 2018; Tibaldi et al., 2019); (iv) fault patterns likely associated to the structural inversion of strike-slip (transtensional) 735 736 faults imaged in seismic profiles in the eastern Adjara-Trialeti fold-and-thrust belt (see cross-737 section of Fig. 7 and Tari et al., 2021), and (v) the high subsidence rates evidenced in the 738 modelling results (Fig. 10). Additional field-based structural studies are needed to test this 739 hypothesis.

Early to Middle Miocene (20-15 Ma) Adjara-Trialeti basin inversion is constrained by inverse modelling of thermochronologic data (Figs. 8 and 9; Table 1) and confirms previous results obtained more to the west along the orogenic belt (Gusmeo et al., 2021). Exhumation 743 can be framed in the context of the Middle Miocene hard collision between the Arabian and 744 Eurasian plates along the Bitlis-Zagros suture zone (Cavazza et al., 2018; Okay et al., 2010; 745 Rolland et al., 2012) that caused reactivation of tectonic structures, basin inversion, and strike-746 slip deformation in the hinterland of the collision zone, from the eastern Pontides and the East Anatolian-Iranian Plateau, to the Lesser and Greater Caucasus, to the Talysh and Alborz ranges 747 (Albino et al., 2014; Avagyan et al., 2005; Avdeev and Niemi, 2011; Axen et al., 2001; Ballato 748 749 et al., 2008, 2016; Barber et al., 2018; Cavazza et al., 2017, 2019; Corrado et al., 2021; Gavillot 750 et al., 2010; Gusmeo et al., 2021; Madanipour et al., 2017; Mosar et al., 2010; Paknia et al., 751 2021; Vasey et al., 2020; Vincent et al., 2020).

Our preferred model describing the HF evolution in the western Kura Basin assumes a constant HF of 45 mW/m² (Fig. 11c) throughout the Oligocene-to-Present basin history. Applying such model, in the western Kura basin the subsidence curves derived from the burial histories of the two analysed wells (Fig. 11) mostly describe the evolution during Maikop deposition and show continuous burial since the Oligocene, with two main pulses of enhanced subsidence in the Oligocene and in the Middle-Late Miocene, respectively.

758 A first phase of relatively fast subsidence (higher in Satskhenisi 102 than in Norio 200) 759 occurred during the Oligocene (Fig. 11), when the western Kura foreland basin behaved as a flexural basin, reacting by prominent fill asymmetry to loading by the northward advancing 760 761 Lesser Caucasus - Adjara-Trialeti system (Nemčok et al., 2013). It was only in the Middle-Late 762 Miocene that the flexural wave induced by the south-verging advancement of the Greater 763 Caucasus structural front reached the southern margin of the Kura Basin (Figs. 11 and 12). The 764 sedimentation pattern at that time is typical of foreland basins, characterized by convex-upward 765 subsidence curves (e.g. Allen and Allen, 2013; Fig. 11).

Competing and asymmetrical episodes of flexural subsidence within the western Kura Basin
have been envisioned by Nemčok et al. (2013), who interpreted the marked southward

thickening of the Oligocene section and the northward thickening of the Early-Middle Miocene
one as effects of flexural loading by the advancing Lesser Caucasus and Greater Caucasus,
respectively.

771 Finally, in Late Miocene times (late Sarmatian-Pontian; Alania et al., 2017; Nemčok et al., 2013) the southward propagation of deformation from the Greater Caucasus affected the Kura 772 Basin in the area of the Norio 200 and Satskhenisi 102 wells (Fig. 12). This resulted in the 773 774 emplacement of a complex system of thin-skinned south-verging thrusts, arguably responsible 775 for the additional 1.3-1.8 km of tectonic loading required to fit thermal maturity data (Figs. 11 776 and 12). After this fast burial, which led to maximum paleo-temperatures of more than 80°C at 777 the bottom of the succession, the area was ultimately exhumed and experienced significant 778 erosion. The complex deformation that took place in the southern part of the Kura foreland 779 basin is represented by deformation and uplift of Miocene strata by thin-skinned thrusting at 780 the top of the triangle zone (Fig. 7). Such a structural thickening induced the erosion of a ca. 781 1.3-1.8 km thick section since latest Miocene-Pliocene times.

782 The overall tectonic evolution and burial-exhumation history reconstructed for the Adjara-783 Trialeti and Kura basins, in the central Transcaucasian sector, can be framed in the context of 784 the broad Arabia-Eurasia collision zone. Initial flexural subsidence and subsequent back-arc rifting in the Adjara-Trialeti Basin can be interpreted as a consequence of continental collision 785 786 along the Erzinçan-Sevan-Akera suture during Paleocene-Early Eocene times and roll-back 787 during the Middle Eocene, respectively. During the Oligocene, thermal subsidence was 788 affecting the Adjara-Trialeti basin (Fig. 10), whereas the Kura Basin was flexured by the 789 advance of the Lesser Caucasus system (Fig.11). The Middle Miocene inception of inversion 790 of the Adjara-Trialeti basin defined in this study and in Gusmeo et al. (2021), as well as the 791 timing of renewal of flexural behaviour in the Kura Basin highlighted by thermal modelling 792 results (Fig. 11), can both be ascribed to far-field stress propagation from the Bitlis-Zagros 793 suture zone, hundreds of kilometres to the south, where the Middle Miocene hard collision 794 between the Arabian and Eurasian plates took place (Cavazza et al., 2018; Okay et al., 2010). 795 Furthermore, continued northward stress transmission may have been also responsible for 796 shortening/uplift in the Greater Caucasus. Given that in its central sector this orogen is mainly 797 south-verging (Forte et al., 2014), far-field stress transmission from the Bitlis-Zagros suture 798 zone could ultimately be responsible for southward propagation of deformation from the 799 Greater Caucasus, affecting also the Kura Basin (Fig. 12). Such a stress field is active also at 800 present in the Transcaucasus, as demonstrated by GPS and earthquakes data (Karakhanyan et 801 al., 2013; Reilinger et al., 2006; Sokhadze et al., 2018; Tsereteli et al., 2016).

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804 6. Conclusions

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In this paper we apply an integrated approach to the study of the complex transition zone between the eastern Adjara-Trialeti FTB and the western Kura Basin (central Georgia). The combination of AFT inverse modelling, well thermal modelling and seismic interpretation has elucidated the pattern of subsidence/exhumation and has provided new constraints on the overall tectonic evolution of the eastern Georgian sector of the Transcaucasus.

New AFT inverse modelling results from the eastern Adjara-Trialeti FTB indicate latest Paleocene-Early Eocene fast cooling/exhumation, arguably linked with final closure of the Northern Neotethys ocean and subsequent building of the Lesser Caucasus. A previously unrecognized and localized Early Miocene phase of fast subsidence and heating is tentatively attributed to strike-slip motion components between the Greater and Lesser Caucasus orogenic systems. AFT modelling results also confirms the mid-Miocene inception of structural inversion of the Adjara-Trialeti basin. Thermal modelling of the Adjara-Trialeti inverted back-arc basin delineates three pulses of enhanced subsidence in Late Paleocene-Early Eocene, Middle-Late Eocene and Early Miocene times in the Adjara-Trialeti basin, associated respectively to flexural subsidence, rifting and strike-slip tectonics. Modelling results also predict that about 1.0-1.3 km of sedimentary rocks have been eroded since inversion started.

Best-fit thermal models from the Kura Basin describe a complex subsidence pattern during Oligocene-Miocene times, resulting from the interference between the competing and oppositely advancing Lesser and Greater Caucasus orogenic systems. During the Late Miocene the southwestern Kura Basin experienced rapid tectonic burial (ca. 1.3-1.8 km), related to south-verging thrusts linked to southward propagation of deformation from the Greater Caucasus, ultimately followed by exhumation and erosion.

On a larger scale, the tectonic evolution and burial/exhumation history of central Transcaucasia can be correlated with episodic continental accretion along the Eurasian plate margin related to (i) collision of the Anatolide-Tauride terrane and the ensuing development of the Erzinçan-Sevan-Akera suture in the latest Cretaceous - Eocene, and (ii) the hard collision of Arabia along the Bitlis-Zagros suture zone in the Miocene.

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Figure 1: Main tectonic units and structures of the Eastern Anatolia-Caucasus region superimposed on an ASTER GDEM shaded relief map (source: USGS) (modified after Gusmeo et al., 2021; tectonic structures after Cavazza et al., 2019; Forte et al., 2014; Sosson et al., 2010). ASASZ = Amasia-Sevan-Akera suture zone; D = Dzirula Massif; IAESZ = Izmir-Ankara-Erzinçan suture zone; K = Khrami Massif; L = Loki Massif; MCT = Main Caucasian Thrust. Red lines with triangles indicate thrusts; red lines are normal, strike-slip or unknown kinematics faults. Dashed rectangle indicates location of Figures 2 and 12. Inset: Tectonic sketch map of the Arabia-Eurasia collision zone, after Cavazza et al. (2019) and Sosson et al. (2010). Red arrows represent selected GPS vectors after Reilinger et al. (2006); numbers indicate relative displacement with respect to stable Eurasia (in mm/yr). EAF = East Anatolian Fault; NAF = North Anatolian Fault.



Figure 2: Geological map of the study area (USSR Geological Survey, 1971), with location of the six wells considered in this study, the two samples analysed for AFT inverse modelling, and the three seismic reflection profiles interpreted to build the cross-section in Figure 7. The trace of the cross-section in Figure 7 is also shown. Map location is indicated in Figure 1. See Figure 3 for regional stratigraphic stages.



Figure 3: Detailed stratigraphy of the six wells analysed in this study, with total depth (T.D.) and ground elevation (G.E.) of the opening pit reported for each well. The chronostratigraphic chart at the left side is after Adamia et al. (2010), Lazarev et al. (2019) and Neubauer et al. (2015). Numerical ages after Cohen et al. (2021).



Figure 4: TOC vs S2 plots for the five wells for which thermal maturity data are available, showing the kerogen type of each data (prevailing Type III, alternatively Type II-III). Data from DIG (2014), Sachsenhofer et al. (2021), Stratochem Egypt (2014). See Supplementary Materials Figs. S1, S2, S3, S4, S5 for additional diagrams showing kerogen types with greater detail.



Figure 5: Sensitivity analysis for the three wells located in eastern Adjara-Trialeti FTB (see Fig. 2 for location), showing the different fitting of thermal maturity data with various amounts of additional burial, assuming a constant heat flow (a, c, and e) or a rifting model with an HF peak around 45 Ma (b, d and f). Data from Sachsenhofer et al. (2021), Stratochem Egypt (2014).



Figure 6: Sensitivity analysis for two of the wells located in the western Kura Basin (see Fig. 2 for location), showing the different fitting of thermal maturity data with various amounts of additional burial, assuming a constant heat flow (a, c) or a rifting model with an HF peak around 45 Ma (b and d). Data from DIG (2014), Sachsenhofer et al. (2021).



Figure 7: Geological cross-section based on the interpretation of three depth-migrated seismic reflection profiles (lines 1401, 13 and 3004) across the eastern Adjara-Trialeti FTB and the western Kura Basin. Uninterpreted seismic profiles are reported on top. Seismic interpretation by V. Alania and P. Pace integrates also surface data, from geological maps (USSR Geological Survey, 1971) and field observations, and wells data. Wells are

projected on the section (K-1 = Kumisi 1; K-2 = Kumisi 2; NOR200 = Norio 200). Original seismic data courtesy of Georgia Oil & Gas Limited. No vertical exaggeration. See Figure 2 for location of cross-section and seismic profiles.



Figure 8: A) Time-temperature path obtained from inverse modelling of sample TU504. See Fig. 2 for sample location. Green area marks the envelope of all thermal histories that have a good (>0.5) fit with the data, red line represents the mean of all good paths, and the blue line is the best-fit time-temperature path. Parameters related to inverse modelling are reported: GOF, goodness-of-fit, gives an indication about the fit between observed and predicted data (values closer to 1 are best). B) Radial plot of single-grain AFT ages. C) D) Confined-track length frequency distribution.



Figure 9: A) Time-temperature path obtained from inverse modelling of sample TU505. See Fig. 2 for sample location. Green area marks the envelope of all thermal histories that have a good (>0.5) fit with the data, red line represents the mean of all good paths, and the blue line is the best-fit time-temperature path. Parameters related to inverse modelling are reported: GOF, goodness-of-fit, gives an indication about the fit between observed and predicted data (values closer to 1 are best). B) Radial plot of single-grain AFT ages. C) Confined-track length frequency distribution.



Figure 10: 1D burial and thermal history for the Kumisi 1 (a), Kumisi 2 (b) and Patardzeuli-E1 (c) wells, located in the eastern Adjara-Trialeti fold-and-thrust belt. See Fig. 2 for location. The models are calibrated against Tmax data. A rifting heat-flow model, with a peak around 45 Ma, was used for modelling (d). Vertical bars highlight the main subsidence pulses and the related tectonic events (see text for further discussion).



Figure 11: 1D burial and thermal history for the Norio 200 (a) and Satskhenisi 102 (b) wells, located in the western Kura Basin. See Fig. 2 for location. The models are calibrated against Tmax data (Norio 200) and Tmax and vitrinite reflectance data (Satskhenisi 102). A steady-state heat flow of 45 mW/m² was adopted (c). Vertical bars highlight the main subsidence pulses and the related tectonic events (see text for further discussion).



Figure 12: Block diagrams showing the Cenozoic tectonic evolution of the eastern Adjara-Trialeti FTB-western Kura Basin system (see Fig. 1 for location) as reconstructed in this paper. During the Middle Miocene the Kura Basin experienced cumulative subsidence due to structural inversion of the Adjara-Trialeti basin and southward propagation of the Greater Caucasus deformation front. In the latest Miocene south-directed thrusts reached the southern margin of the Kura Basin and covered the eastern Adjara-Trialeti FTB, forcing its eastward plunge. To the west the south-directed thrusts affecting the Kura Basin and the north-directed structures of the Adjara-Trialeti FTB were not yet interfering.

			Type Age		Fl	UTM Coordinates	N-	Spont	Spontaneous		Induced		Dosimeter			MCTL ()	Standard	N	. M
S	ample	Rock Type		Location	Elevation (m)		No. crystals	ρ_s	Ns	ρ_{i}	Ni	Ρ (χ ²)	ρ_d	N _d	Age (Ma) ±1s	standard error	Standard deviation	measured	Mean D-par
1	TU504	Sandstone	Early Miocene (Burdigalian)	Eastern ATFTB	396	38T 0500933 4602375	61	0.15	333	0.81	1770	99.98	11.64	7276	36.3 ± 2.8	13.34 ± 0.17	1.57	83	2.75
T	TU505	Sandstone	middle-late Oligocene	Eastern ATFTB	512	38T 0500906 4615010	48	0.24	270	1.17	1307	97.99	11.57	7230	39.6 ± 3.3	13.41 ± 0.18	1.47	67	2.31

Table 1: Results of apatite fission-track analyses (see Fig. 2 for location of samples).

ATFTB = Adjara-Trialeti fold-and-thrust belt. MCTL = mean confined tracks length. Central ages are calculated using dosimeter U-free mica CN5 as external detector and $\zeta = 332.68 \pm 16.54$ (analyst T. Gusmeo); ρ_s = spontaneous track densities (x 10⁵ cm⁻²) measured in internal mineral surfaces; Ns= total number of spontaneous tracks; ρ_i and ρ_d = induced and dosimeter track densities (x 10⁶ cm⁻²) on external mica detectors (g= 0.5); N_i and N_d= total number of induced and dosimeter tracks; P(χ^2)= probability of obtaining χ^2 -value for n degrees of freedom (n= number of crystals-1): a probability >5% is indicative of a homogeneous population.

Table 2: Summary of thermal maturity data used as input for wells modelling. Average, minimum and maximum values of TOC (>0.5%), Rock-Eval Pyrolysis data (S1, S2, S3, Tmax, HI, OI) and vitrinite reflectance data (either measured in situ or calculated from Tmax) are provided, subdivided for age interval in each well analysed. Equivalent VR_0 % in the Satskhenisi 102 well was calculated from Tmax using the equation by Jarvie et al. (2001). Data derive from DIG (2014), Sachsenhofer et al. (2021) and Stratochem Egypt (2014), and were kindly provided by the GOGC.

	GPS Coordinates	Samples depth		N° samples	TOC (>0.5) (%)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI (mgHC/gTOC)	OI (mgCO2/gTOC)	VR₀% (measured)	VR ₀ % (calculated from Tmax)
Well name	(UTM Zone 38N)	interval (m)	Age of interval		Average	Average	Average	Average	Average	Average	Average	Average	Average
					min, max	min, max	min, max	min, max	min, max	min, max	min, max	min, max	min, max
		165 425	Mailtan (Oligagana)	5	1.09	0.08	1.17	1.17	429	107	117	-	-
Kumici 1	0482287 4605221	105-425	Markop (Ongocene)		0.82, 1.46	0.05, 0.11	0.74, 1.72	0.75, 1.52	426, 432	73, 146	51, 185	-	-
Kullisi I	0482387 4003231	555-1245	Late Eccene	9	1.01	0.08	1.47	0.92	434	136	102	-	-
		555-1245	Late Lotene	,	0.52, 1.36	0.05, 0.10	0.38, 2.67	0.66, 1.34	428, 437	74, 196	53,196	-	-
Kauniai 2	0492141 4(07212	1240 1525			1.44	0.16	3.30	-	439	222	-	-	-
Kumisi 2	0483141 460/313	1340-1535	Late Eocene	21	1.05, 1.95	0.05, 0.27	1.55, 6.20	-	434, 441	117, 318	-	min, max - - - - - - - - - - - - -	-
		220 1250	Maikop (Oligocene-Early Miocene)	35	1.01	0.15	1.63	-	430	158	-	-	-
Patardzeuli	0515117 4(19(07	330-1330			0.64, 1.26	0.08, 0.27	0.64, 2.92	-	422, 440	96, 238	-	-	-
	051511/401809/	1380 2260	Lata Facana	45	1.18	0.24	1.98	-	436	160	-	-	-
		1380-2200	Late Eocene	43	0.59, 1.77	0.06, 0.55	0.57, 3.75	-	430, 445	97, 212	-	(measured) Average min, max - - - - - - - - - - - - - - - - - - -	-
			CI 1 1	2	1.42	0.16	3.38	-	431	238	-		-
		665-675	Chokrakian	2	1.37, 1.46	0.14, 0.18	2.71, 4.04	-	430, 432	198, 277	-	-	-
Norio 200	0404725 4620461	745 066	Middle Meiken (Lete Oligogene)	5	1.47	0.20	2.83	-	424	191	-	-	-
10110 200	0494733 4029401	/45-900	Middle Markop (Late Oligocelle)	5	1.13, 2.51	0.12, 0.24	1.36, 4.09	-	419, 427	93, 228	-	-	-
		1062 1233	Lower Maikon (Early Oligocene)	12	1.96	0.28	4.75	-	426	234	-	-	-
		1002-1255	Lower Markop (Larry Oligocene)	12	1.32, 2.93	0.06, 0.46	1.48, 7.13	-	421, 431	90, 318	-	-	-
Satskhenisi 101	0506512 4626657	-	-	-	-	-	-	-	-	-	-	-	-
G-4-1-1 :-: 102	0507754 4(25025	200 1205	Middle Mattern (Late Oliver)	70	1.88	-	2.85	-	424	175	55	0.51	0.48
Satskneniši 102	0307734 4623923	309-1205	Middle Maikop (Late Oligocene)	/ð	0.50, 2.58	-	2.05, 5.43	-	417, 430	90, 260	25, 85	0.43, 0.56	0.35, 0.58

Table 3: Lithological data used as input for wells modelling, subdivided for each well. Keys for abbreviations are: mds = mudstone; sds = sandstone; cng = conglomerate; lms = limestone; tff = tuff.

	Kumisi 1											
Event name	Tuna	End Age (Ma)	Top depth (m)	Present thickness (m)	Enoded thiskness (m)	Lithology						
Event name	туре	Ellu Age (Ma)			Eroueu tinckness (iii)	mds (%)	sds (%)	cng (%)	lms (%)	tff (%)		
Quaternary	Formation	0.1	0	10	-	-	-	100	-	-		
Erosion	Erosion	1	-	-	-1.300	-	-	-	-	-		
Deposition (Maikop)	Deposit	15	-	-	1.300	100	-	-	-	-		
Maikop	Formation	20	10	560	-	70	30	-	-	-		
Lata Farana	Formation	34	570	500	-	45	45	-	10	-		
Late Eocene	Formation	36	1.070	233	-	100	-	-	-	-		
Middle Eocene	Formation	38	1.303	217	-	-	-	-	-	100		
Early Eocene	Formation	48	1.520	1.150	-	50	50	-	-	-		
Paleocene	Formation	56	2.670	210	-	70	-	-	30	-		
	Formation	66	2.880	390	-	-	-	-	100	-		
Late Cretaceous	Formation	90	3.270	339	-	-	-	-	-	100		

Event name	Tuno	End Age (Me)	Top depth (m)	Present thickness (m)	Enoded thiskness (m)	Lithology					
Event name	гуре	Enu Age (Ma)			Eroueu tinekness (iii)	mds (%)	sds (%)	cng (%)	lms (%)	tff (%)	
Erosion	Erosion	1	-	-	-1.000	-	-	-	-	-	
Deposition (Maikop)	Deposit	15	-	-	1.000	100	-	-	-	-	
	Formation	20	0	100	-	100	-	-	-	-	
Mailan	Formation	24	100	190	-	60	40	-	-	-	
макор	Formation	26	290	250	-	40	60	-	-	-	
	Formation	28	540	180	-	90	10	-	-	-	
Lata Farana	Formation	34	720	440	-	90	10	-	-	-	
Late Locene	Formation	36	1.160	390	-	80	10	-	10	-	
Middle Eocene	Formation	38	1.550	260	-	-	-	-	-	100	

				Patardzeuli-E1							
Event neme	Type	End Ago (Ma)	Top depth (m)	Propost thickness (m)	Freded thickness (m)	Lithology					
Event name	туре	Ellu Age (Ma)		Trescut thickness (iii)	Eroueu thickness (iii)	mds (%)	sds (%)	cng (%)	lms (%)	tff (%)	
Quaternary	Formation	0.1	0	40	-	-	-	100	-	-	
Akchagylian	Formation	2.5	40	270	-	-	-	100	-	-	
Erosion	Erosion	3.5	-	-	-1.000	-	-	-	-	-	
Deposition (Maikop)	Deposit	15	-	-	1.000	100	-	-	-	-	
	Formation	20	310	195	-	100	-	-	-	-	
Maikop	Formation	23	505	445	-	80	20	-	-	-	
	Formation	28	950	415	-	90	10	-	-	-	
	Formation	34	1.365	225	-	100	-	-	-	-	
Late Eocene	Formation	35	1.590	260	-	60	-	-	40	-	
	Formation	36	1.850	410	-	80	20	-	-	-	
Middle Eocene	Formation	38	2.260	690	-	-	-	-	-	100	
Forly Focore	Formation	48	2.950	960	-	70	-	-	30	-	
Early Eocene	Formation	52	3.910	840	-	20	-	-	80	-	
Paleocene	Formation	56	4.750	270	-	-	-	-	100	-	

Event name	Туре	End Age (Ma)	Top depth (m)	Present thickness (m)	Eroded thickness (m)	Lithology					
						mds (%)	sds (%)	cng (%)	lms (%)	tff (%)	
Erosion	Erosion	0.1	-	-	-1.800	50	50	-	-	-	
Deposition (Late Miocene)	Deposit	6	-	-	1.800	50	50	-	-	-	
Sarmatian	Formation	8	0	85	-	50	50	-	-	-	
	Formation	9	85	415	-	80	20	-	-	-	
Konkian	Formation	12	500	60	-	100	-	-	-	-	
Karaganian	Formation	13	560	30	-	100	-	-	-	-	
Chokrakian	Formation	14.5	590	95	-	100	-	-	-	-	
Upper Maikop (Early Miocene)	Formation	16	685	55	-	100	-	-	-	-	
Middle Maikop (Late Oligocene)	Formation	23	740	130	-	100	-	-	-	-	
	Formation	25	870	132	-	90	10	-	-	-	
Lower Maikop (Early Oligocene)	Formation	28	1.002	250	-	100	-	-	-	-	
	Formation	31	1.252	83	-	90	10	-	-	-	

Event name	Туре	End Age (Ma)	Top depth (m)	Present thickness (m)	Eroded thickness (m)	Lithology				
						mds (%)	sds (%)	cng (%)	lms (%)	tff (%)
Erosion	Erosion	0.1	-	-	-1.800	50	50	-	-	-
Deposition (Middle-Late Miocene)	Deposit	6	-	-	1.300	50	50	-	-	-
Deposition (Middle-Late Miocene)	Deposit	8	-	-	500	50	50	-	-	-
Upper Maikop (Early Miocene)	Formation	16	0	240	-	100	-	-	-	-
	Formation	23	240	30	-	100	-	-	-	-
	Formation	23.5	270	135	-	90	10	-	-	-
	Formation	24	405	60	-	60	40	-	-	-
Middle Maikop (Late Oligocene)	Formation	24.5	465	390	-	80	20	-	-	-
	Formation	25.5	855	45	-	60	40	-	-	-
	Formation	26	900	140	-	50	50	-	-	-
	Formation	27	1040	170	-	90	10	-	-	-