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1 ***Structural styles of the Tellian fold-and-thrust belt of Tunisia based on***  
2 ***structural transects: Insights on subsurface pre-salt play system and future***  
3 ***prospectivity***

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16 **Abstract**

17 We present several structural transects throughout the internal part of the Tunisian Tell focusing  
18 on some representative structures and domains. We used also an interpreted seismic cross-  
19 section and a 3-D structural view to highlight the styles within the Tellian Units in the Fernana-  
20 Adissa allochthon domain. The structural style is mainly represented by active roof-thrust and  
21 duplex structures affecting the Mesozoic-Cenozoic sequences belonging respectively to the  
22 Infra-Kasseb and Kasseb Units. The main decollement thrusting layer is located in the Triassic  
23 evaporites while the roof thrust corresponds to the Upper-Cretaceous or to the Paleocene shaly  
24 levels. The structural transects allow to view that the Numidian Flysch unit presents different  
25 structural configurations and relationships with its subsurface supporting units; (1) it rests on  
26 an apparent stratigraphic contact above the underlying Kasseb nappe or even over pre-existing  
27 Triassic salt structures while elsewhere (2) it is detached above these infra-Numidian units  
28 reworking an originally downlap contact. The area is also characterized by important  
29 halokinetic movements controlling the overall architecture of the Tell fold and thrust belt that

30 allows the thrusting of the whole Tellian wedge. In addition, originally apical parts of former  
31 diapiric structures were remobilized subsequently as sole thrust allowing the displacement of  
32 the Numidian Flysch. The upper-Miocene syn-folding sequences sourced by the erosion of the  
33 precedent uplifted reliefs are folded and tectonically transported along some active thrusts by  
34 the Tell tectonic units suggesting a recent reactivation and rejuvenation of thrusts during the  
35 Upper Miocene to Quaternary Alpine events. Since the Late Miocene, shortening is still active  
36 today, allowing the refolding of older nappes contacts as well as the rejuvenation of inherited  
37 faults and thrust folds.

38 **Key-words**

39 Maghrebides – Tell – Thrust – Duplexes – Numidian – Kasseb – Triassic evaporites

40 **Declarations**

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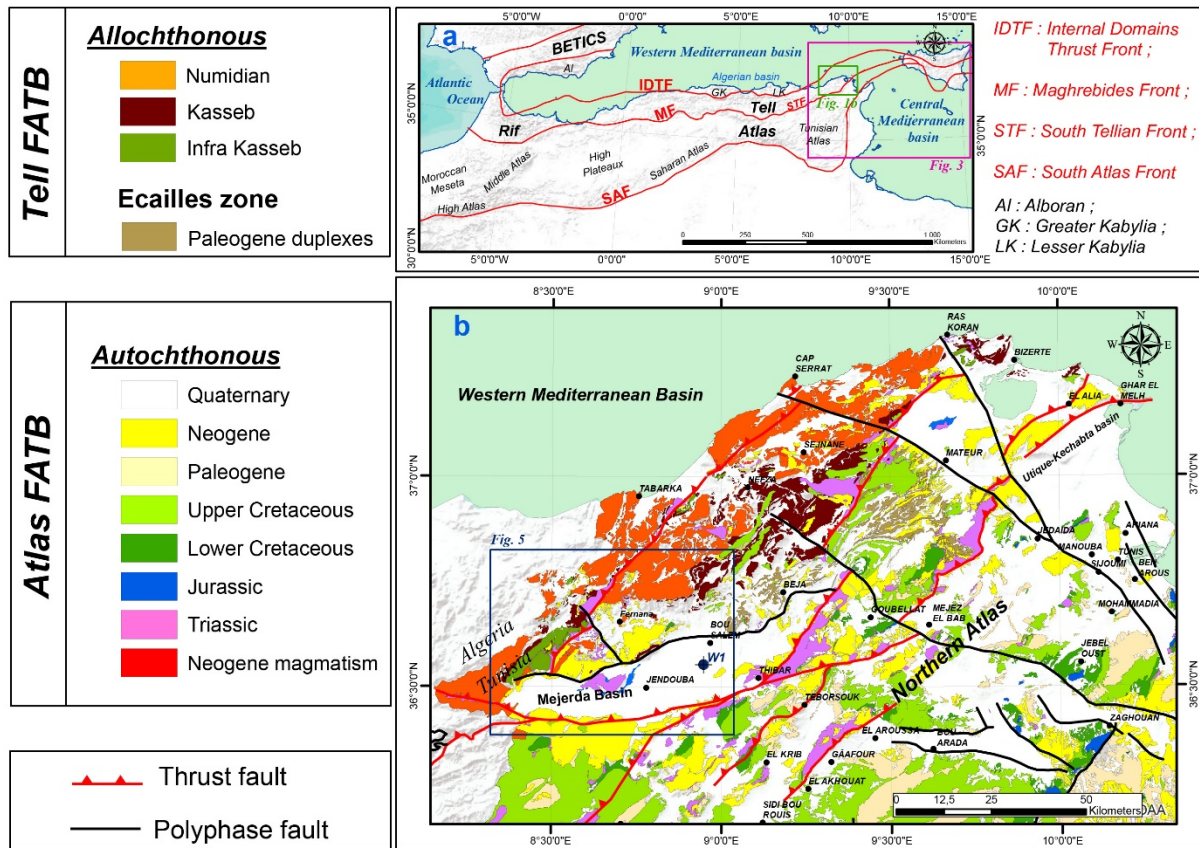
46 **Availability of data and material:** Not applicable

47 **Code availability:** Not applicable

48 ***1. Introduction and problematics***

49 The Tellian fold-and-thrust belt (Fig. 1) is a collisional belt resulting from the lower Miocene  
50 docking of the Kabylia block against the African north-western plate margin (Durand–Delga  
51 and Fontboté, 1980; Wildi, 1983; Bouillin, 1986; among others). Its internal part is essentially  
52 constituted by thick turbiditic series of Oligocene-lower Miocene age (Carr and Miller, 1979;  
53 Rouvier, 1985; Khomsi et al., 2009b and 2021). The relation between the Numidian series,  
54 widely outcropping (Fig. 1) and broadly studied (Rouvier, 1985; Yaich et al., 2000; Talbi et al.,  
55 2008; Riahi et al., 2010, 2015, 2021; Thomas et al., 2010; Guerrera et al., 2012; Belayouni et

56 al., 2013; among others), and its meso-cenozoic substratum led since a long-time to strong  
 57 discussions, ending in various and often opposite interpretations.



58  
 59 **Fig. 1** Structural scheme of North Africa (after Frizon de Lamotte et al. 2000) highlighting the  
 60 main structural domains: Atlas and Rif-Tell systems (a); geological map of Northern Tunisia  
 61 (b) with the location of the studied area (Fig. 5)

62 Many authors, i.e., Gottis (1953), Gottis and Fallot (1962), Kujawski (1964), Crampon (1973),  
 63 and De Jong (1975), concluded that both the Tellian Mesozoic to Eocene sedimentary units and  
 64 overlying Numidian Complex represent a conformable sequence of deposits and considered  
 65 that the Numidian is transgressive over the underlying deformed Tellian series, with a  
 66 sedimentary hiatus occurring between them during the Priabonian. By contrast, Jauzein (1967)  
 67 had proposed that only the Numidian is allochthonous. Otherwise, Carr and Miller (1979),  
 68 Rouvier (1985), El Euchti et al. (2004) and Khomsi et al. (2009b), emphasized the existence a  
 69 set of “thrust sheets” characterized by the pile of various allochthonous units where the  
 70 Numidian series are thrust over the Infra-Numidian units represented by Upper Cretaceous

71 as well as Eocene pelagic limestones of the Kasseb Units. It was shown that the Numidian  
72 nappe was defined as an “out of sequence thrust” (Morley 1988). Since then, several authors  
73 did not admit the existence of nappes in the Tell (Tlig et al. 1991; Alouani et al. 1996; Jaafari  
74 1997; Melki 1997; Melki et al. 1999; Talbi et al. 2008). Although the structural styles of the  
75 Tellian fold-and-thrust belt is still widely debated, many interpretations from previous work  
76 and literature remain controversial. More recently Khomsi et al. (2021) emphasized the  
77 structural relationships between the Numidian Flysch and the underneath structures of Kasseb,  
78 showing strong evidences of an onlapping and stratigraphic contact of the Oligo-Miocene  
79 Numidian flysch over the Kasseb Units in a piggy-back configuration.

80 In this paper, we aim to present the configuration of the structural units in the inner part of the  
81 Tellian fold-and-thrust belt along the Tunisia-Algeria borders, deciphering their structural  
82 relations and allowing to propose a revised deformational model. The timing and tectonic  
83 evolution of this part of the Maghrebides belt are also discussed below. In addition, the Mejerda  
84 Basin and the overall structural evolution of the Northern Tunisian Atlas will be also presented,  
85 discussed, and integrated in the regional tectonic evolution. This study is based onto the  
86 interpretation and integration of all the available surface and subsurface geological and  
87 geophysical data by the use of regional structural surface-subsurface transects.

88 The structural transects in the Tell FABT presented in this work and others (El Euch et al.,  
89 2004; Aissaoui et al., 2016; Kiely and Tari, 2017; Khomsi et al., 2019 and 2021) emphasize the  
90 interest to undertake oil/gas exploration in the Maghrebides. In fact, two major petroleum  
91 systems are potentially productive in the Tell: the Pre-salt Paleozoic system and the Meso-  
92 Cenozoic system (Khomsi et al., 2019 and 2021). In a precedent paper, Khomsi et al. (2021)  
93 discussed the interest of the Cenozoic-Mesozoic petroleum system underneath the Tellian  
94 allochthon units, emphasizing its importance and high potentialities (see Khomsi et al., 2021).  
95 Thus, in this paper we will focus only on the Paleozoic system and the pre-salt traps.

## 96 **2. Tectonostratigraphy and geology of the Tunisian Tell**

97 The Tunisian Tell (Fig. 1) occupies the eastern part of the Tell-Rif orogenic system (Caire,  
98 1971; Gélard, 1979; Rouvier, 1985; Khomsi et al., 2009b and 2016) and results from the  
99 progressive closure of the Maghrebian Tethys during the Miocene (Frizon de Lamotte et al.,  
100 2009; Khomsi et al., 2016). The compressional deformational pulses reached their climax in  
101 the late Miocene period, resulting in the development of a south-verging accretionary prism in  
102 front of the AlKaPeCa (for Alboran, Kabylies, Peloritan and Calabria; Bouillin, 1986) domain  
103 until its collision/docking against northern Africa (Catalano et al., 1996; Doglioni et al., 1999;  
104 Vergès and Sàbat, 1999; Jolivet and Faccenna, 2000; Benaouali-mebarek et al., 2006; Roure et  
105 al., 2012; Van Hinsbergen et al., 2014; Khomsi et al., 2016; .., 2019). Vergès Mebarek

106 The Tell of northern Tunisia (Fig. 1) is characterized by several structural units detached and  
107 transported toward the southeast. Previous works refer to a geographically variable  
108 nomenclature, leading to confusions (see Khomsi et al., 2021), with the definition of more than  
109 7 structural units in northern Tunisia, based only on typology, lateral facies variations,  
110 paleoenvironment records and biostratigraphic contents. However, and in line with Khomsi et  
111 al., (2021) we emphasize that the Tell series of Tunisia can be better subdivided into three major  
112 tectono-stratigraphic packages (Khomsi et al., 2019 and 2021), which account for the overall  
113 stratigraphic and structural evolution of the Tell domain of Tunisia and its tectonic history: (i)  
114 the allochthonous units represented by the Kasseb Units and their lateral equivalents supporting  
115 the Numidian Flysch deposits. The Kasseb Units rest tectonically on the Langhian Miocene  
116 deposits pertaining to the foreland domain of the Tell, (ii) the foreland structures of the Tell  
117 represented by the Meso-Cenozoic deposits ending with the major angular/erosional  
118 unconformity at the base of the Langhian deposits set up during the post-Eocene compressions.  
119 (iii), the foredeep synkinematic layers of the late Miocene-Quaternary deposits issued from the

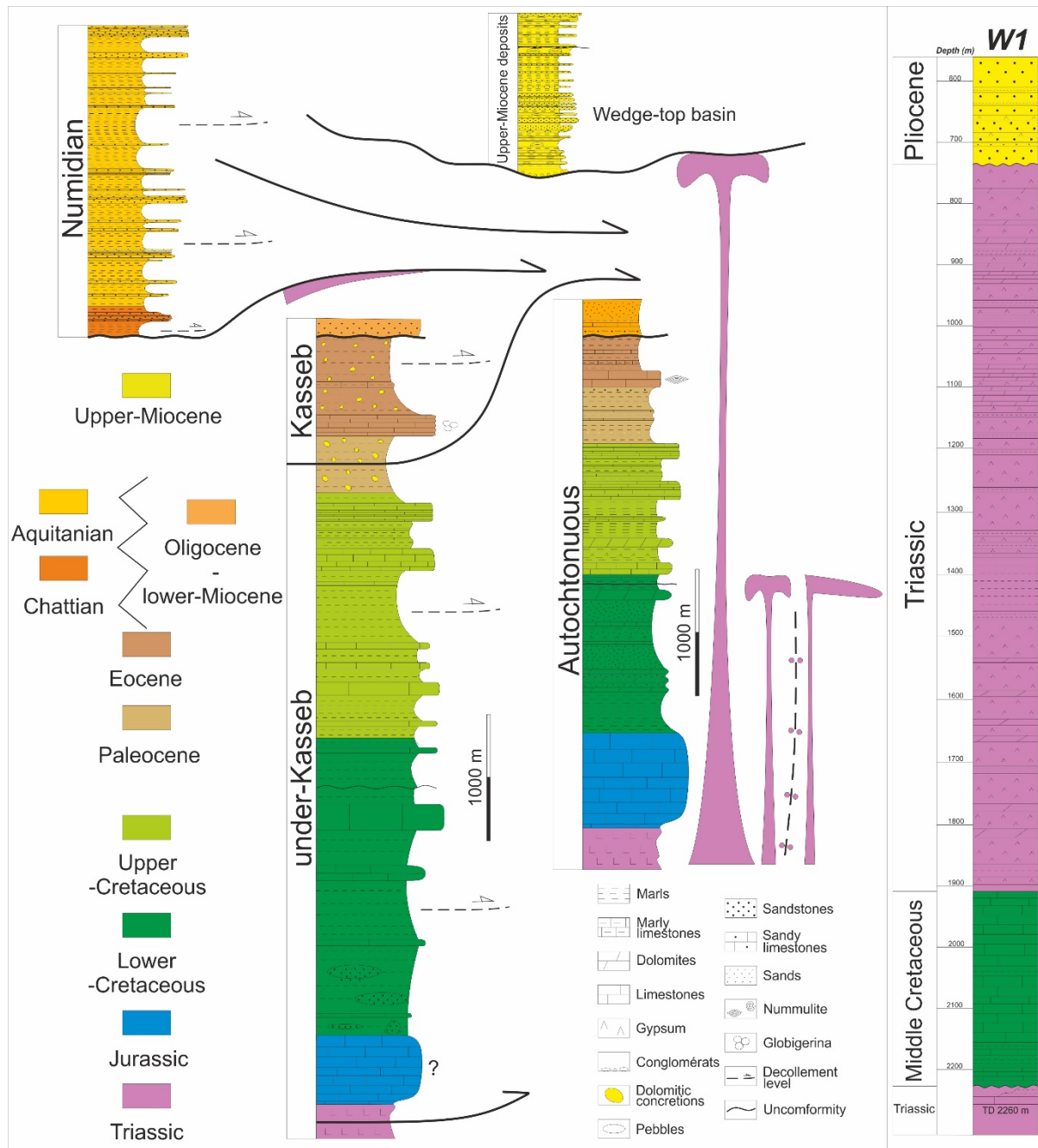
120 recent erosion of the rejuvenated structures with in many transported mini-basins of more than  
121 1000 m of continental deposits.

122 The following part deals with the description of the lateral facies changes observed between the  
123 various structural units, resulting in our subdivision which are therefore based on field  
124 observations, geological mapping, and key cross-sections. They are described from external to  
125 internal part of the Alpine chain of northern Tunisia.

#### 126 2.1. Décollement levels

127 We have used field data supported by seismic and wells data, to localize and identify individual  
128 detachment levels (Fig. 2). Obviously, salt is constituting mechanically weak detachment  
129 horizon. Therefore, Upper Triassic series, which are made up thick salt layers of hundred  
130 meters, acted as the main décollement level at the sole and within the Tellian fold-and-thrust  
131 system. Thick Cretaceous and Paleogene marls series constitute secondary potential  
132 décollement levels. Examining the lithostratigraphic column, we have identified numerous  
133 weak horizons within the Lower Cretaceous, Coniacian-Santonian, Paleocene, middle to upper-  
134 Eocene and infra-Numidian series (Fig. 2).

135

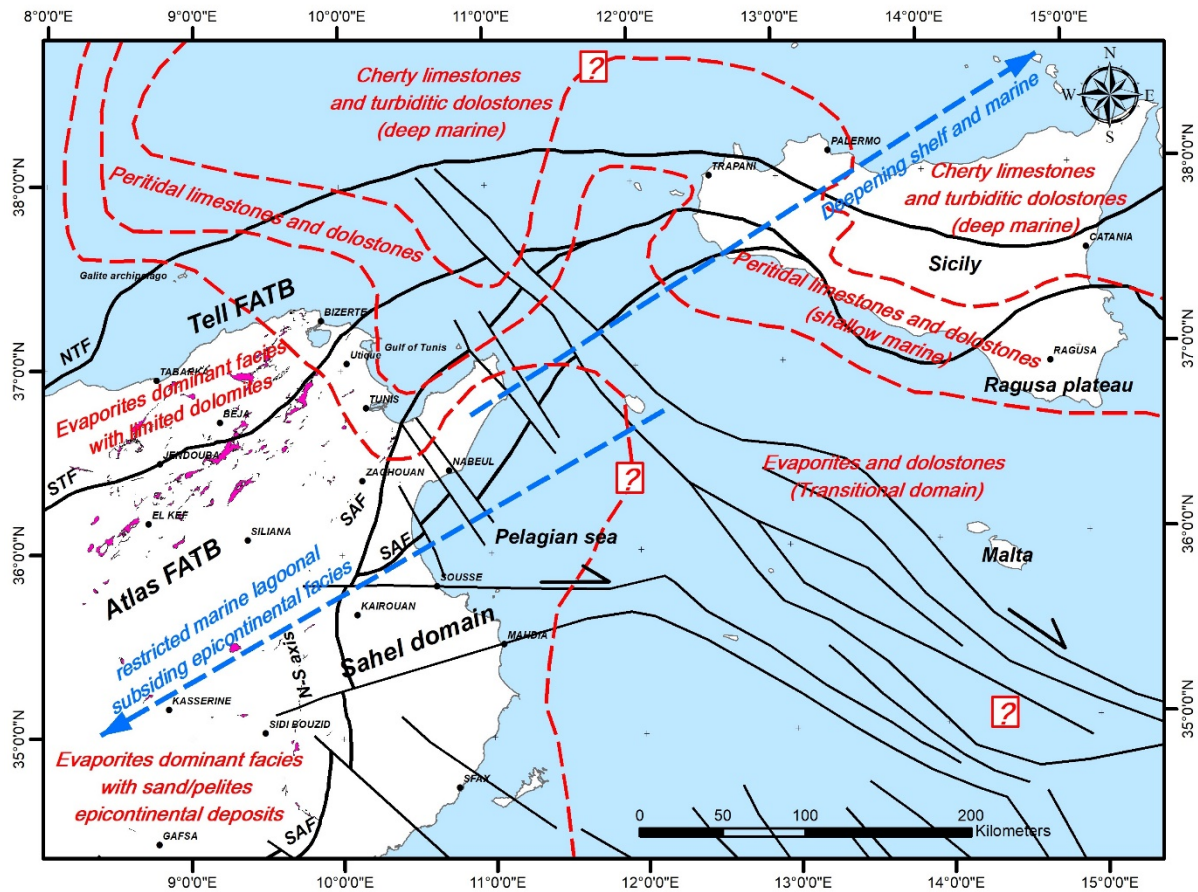


136 **Fig. 2** Lithostratigraphic columns of the different units of the Tunisian Tell and well data (W1)  
 137 from the Mejerda basin. The well characterizes a thick possibly allochthonous Triassic  
 138 evaporites body which is overlying Cretaceous series and capped directly with upper Miocene  
 139 rocks. The different discontinuities, décollements and major unit thrusts are presented. Notice  
 140 that the contact of the Numidian flysch over the Kasseb Units is a stratigraphic contact which  
 141 was later on reactivated as a tectonic contact during the Alpine compressions.



## 142 2.2. Importance of the Triassic salt

143 Both in the onshore as well as in the offshore of the Tellian domain in Tunisia, seismic  
144 interpretations (El Euch et al., 2004; Khomsi et al., 2009b and 2019) show a structural style  
145 characterized by Numidian thrust sheets detached over the Triassic salt. whereas the underlying  
146 para-autochthonous series were affected by inherited faults and tilted blocks which were  
147 subsequently inverted during Eocene and late Miocene compressional events. The Numidian  
148 thrust faults are deeply rooted within the major décollement level represented by the interface  
149 between allochthonous Triassic salt and the underlying Mesozoic-Cenozoic para-  
150 autochthonous cover. Vila (1980), and more recently, Amri et al. (2020) and Khelil et al. (2021)  
151 recognized the occurrence of salt canopies in the foreland domain of the Tell in Algeria and  
152 Tunisia, respectively, that might correspond to the long Morocco-Algeria-Tunisia diapiric  
153 province that was active since the Early Jurassic as described in Moragas et al. (2018).  
154 On the other hand, it is worth noting that the evaporitic facies of the Upper Triassic series  
155 change laterally from SW to NE into dolomites/carbonates when approaching the coastline and  
156 in the northern part of the Gulf of Tunis. In fact, in the northern part of the Tell, the Triassic  
157 series become more dolomitic with a decrease in the evaporite proportion leading possibly to  
158 pure dolomitic series in the Gulf of Tunis (Fig. 3).



159

160 *Fig. 3 Present distribution of the Late Triassic facies in Tunisia, Sicily channel, and Sicily*  
 161 *(Casero and Roure 1994; Catalano et al. 1996; Di Stefano and Gullo 1997; Kamoun et al.*  
 162 *2001; Soto et al. 2017; in Khelil et al. 2021).*

163 Otherwise, and despite the fact that few petroleum wells have been drilled in the Tell, either in  
 164 the onshore or the offshore, the Triassic series encountered in the wells of the Gulf of Tunis are  
 165 rather thick with dolomitic facies in their upper part (Melki et al. 2010). By contrast, the  
 166 Mejerda well shows a predominance of the evaporitic component (Troudi et al. 2017) (Fig. 2).  
 167 These changes are important in terms of structural control of the deformations and the  
 168 occurrence of alternative detachment layers, which do not involve here the Triassic-Jurassic  
 169 interface as in the onshore, but rather involve shallower detachment layers situated within  
 170 Upper Cretaceous and Paleogene in the offshore.

171 The southeastern edge of the Tell corresponds to a complicated foredeep (Khomsni et al., 2019;  
 172 Khelil et al., 2019 and 2021) tectonic domain in front of the Tell, in the footwall of the South

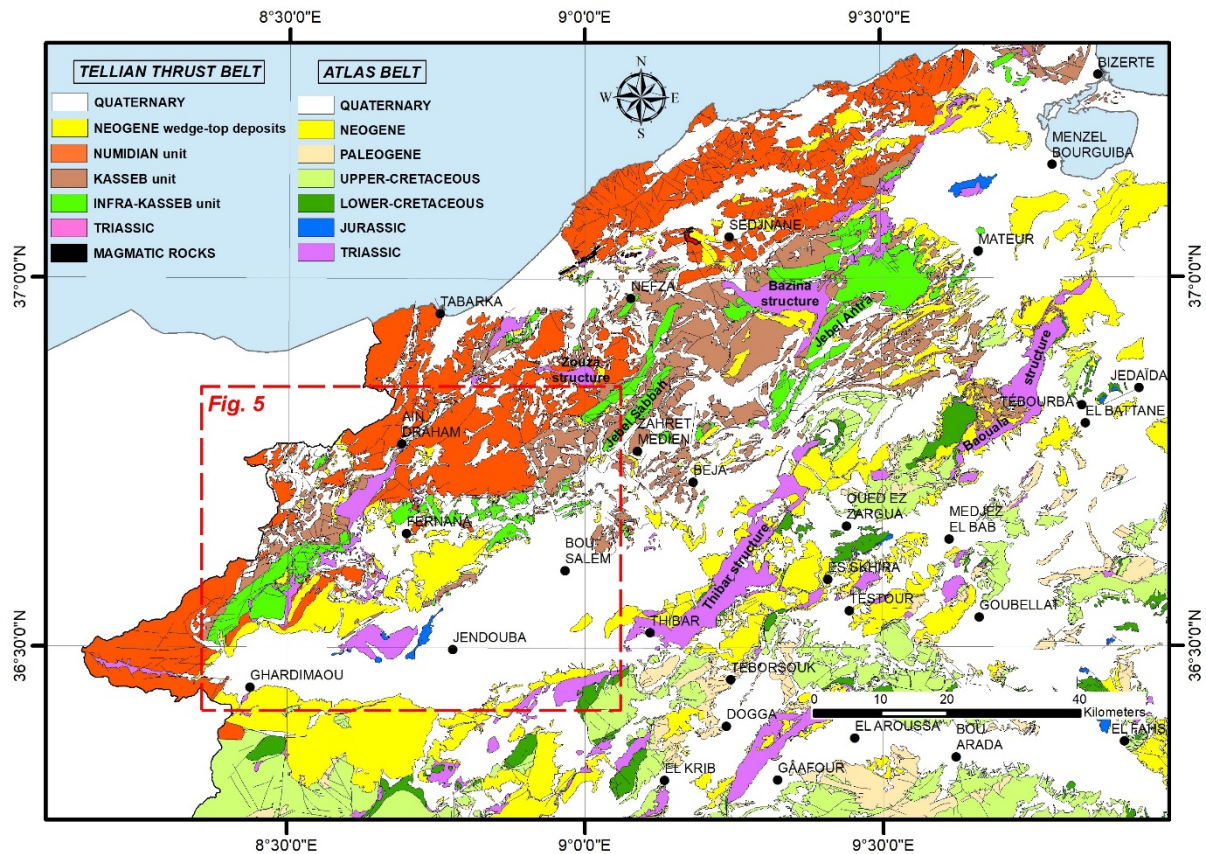
173 Tellian thrust front. This area comprises Triassic salt plugs associated with thrusting that  
174 occurred during strong late Miocene-Quaternary Alpine compressions (Khomsı et al. 2019;  
175 Khelil et al. 2021). The South Tellian Front is also located in this important deformation zone,  
176 along which the Tell domain overthrusts the Neogene foredeep deposits. In fact, this foredeep  
177 basin, parallel to the Tellian fold-and-thrust belt, presents locally a more than 1300 m-thick  
178 Miocene sedimentary sequences, mainly constituted by continental molasse and evaporitic-  
179 lacustrine late Miocene deposits. It constitutes the uppermost part of the sedimentary infill of  
180 the Mejerda Valley, reworking some allochthonous Tellian tectonic units and lying directly on  
181 top of the underlying Triassic halokinetic series (Khomsı et al. 2009b, 2016). The Mejerda well  
182 (Fig. 2), drilled in the central part of the basin, shows a highly complicated setting with late  
183 Miocene-Pliocene continental deposits overlying unconformably the Triassic evaporites. The  
184 latter are locally thrust on top of the tectonic pile, but elsewhere the Triassic salt remains  
185 buried beneath the Upper Cretaceous-Cenomanian strata (Fig. 2).

## 186 2.3. The tectono-stratigraphic units

### 187 2.3.1- The Infra-Kasseb unit

188

189 The Infra-Kasseb tectonic unit (Figs 2 and 4) comprises the entire Mesozoic succession with an  
190 average thickness of 2500 m. Its lower part is made up of Triassic salt and breccia which pass  
191 to Jurassic carbonates upwards. The Early Cretaceous is characterized essentially by thick clay  
192 strata, sandstone at the bottom and carbonate turbidites at the top of the sequence. The upper  
193 part of the Cretaceous succession is made up of interbedded shales and carbonates recording  
194 deep-water paleo-depositional environments (Khomsı et al., 2021). The top of this tectonic unit  
195 exhibits shales of Paleocene age, which also form the lower part of the Kasseb unit ensuring  
196 also the decoupling of the Kasseb Units from the underlying Cretaceous structures.



197  
 198 *Fig. 4 Northern Tunisia Tectono-lithostratigraphic units mapping (based and compiled from*  
 199 *the existing 1/50.000 geologic maps, published by ONM). Notice that the Numidian flysch*  
 200 *occupies the NW corner of the map and is dipping towards the NW with an onlapping lateral*  
 201 *configuration above the Meso-Cenozoic structures.*

202 2.3.2- The Kasseb unit  
 203

204 The Kasseb unit (Fig. 2 and 4) is cropping out mainly at the front of the Numidian structures.  
 205 It comprises Paleocene marls and predominantly lower Eocene limestones (*Globigerina* facies),  
 206 upper Eocene marls and Oligocene glauconitic sandstones. Worth noting that these Oligocene  
 207 sandstones rest unconformably on top of the Paleogene succession and form a lateral equivalent  
 208 of the Numidian succession with a shallower water paleo-depositional environment. The  
 209 Kasseb unit of few hundred meters is thrust mostly on top of Miocene strata.

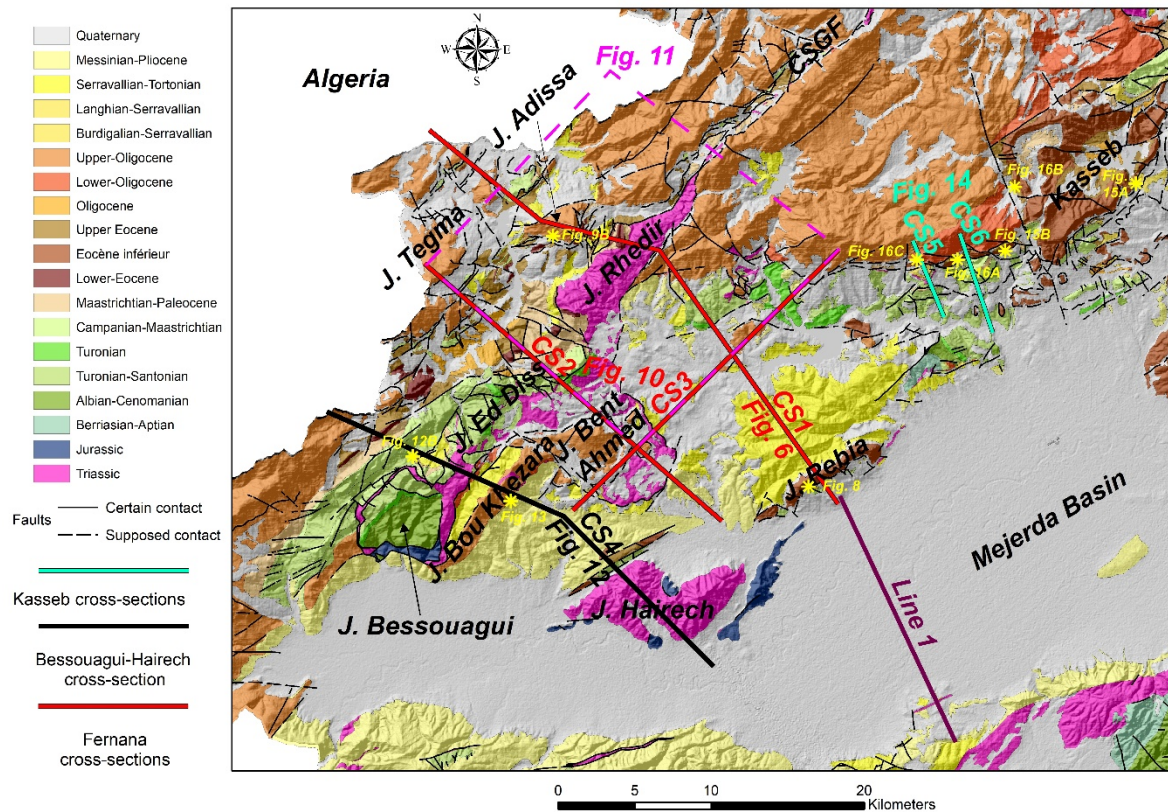
210 2.3.3- The Numidian unit

211 The Numidian (Fig. 2 and 4) is an important structural unit of the Tellian fold-and-thrust belt.  
212 It consists of an alternation of mudstones and quartzarenites with rhythmic character, up to 2500  
213 m thick. The authors agree on the deep-water paleo-depositional environment of the Numidian  
214 domain and the turbiditic character of the sedimentation (e.g., Riahi et al., 2010, 2015 and  
215 2021). In northern Tunisia, it is a clay-sandstone formation that crops out over wide areas. It is  
216 considered as the shallowest structural unit, resting at the top of the tectonic pile over underlying  
217 Infra-Numidian units, Triassic breccia, and younger upper Miocene deposits.

218 It is worth noting that the Numidian unit crops out along more than 2000 km, from Spain to  
219 Italy, across the northernmost parts of Morocco, Algeria, and Tunisia.

### 220 ***3. Structural styles derived from regional transects and seismic interpretations***

221 Several tectonic phases have impacted the geological history of the Tell, leading to a complex  
222 structural configuration. The presented structural cross-sections and transects (Fig. 5) will be  
223 discussed to document the structural styles observed within the Tell and Northern Atlas, as well  
224 as the geological processes responsible for their set up, and finally the tectonic agenda. These  
225 interpretative structural transects were compiled as including set of data field observations  
226 collected through several field-work campaigns in the Tell of Tunisia. The Jebel Rebia,  
227 Fernana, the jebels Adissa and Bessouagui, and ultimately the Kasseb region, constitute key-  
228 outcrops structures for documenting the overall structural style in the Tell. The foreland of the  
229 latter (Mejerda Basin-Northern Atlas; Figs 2 and 5) is mostly constrained by seismic  
230 interpretations in addition to field observations.



231  
 232 **Fig. 5** Geological map of the studied area indicating the emplacement of the different  
 233 observations, cross-sections and seismic cross-section (Line 1).

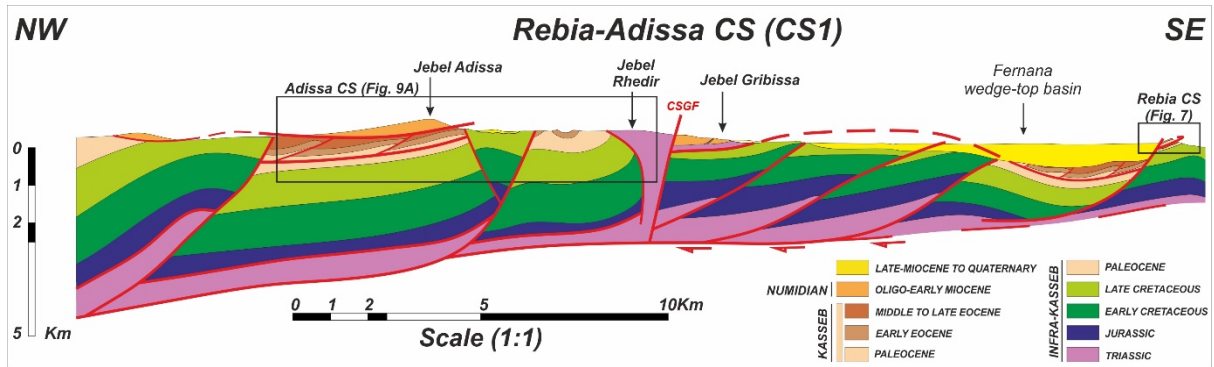
234 3.1. Tell fold-and-thrust belt

235 3.1.1- Fernana cross-sections

236 The Fernana area is documented here by a set of cross-sections cutting the structures in two  
 237 orthogonal directions (two NW-SE cross-sections as well as one NE-SW cross-section;  
 238 positions given in Fig. 5).

239 3.1.1.1- Fernana cross-section (CS1)

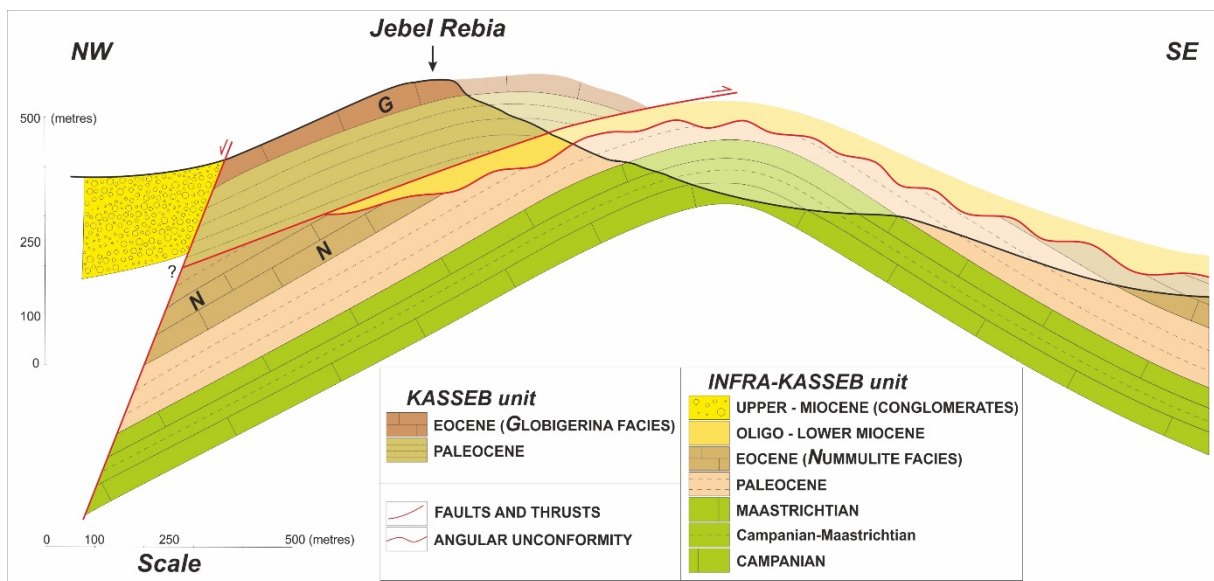
240 Along the first cross-section, two key outcrops have been investigated in details in order to  
 241 better understand the tectonic position of the Kasseb unit (in Jebel Rebia; Fig. 5 and 6) and of  
 242 the Numidian unit (in Jebel Adissa; Fig. 5 and 6).



243

244 *Fig. 6 NW-SE cross section (CS1) through Jebels Rebia, Rhedir and Adissa, showing the main*  
 245 *structures and structural styles; the location is given in Fig. 5. Notice on CS1 transect the late*  
 246 *Miocene-Quaternary synkinematic thrusting/folding deposits.*

247 The Jebel Rebia corresponds to an thrust anticline structure (Fig. 7) trending N035, limited to  
 248 the south by the Mejerda Valley (Fig. 5), which is considered as a wedge-top basin (Khelil et  
 249 al. 2019, 2020, 2021). Locally to the south, blue Jurassic dolomites crop out, forming a part of  
 250 the Hairech inherited paleo-high (see Martinez and Truillet, 1987).



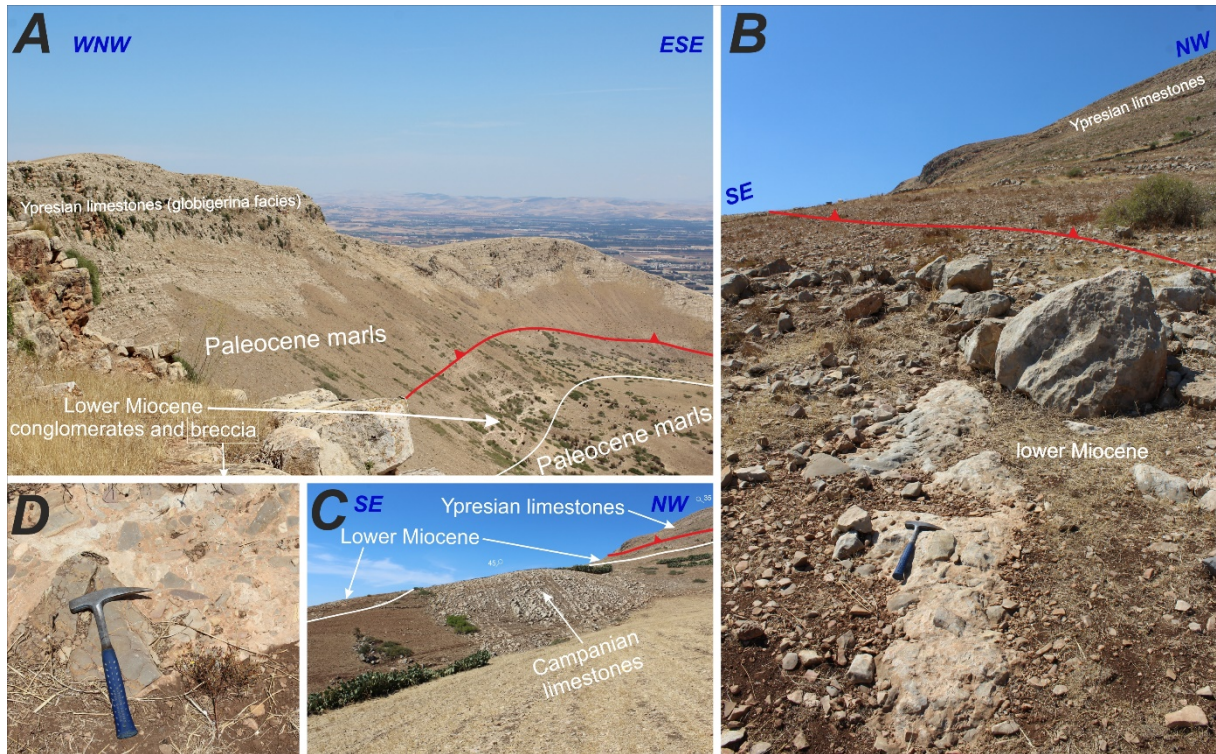
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252 *Fig. 7 NW-SE Jebel Rebia cross section showing mainly the tectonic superposition of the*  
 253 *Ypresian limestones (Globigerina facies) over the folded Meso-Cenozoic autochthon*  
 254 *(Numulitic facies); the location is given in Fig. 6.*

255 The Rebia anticline northern limb (Figs 7 and 8A) shows poorly glauconitic sandstones and  
 256 shales representing the Tellian facies attributed to the Oligocene. The series continue with

257 tabular lower Miocene conglomerates and breccia (Fig. 8D), which are mostly Ypresian in age.  
258 In the Jebel Rebia, the Kasseb unit overlies tectonically the Oligo-Miocene series (Fig. 7 and  
259 Fig. 8A, B and C) and the underlying Campanian carbonates which form the northern limb of  
260 the para-autochthonous anticline (Figs 7 and 8C). This structural unit is affected by a normal  
261 fault delimiting to the north the Fernana wedge-top basin (Figs 6 and 7), which is filled by late  
262 Miocene deposits derived from the erosion of different units. The Infra-Kasseb and Kasseb  
263 structural units, covered by the Fernana wedge-top basin, show different structural styles (Fig.  
264 6). The first one is characterized by a duplex geometry with a set of sub-parallel ramps (Fig. 6).  
265 The sole-thrust corresponds to the Upper Triassic salt representing the main regional  
266 décollement. The ramps are merged upward into the upper roof thrust, which is located in the  
267 Paleocene marls. The stacked imbricated horses form an antiformal stack (Fig. 6). Then, the  
268 Kasseb unit, derived from the unroofing of the underlying duplexes, has been detached from its  
269 initial substratum and moved forelandward to the south, defining thereby an active roof duplex.  
270 The forward propagation of the roof-thrust induced the formation of ramps (Fig. 6). The roof-  
271 thrust is emerging at Jebel Rebia (Figs 6 and 7) while individual ramps were covered later by  
272 post-orogenic molasse deposits, after the set-up of the Fernana wedge-top basin.





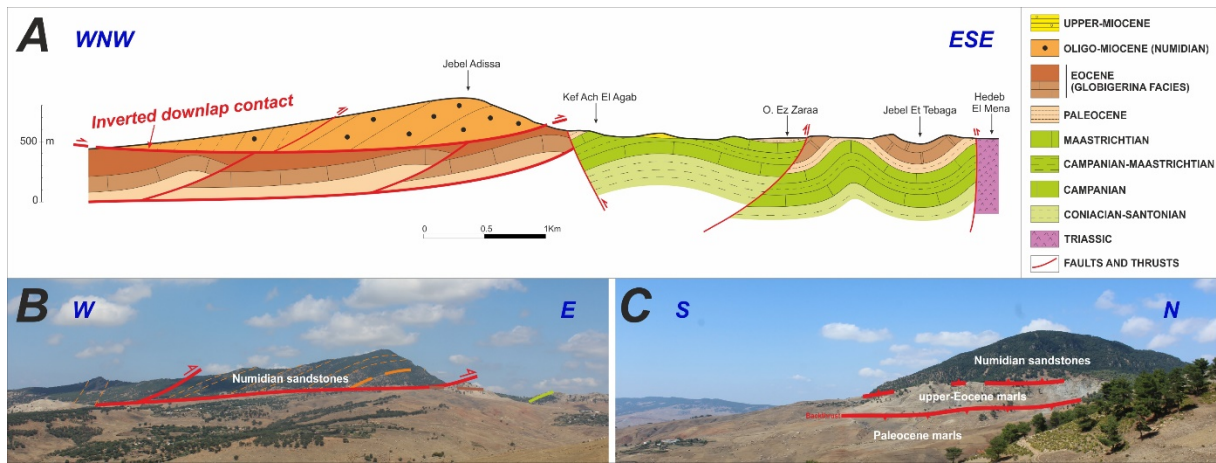
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274 **Fig. 8** Interpreted field photos from Jebel Rebia outlining (A+B) the thrusting of Kasseb unit  
 275 over the lower-Miocene series and, (C) over the folded Campanian limestones and (D) tectonic  
 276 breccia from the lower-Miocene deposits; the location of the photos is shown in Fig. 5.

277 Because they are located beneath the thick and widely distributed Numidian Flysch unit, Infra-  
 278 Numidian units are poorly exposed at the surface in northern Tunisia, except in the Nefza and  
 279 Jebel Ben Amara tectonic windows (Khomsi et al., 2021). Casually, these sparsely exposed  
 280 series crop out around the Jebel Adissa which forms a Numidian Klippe. Therefore, we  
 281 considered the Jebel Adissa as an important sector to study the relations and styles of these  
 282 various structural units.

283 The Numidian sandstones of Jebel Adissa are truncated at a north-vergent contact and overlie  
 284 tectonically the Kasseb unit. The basal thrust of the Numidian allochthon is well exposed and  
 285 cuts down-section in the transport direction (Figs 6 and 9). According to Morley (1988) an out-  
 286 of-sequence thrusting model could explain such thrust geometry, which is mostly characterized  
 287 by simple relationships, younger rocks over older ones, in contrast to a low-angle normal fault  
 288 model proposed in former publications (De Jong, 1975; Rouvier, 1985). Nevertheless, we agree

289 that this fault is not a thrust but instead corresponds to the frontal part of a low-angle listric fault  
 290 (spoon-shaped) which resulted from slope instabilities and then to topographic readjustments.  
 291 Originally, the contact is a sedimentary contact marked by downlaps/lateral onlapping (Fig. 9).  
 292 The upper Paleogene unit shows a duplex configuration with the Paleocene marls form the basal  
 293 décollement (Figs 6 and 9A). Most of the outcropping series are dipping towards the north,  
 294 forming duplicated slices. However, we have noticed at Jebel El Tebaga the occurrence of  
 295 numerous folds (Fig. 9A). This is related to the impediment of thrust propagation caused by the  
 296 Cap Serrat-Ghardimaou master fault. This is confirmed by the development of back-thrusting  
 297 at Kef Ach El Agab (Figs 6 and 9A).

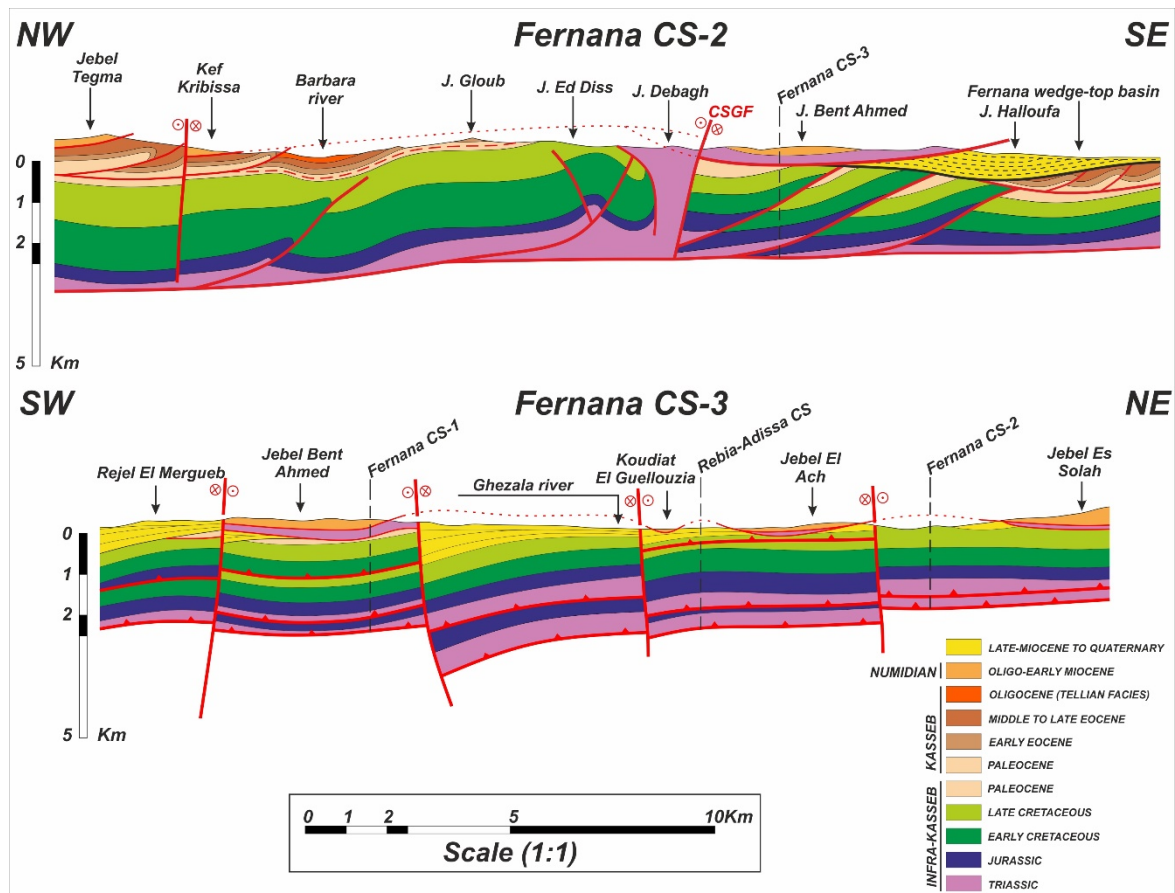


298  
 299 **Fig. 9** (A) WNW-ESE Jebel Adissa cross section (CS1) showing the structures below and  
 300 around Jebel Adissa Numidian Klippe, (B+C) respectively looking N and W interpreted photos  
 301 of the outcrop; the location of A is given in Fig. 6 and of B in A. Notice that the basal contact  
 302 separating the Numidian from the underlying units corresponds chiefly to a downlap erosional  
 303 surface which was reactivated later on during the Alpine late Miocene-Quaternary thrusting  
 304 events.

305 3.1.1.2- Fernana cross-section (CS2)

306 The second cross-section (CS2; position given in Fig. 5) goes from Jebel Tegma in the NW to  
 307 Jebel Halloufa in the SE (Figs. 10). From NW to SE, it shows the Jebel Tegma and Kef Kribissa  
 308 duplex structures, with repeated sections of the Kasseb unit supporting the detached Numidian  
 309 Unit above (Fig. 10). The major detachment level is situated within the Paleocene. The

310 Jebel-Tegma anticline and the Jebel Kribissa NW-dipping monocline are separated by a vertical  
 311 NW-trending transcurrent fault cutting through the entire subsurface structures and presumably  
 312 related to inherited deep faulting rejuvenated during the Late Miocene-Quaternary  
 313 compressions..



314  
 315 **Fig. 10** Structural transects CS2 to CS3 in the Fernana area. Notice the importance of vertical  
 316 Triassic salt movements. The structural styles presented on the dip section CS 2 is  
 317 predominantly thin skinned with an episode of thick skinned tectonic materialized by NW-SE  
 318 transcurrent strike slip subvertical faults occurring during late Miocene-Recent.

319 In the middle part of the transect, the Triassic evaporite of the Jebel Debagh crops out (Figs.  
 320 10). It corresponds to a salt-cored structure, probably an ancient Cretaceous diapiric structure.  
 321 This diapiric structure is limited by two faults: the western fault on the western limb and eastern  
 322 fault on the eastern limb. This diapir seems to be controlled by a major and well-know tectonic  
 323 lineament of the Tunisian Tell , i.e., the Cap Serrat Ghardimaou Fault (CSGF; Fig. 5). On its

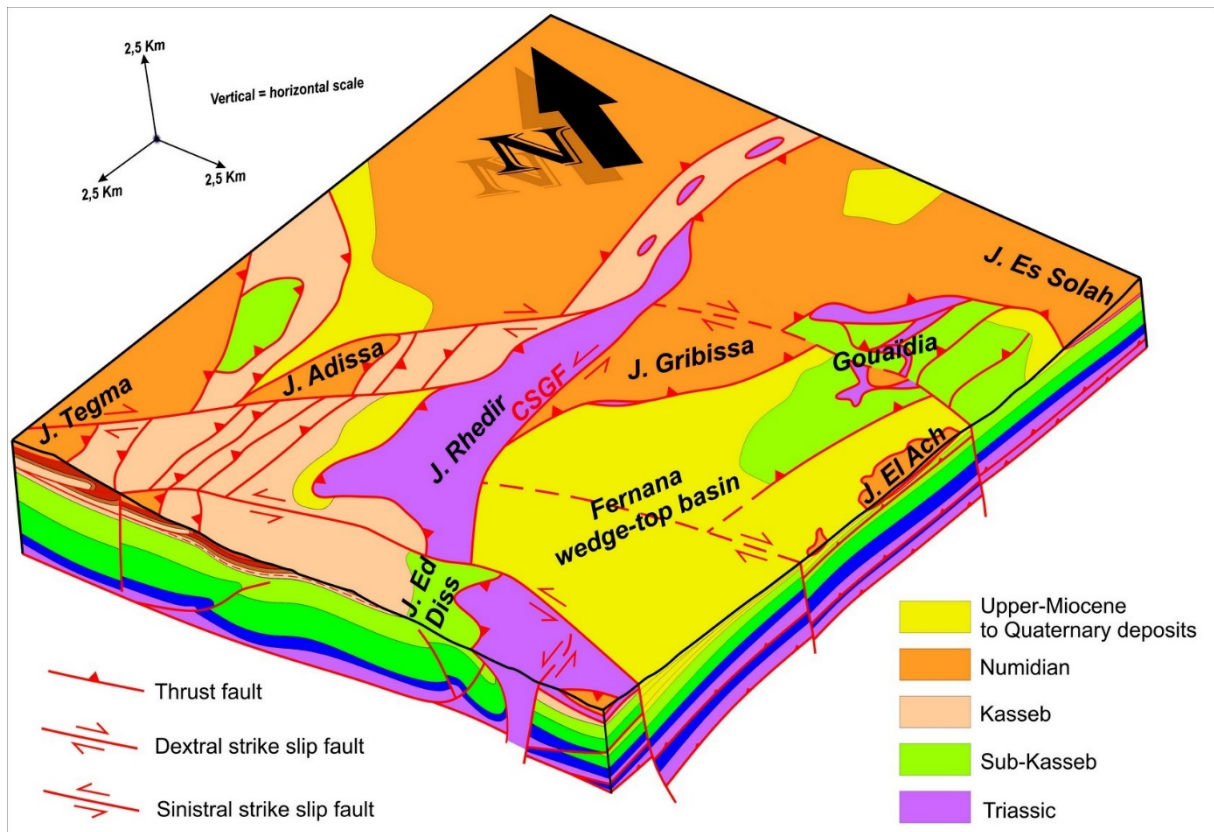
324 western edge, the diapir of Jebel Debagh overhangs the eastern limb of the Jebel Ed Diss  
325 anticline, thus corresponding to a major pop-up structure controlled by two opposite dipping  
326 thrust faults. The Triassic salt overhangs eroded Late Cretaceous strata (Fig. 10). To the east of  
327 the CSGF and Jebel Debagh, the transect crosses the Jebel Bent Ahmed structure, which  
328 corresponds to an outcropping syncline structure. There, a low-angle out-of-the-syncline thrust  
329 has unrooted and transported horizontally the Triassic salt, overhanging a deeper duplex  
330 anticlinorium (Fig. 10). The later is made by duplications of Jurassic-Cretaceous strata,  
331 admitting the Triassic salt as the lower décollement level and the Late Cretaceous-Paleocene  
332 shales as roof décollement. To the east, the Triassic salt of the Jebel Bent Ahmed overhangs  
333 tectonically, at its most eastern edge, the late Miocene Fernana wedge-top basin, which is filled  
334 by more than 1200 m of late Miocene to Quaternary continental sands, shales and  
335 conglomerates. These wedge-top basin deposits overlap unconformably the underlying duplex  
336 structure made up by the duplicated Kasseb unit

### 337 3.1.1.3- Fernana cross-section (CS3)

338 This transect has a strike direction (CS3; position given in Fig. 5), being parallel to the dip of  
339 strata. It was compiled to show a three dimensional view of the structure and better characterize  
340 two distinct sets of faults, i.e. NE-trending thrust faults and orthogonal NW-trending  
341 transcurrent polyphased faults. In fact, we can distinguish 4 major subvertical and transcurrent  
342 faults separating 5 structural compartments, i.e., from SW to NE: Rejel El Mergeb, Jebel Bent  
343 Ahmed, Ghezala River, Jebel El Ach and Jebel Es Solah (Fig. 10).

344 These different panels are resulting from the tectonic activity of the inferred strike-slip faults  
345 which seem to control block tilting and differential infilling for the late Miocene-Quaternary  
346 wedge-top deposits. The recent reactivation of this transcurrent fault system seems post-date  
347 the emplacement of the nappes duplexes, because the nappes contacts are cross cut by the  
348 system orthogonally.

349 A 3-D view with map allows to visualize the junction of the different units spatially (Fig. 11).



350

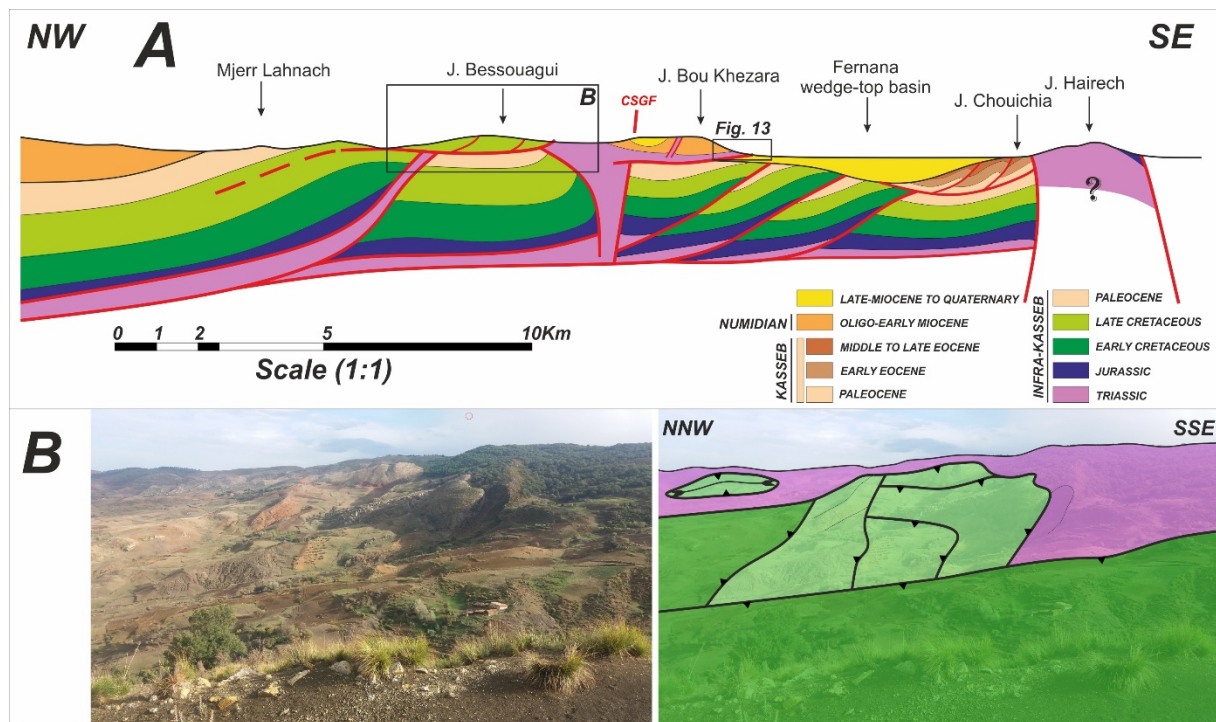
351 *Fig. 11 Structural 3-D view looking North showing the major structures and structural styles.*  
 352 *Notice that the transcurrent NW-SE fault crosscut the structures as Jebel Rhedir Diapir and*  
 353 *rooting deeper underneath the allochthon cover. Location is given on Fig. 5.*

354 In fact, this 3-D view plunging towards the N depicts clearly the local morphotectonic  
 355 configuration, with transcurrent NW-trending strike-slip faults cross-cutting all the tectonic  
 356 units and structures.

357 It is worth notice that the Triassic salt diapir south of Jebel Ed Diss is crosscut by the  
 358 southernmost strike -slip fault, with a left-lateral horizontal offset of more than 2 km (Fig. 11).

359 3.1.2- Jebels Bessouagui-Hairech cross-section (CS4)

360 North of Jebel Bessouagui (Fig. 12A), the Numidian, Kasseb and the infra-Kasseb units are  
 361 involved in the same overall structure, which is best described as an antiformal stack of  
 362 duplexes (Fig. 12A).



363

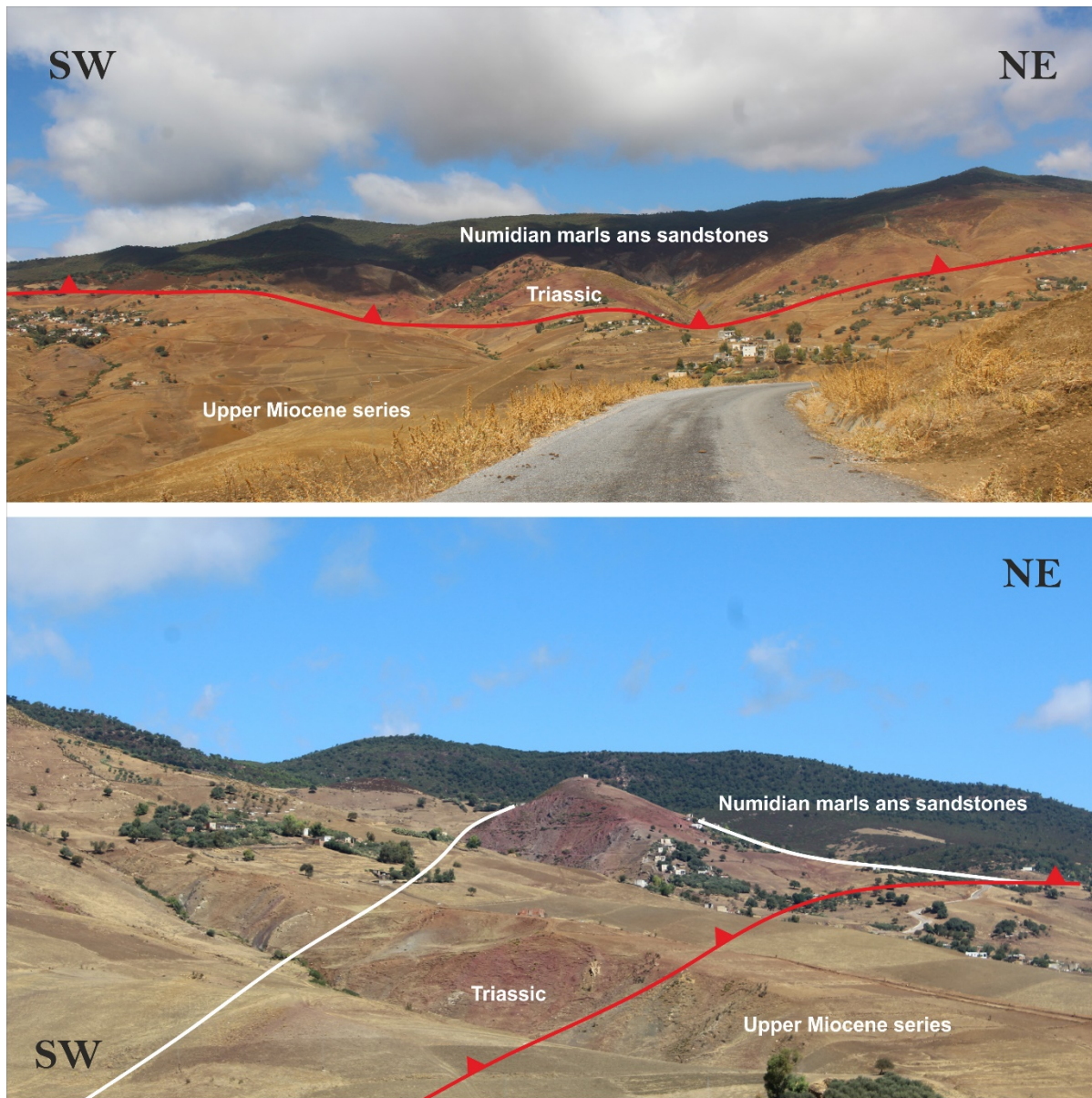
364 *Fig. 12 NW-SE cross-section through Jebels Hairech, Bou Khezara and Bessouagui (A),*  
 365 *showing the main structures and structural styles (the location is given in Fig. 5) and looking*  
 366 *E interpreted field photo (B), showing a duplex structure affecting Upper Cretaceous series at*  
 367 *Jebel Bessouagui (the location of the photo is located in A).*

368 This entire structure is thrust forelandward over the infra-Kasseb series; the sole thrust  
 369 corresponds to the Upper Triassic evaporite, which represents the main regional décollement.

370 **On the one hand,** the Kasseb unit issued from the unroofing of the underlying unit is detached  
 371 and moved forward farther to the south (Fig. 12A). The Santonian shale forms an intermediate  
 372 décollement layer with the development of duplex or horse structures made up of Campanian-  
 373 Maastrichtian limestones and upper Miocene deposits (Fig. 12A and B). Viewing towards the  
 374 north, a field photo (Fig. 12B) shows a syncline formed by the same series, lying over the  
 375 Triassic salt. This syncline is interpreted as resulting from an out-of-the-syncline thrust  
 376 detached and transported towards the south over the salt. On the other hand, south of CSGF,  
 377 the Jebel Bou Khezara is essentially formed by the Numidian Flysch. The latter overlies  
 378 tectonically the upper Miocene to Quaternary deposits which are essentially made up by shales,  
 379 gypsum and conglomerates (Figs 12A and 13). The Triassic salt and tectonic breccia constitute

380 the tectonic contact supporting the Numidian Flysch (Fig. 12A and 13). These evaporites are  
381 likely to correspond to a former salt glacier or salt canopy developed along the Cap Serrat-  
382 Ghardimaou Fault (CSGF) during the Cretaceous.

383 The Jebel Chouichia (Fig. 12) corresponds to a monocline structure trending N035, limited to  
384 the north by the Fernana wedge-top basin and to the south by the Triassic and Jurassic rocks  
385 belonging to Jebel Hairech. In the same area, the Kasseb unit series are cropping out at Jebel  
386 Chouichia. We have adopted here the same structural interpretation as for the Jebel Rebia cross-  
387 section, with the Infra-Kasseb and Kasseb structural units covered by the Fernana wedge-top  
388 basin (Fig. 12A), thus characterizing again an antiformal stack. The thrust faults join together  
389 upward into an upper roof thrust made up of Paleocene marls. In a similar way as in the previous  
390 cross-section, the Kasseb unit issued from the unroofing of the underlying duplexes is detached  
391 and moved forward towards the south, thereby accounting for an active roof-duplex.



392

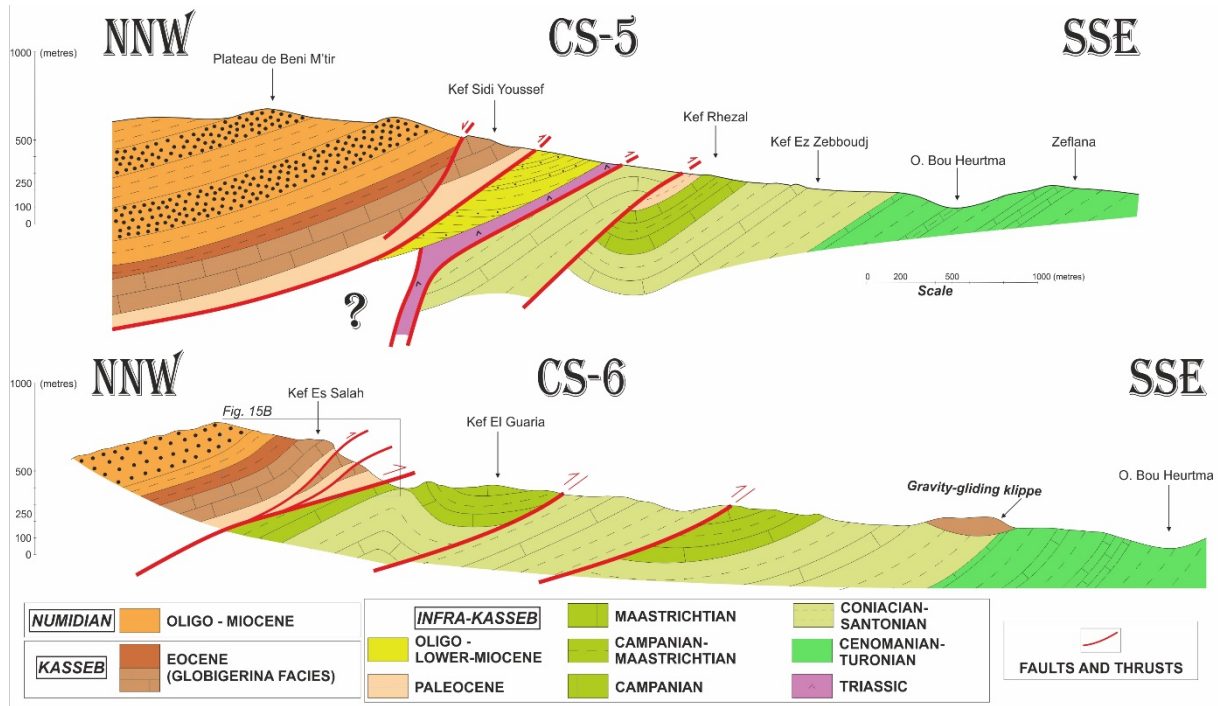
393 *Fig. 13 Interpreted looking NW field photos from Jebel Bou Khezara outlining the thrusting of*  
 394 *the Numidian unit over the upper-Miocene wedge-top deposits where the Triassic salt decorates*  
 395 *the contact.*

396 3.1.3- Kasseb cross-sections

397 The Kasseb area (Fig. 5), where the Kasseb unit was first described by Rouvier (1985), contains  
 398 important outcrops outlining the different structural relations between the Kasseb unit, the  
 399 Numidian unit and overlying Miocene series, characterized by the Bejaoua facies (cross-  
 400 sections, Fig. 14). Along their southern and eastern limits, the Ypresian limestones, made up of  
 401 pelagic and organic-rich Globigerina facies (Khomsi et al. 2018, 2021), overhang tectonically



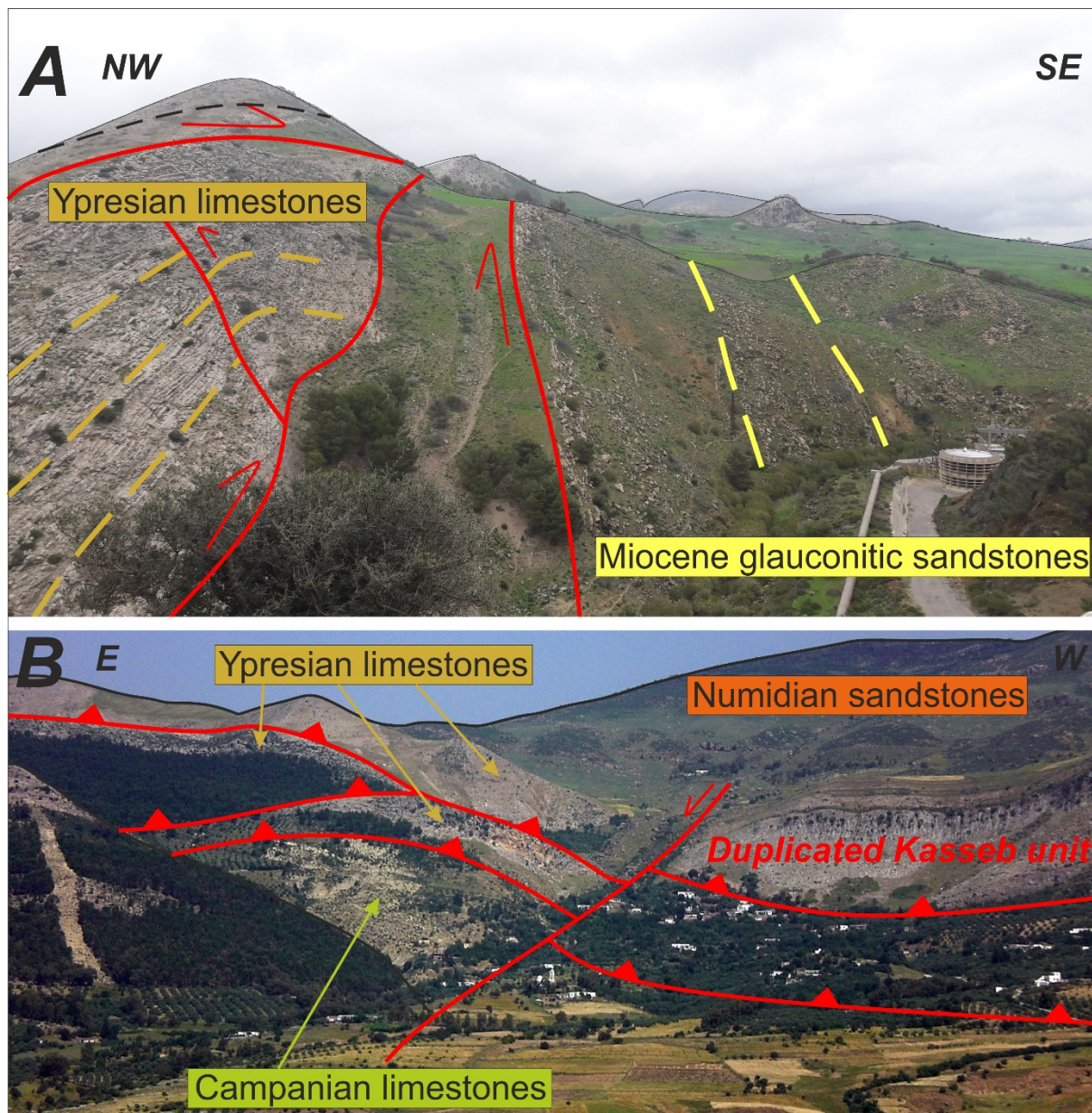
402 the Aquitanian-Langhian marine sandstones of the Bejaoua Group (Fig. 15A). These Miocene  
 403 deposits are unconformable over the Mesozoic to Paleogene series, including the Ypresian  
 404 Numulitic limestones which belong to the para-autochthonous sedimentary package equivalent  
 405 in time of the Kasseb deep marine sequence.



406

407 *Fig. 14 NNW-SSE cross-sections through Kef Sidi Youssef (CS5) and Kef Es Salah (CS6)*  
 408 *showing the structures at the front of the Kasseb unit; location given in Fig. 5.*

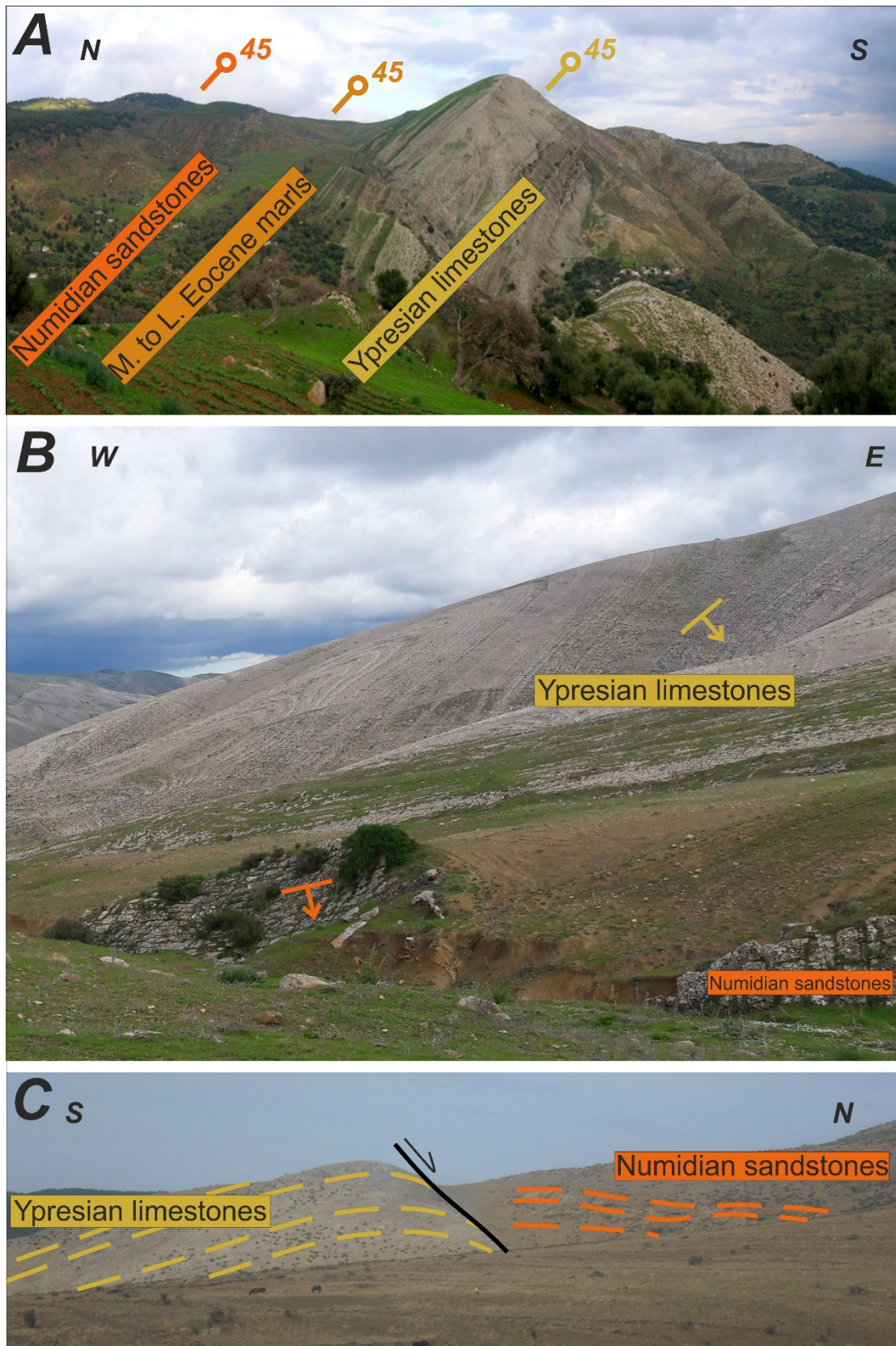
409 The para-autochthonous series were presumably folded during the middle to late Eocene (the  
 410 so-called “Atlas Event” (e.g. Frizon de Lamotte et al., 2000, 2009; Khomsi et al., 2004, 2009a;  
 411 Frizon de Lamotte, 2005) while the overthrusting of the Kasseb unit over underlying Miocene  
 412 deposits occurred during the Neogene Alpine orogeny.



413  
 414 **Fig. 15** Interpreted field photos showing the structural relations between the different unit; (A)  
 415 Looking NE photo of the Ypresian limestones thrusts lower-Miocene sandstones, (B) and  
 416 Looking to the North panorama showing duplications of the Ypresian limestones belonging to  
 417 the Kasseb unit. Notice the apparent stratigraphic continuity of the Numidian over the Kasseb  
 418 Unit.

419 In the Kasseb area, to the northeast of Jebel Bou Khezara (Figs. 12 and 13), the Numidian  
 420 Flysch unit occupies different structural positions. In fact, the Numidian sandstone bars show  
 421 an apparent continuous stratigraphic contact (Khomsni et al., 2021) with underlying deep marine  
 422 deposits of the Kasseb unit (i.e. Kef Es Salah; CS6 of Fig. 14, and Figs. 16A and B).

423 Alternatively, some contacts between the two units correspond to a synsedimentary normal fault  
424 (i.e. Kef Sidi Youssef; CS5 of Figs. 14 and 16C) which can be attributed to the Oligocene  
425 quiescence period (Khomsî et al. 2009b, 2016). Because the Numidian Flysch in this region  
426 presents locally an apparent stratigraphic continuity with the Kasseb unit, it was thus  
427 transported and thrust towards the south jointly with the Kasseb unit, this unique Kasseb-  
428 Numidian assemblage overhanging the already structured para-autochthonous Mesozoic to  
429 Paleogene series (Fig. 14).



430

431 *Fig. 16* Different relations between the Kasseb and Numidian units. (A and B) Looking  
 432 respectively E and N photos showing conformal serie formed by Ypresian limestones of Kasseb

433 *unit and the Numidian sandstones and (C) looking W photo of a normal fault separating the*  
434 *Kasseb and Numidian units. Location is given in Fig. 5*

435 **WOULD YOU LIKE TO SEND ME THE FULL INTERPRETATION OF THE FIG. 16A??**

436 At Kef Es Salah (CS6 of Fig. 14), the duplicated Eocene limestones belonging to the Kasseb  
437 unit form a duplex (Fig. 14 and 15B) with a sole thrust located in the Paleocene shales.

438 On the one hand, the Mesozoic series (namely Zaflana section, Rouvier, 1985) in front of the  
439 Kasseb unit pertains to the para-autochthonous series. It is affected by a set of thrust faults  
440 duplicating the Upper Cretaceous series which crop out around Kef Guaria and to the north of  
441 Kef Rhezal (Fig. 14).

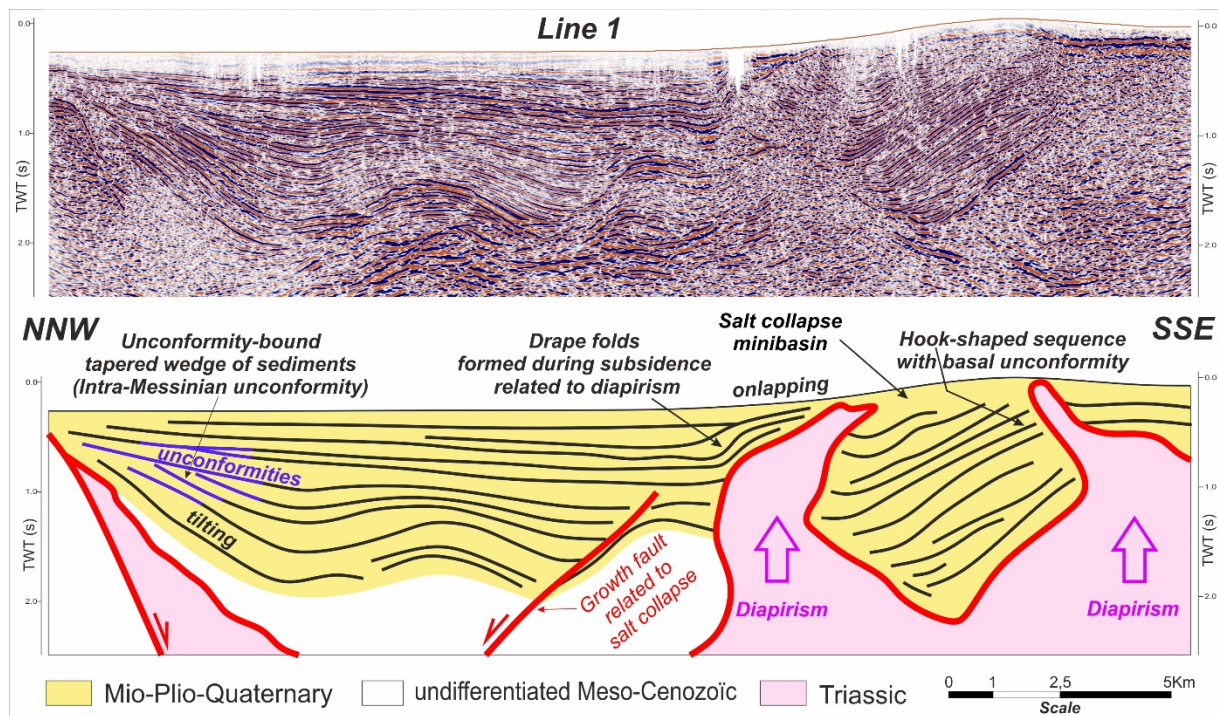
442 On the other hand, and as a whole, the structural configuration of the Kasseb area is complicated  
443 by the N160 Balta sinistral strike-slip fault which affects the whole structure and contributes to  
444 its tectonic transport towards the south. In fact, the horizontal lateral displacement of the  
445 Numidian front amounts to 6 km along this transcurrent fault (Fig. 5).

### 446 3.2. South-Tellian-Front: the Mejerda Basin

447 The upper Miocene Mejerda Basin is a major graben lying at the boundary between two distinct  
448 fold-and-thrust belts: The allochthonous Tell to the north and the inverted foreland domain of  
449 the Northern Atlas to south (Khelil et al., 2019 and 2020). It is filled by upper Miocene to  
450 Quaternary deposits. Several diapirs are documented in the Mejerda zone (El Euchel et al., 2004;  
451 Khomsi et al., 2009 b; Amiri et al., 2011; Ayed-Khaled et al., 2015). Although developed in an  
452 overall contractional context with the thrust emplacement of allochthonous nappes and  
453 mountain-building processes of the Tell, the Mejerda Basin is characterized by dominantly  
454 extensional deformation affecting Neogene-Quaternary deposits (Khelil et al., 2019 and 2020).

455 The structural interpretation of the seismic section (Line 1; Fig. 17) documents the occurrence  
456 of a major extensional tectonic event as outlined by a set of normal and faults (Fig. 17), which

457 controlled local thickness variations within the Miocene to Quaternary series. The innermost  
 458 normal fault represents the northern tectonic boundary separating the Mejerda Basin from the  
 459 Tell. This extensional fault boundary does not match with the overall regional Miocene to  
 460 Present-day tectonic framework which corresponds to a contractional episode. Therefore, the  
 461 Mejerda Basin build up is a result of special conditions (Khelil et al. 2019) related to salt  
 462 diapirism that created several deep minibasins (Fig. 17).



463  
 464 **Fig. 17** Seismic line interpretation (line 1) through the Mejerda basin outlining the extensional  
 465 faults and important salt activities; location is given in Fig. 5

466 The Jebel Hairech (Figs 5 and 12) is made up of two NE-trending anticlines structures,  
 467 separated by a syncline showing highly brecciation (Ghorabi and Henry, 1991; Martinez and  
 468 Truillet, 1987). It presents two distinct stratigraphic series; the first one is Triassic (Perthuisot  
 469 1978; Rouvier 1985) and the second one dates from Liassic times (Rouvier 1985; Alouani  
 470 1991). These rocks were affected according to (Ghorabi and Henry 1991) by burial  
 471 metamorphism, which caused crystallization of strongly oriented phyllosilicates. This  
 472 metamorphism was developed before the main Alpine folding and after a local tilting episode

473 (Ghorabi and Henry 1991). The exhumation of these metamorphic rocks is related to the local  
474 extension characterizing the Mejerda Basin in front of the Tellian wedge during the Alpine  
475 orogeny.

## 476 **4. Discussion**

### 477 4.1. Revised tectonic styles

478 The analysis of field data allowed us to distinguish several superimposed structural units,  
479 resulting from thrust tectonics with horizontal displacements of different styles and magnitudes.  
480 For instance, we have differentiated three main structural units, i.e., from bottom to top, the  
481 Infra-Kasseb, Kasseb and Numidian units, and the two first units being also known as Infra-  
482 Numidian units.

483 Through the observations made in this paper, several deformation styles (Fig. 18) are described:

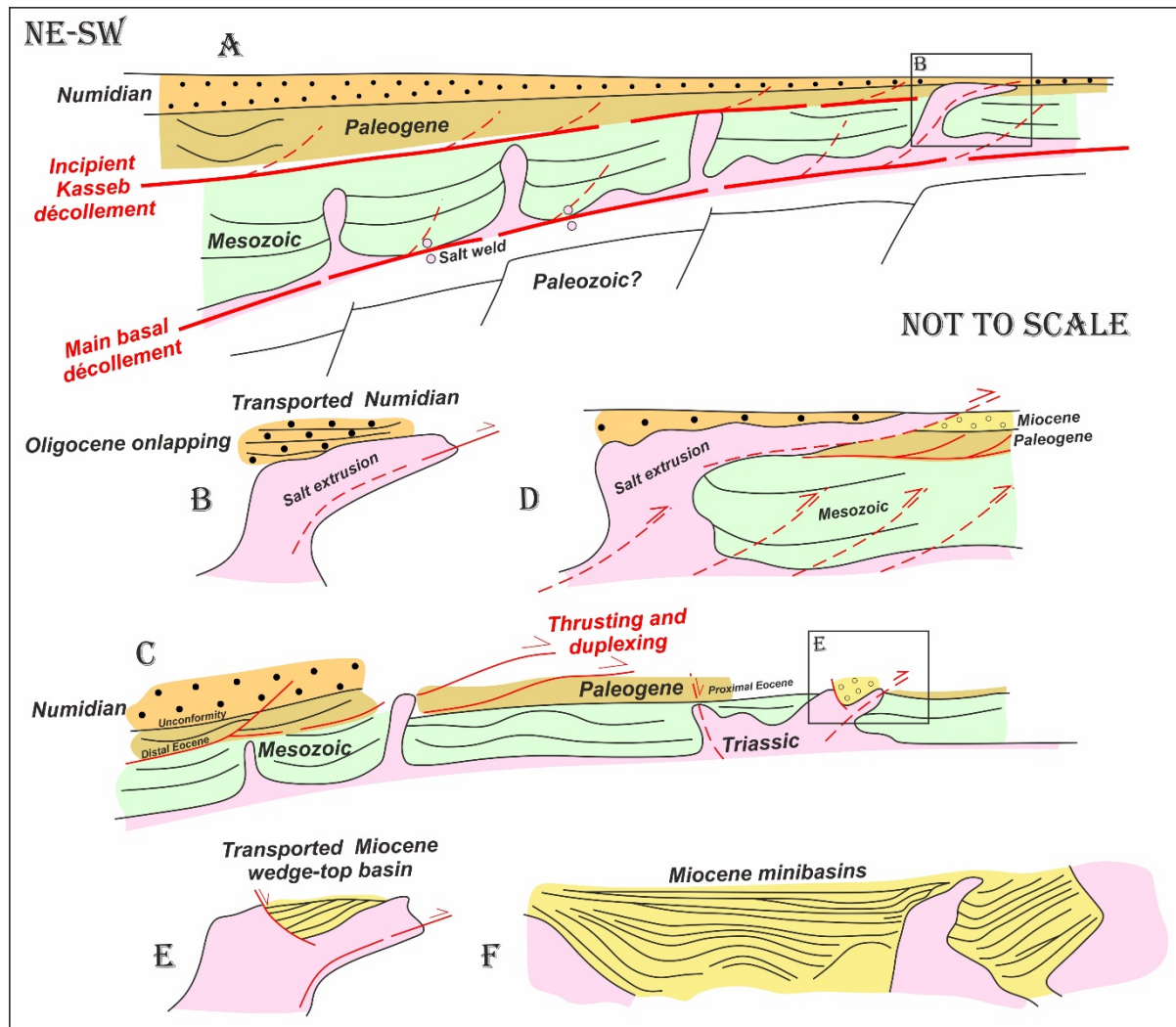
484 **(I)** Covered by the thick Neogene wedge-top basins and/or the Numidian deposits, the  
485 Infra-Kasseb unit is characterized by several thrust slices (Fig. 18A and C); the sole  
486 décollement is represented by the Triassic salt while the roof thrust is embedded  
487 mostly in Santonian or Paleocene marls (as demonstrated to the north of Jebel  
488 Bessouagui). This unit forms active antiformal stacks (Figs 6, 10 and 12).

489 **(II)** The roof thrust (Incipient Kasseb décollement, Fig. 18A) was activated to displace  
490 shallower and undeformed Paleogene units towards the south (Fig. 18C). The  
491 forward propagation of this roof thrust was hampered, inducing the propagation of  
492 thrusts affecting the Kasseb unit, thus resulting in local duplex structures Fig. 18C  
493 and D). The Kasseb unit is interpreted as made up of a succession of active roof-  
494 thrust structures (Figs 6, 10 and 12; i.e., Jebel Rebia).

495 **(III)** The Numidian unit overlies these tectonic duplex/horse units and shows different  
496 deformation styles:

497           **(III-1)** it constitutes a neo-autochthon series (Fig. 18D), transported jointly towards  
498           the south with the Kasseb unit (i.e., in the Kasseb area) or  
499           **(III-2)** The Numidian unit is also locally and slightly displaced towards the South  
500           near the morphologic top of the Tell over north-verging low-angle normal faults  
501           remobilizing mostly Triassic salt (i.e., Jebel Bou Khezara; Fig. 18C), due to  
502           topographic instability induced by the stacking of the underlying structural units.  
503           The salt was cropping out during pre-inversion times (Fig. 18B; Khelil et al., 2020).  
504           **(IV)** Localized wedge-top basins (Fig. 18E) are filled with **Mio-Plio-Quaternary** deposits  
505           and developed since the late-Miocene in a similar way as in the model proposed by  
506           Platt and Leggett (1986). These minibasins are mostly related to the wedge  
507           topographic readjustment or mostly in relation with salt collapse (Figs 18E and F).





508

509 **Fig. 18** (A) Schematic-idealized cross-section through the Tell in a pre-inversion stage (Pre-  
 510 Langhian, representing the tectonic units, salt activity and incipient décollements, (B) A zoom  
 511 from A showing the onlapping of the Numidian sandstones on the pre-existing salt structure  
 512 which is used lately as décollement, (C) Schematic-idealized cross-section highlighting the  
 513 inversion structures such as the thrusting and duplexing of the Paleogene unit (Kasseb), (D)  
 514 Schematic-idealized cross-section showing the duplexing of the Mesozoic unit (Infra-Kasseb),  
 515 active-roof thrust duplexes affecting the Kasseb unit and the overthrusting of the Numidian and  
 516 Triassic salt over the late Miocene wedge-top basin deposits, (E and F) show the important salt  
 517 activity and mini-basins set-up

518 4.2. Regional tectonic events

519 In this final part, we propose a tectonic calendar that encompasses the regional events affecting  
 520 the Tellian zone. **The timing of this tectonic evolution** is based on our observations and

521 interpretations, coupled to those of our antecessors (e.g. Carr and Miller, 1979; Rouvier, 1985;  
522 Morley, 1988; Khomsi et al., 2004, 2009b, 2009a) as well as on the tectonic scenario  
523 documented in Algeria (e.g. Frizon de Lamotte et al., 2000; Bracène and Frizon de Lamotte,  
524 2002; Benaouali-mebarek et al., 2006; Roure et al., 2012) and Morocco (e.g. Frizon de Lamotte  
525 et al., 2000; Missenard et al., 2007).

526 The former Tellian basin, along the African plate margin, registered multiple rifting and  
527 inversion episodes:

528 **(1)** The main rifting stage that highlighted the Northern African Tethyan margin started in late  
529 Jurassic and continued during the Early Cretaceous. The NE-trending master faults cropping  
530 out in northern Tunisia (i.e., Cap Serrat-Ghardimaou), are involving the infra-Mesozoic  
531 substratum, being, inherited from this rifting episode:

532 **(2)** The Mesozoic basins installed along the African margin are inverted repeatedly. The first  
533 compressional events clearly expressed in the Tell occurred during the middle to late Eocene in  
534 relation with the onset of active convergence between Africa and Europe. We highlight the  
535 existence [i.e. in Jebel Ben Amara (Khomsi et al. 2009b), Jebel Rebia, etc.] of several angular  
536 unconformities separating the Oligo-Miocene from the Pre-Oligocene series. The Tellian  
537 foreland domain records far-field effects of this tectonic event inducing sedimentary hiatuses  
538 and erosion near the forebulge and in the vicinity of active thrusts (Khomsi et al. 2016). The  
539 Infra-Kasseb unit is characterized by a stack of imbricated slices involving Mesozoic layers,  
540 result also from this compressional event.

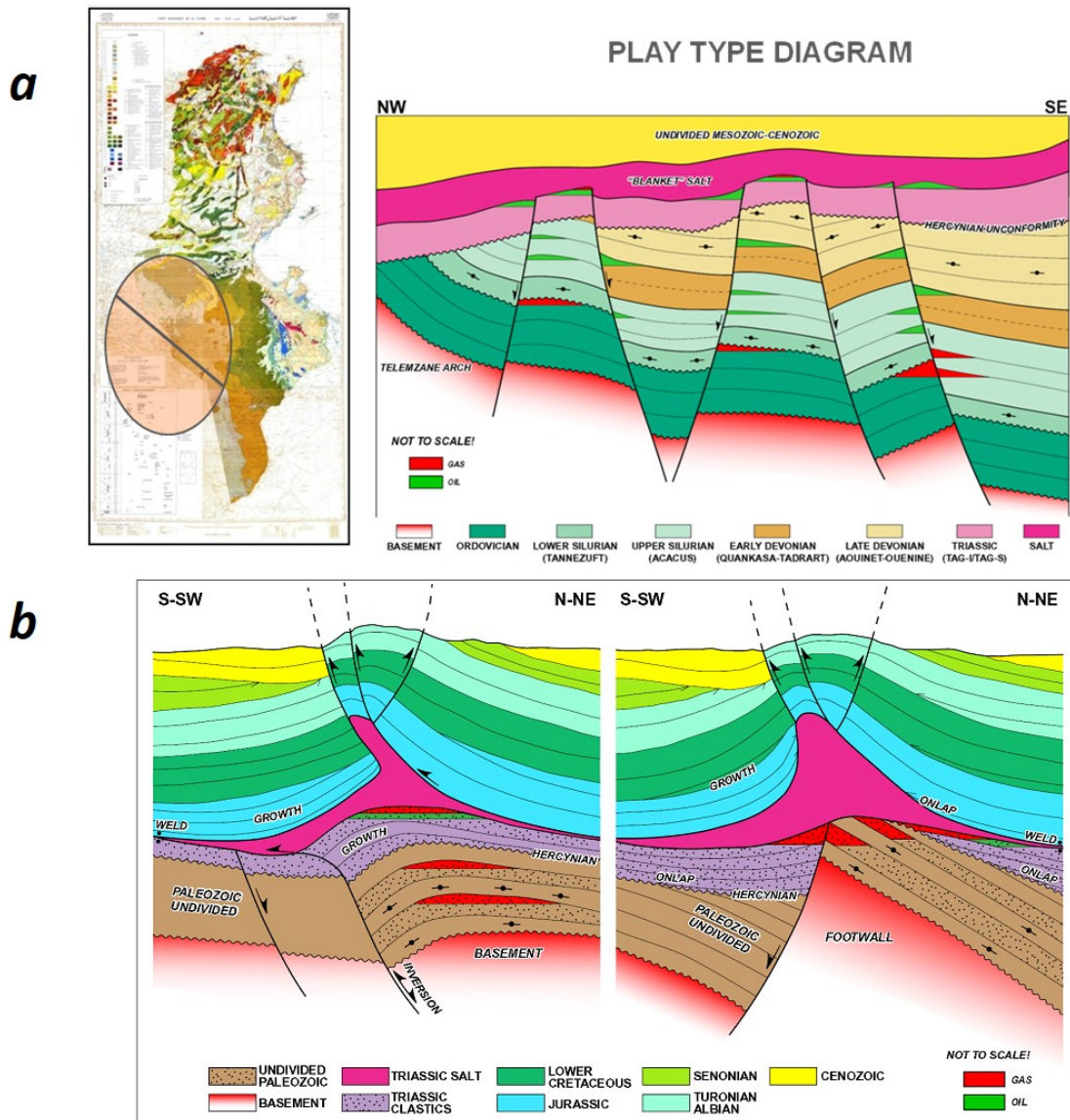
541 **(3)** The resumption of shortening was set in middle Miocene times as a response of the major  
542 stage of the Africa-Europe collision. Since then, the Kasseb unit has moved forelandward,  
543 inducing the unroofing its Mesozoic duplexes which overlap early Miocene series, as described  
544 at Jebel Rebia. This event is characterized, also by wedge-top basins development (i.e. Mejerda

545 Basin; (Khelil et al. 2019, 2020, 2021) and the reactivation of major inherited faults (i.e. Cap-  
546 Serrat-Ghardimaou Fault), which are associated to Neogene volcanism and/or Triassic  
547 movements. Shortening was still active during the Pliocene and Pleistocene, and is still active  
548 today. These late contractional events have amplified the south- to southeast-ward translation  
549 of structural units and halokinetic rise of Triassic salt bodies. Therefore, we show the structural  
550 superposition of the Numidian unit over younger series such as the upper Miocene deformed  
551 molasses as observed at Jebel Bou Khezara and Jebel Tagma.

#### 552 4.3. Oil and gas exploration potentialities: The Paleozoic system/ pre-salt traps

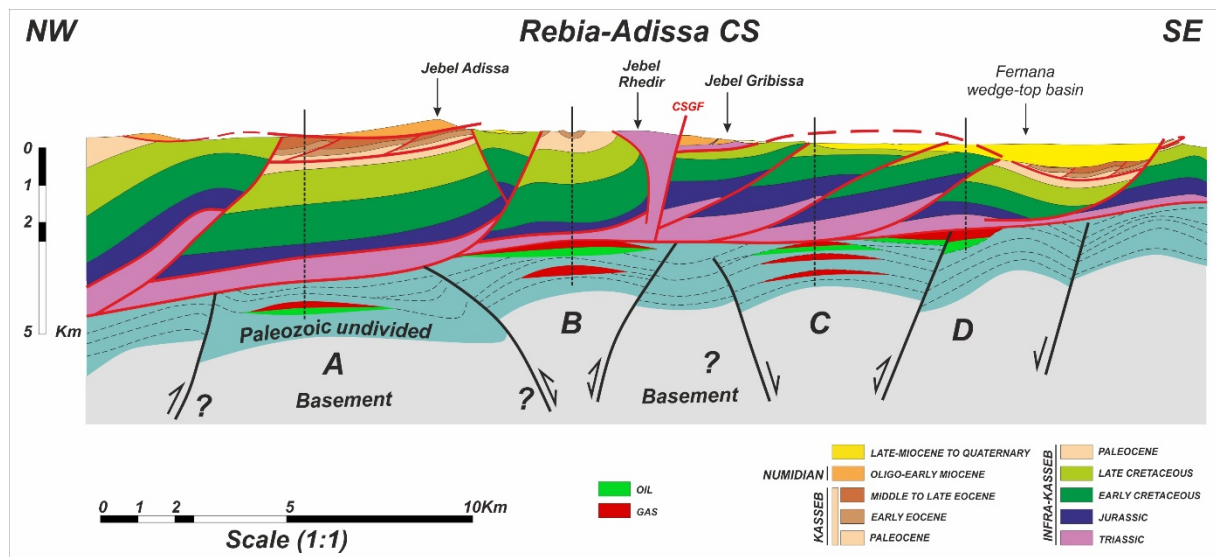
553 As emphasized earlier by Tari and Kiely (2017) for the Atlas FABT and its foreland basin and  
554 by Khomsi et al. (2019) for the Tell and Atlas belt, the Paleozoic system is obviously a very  
555 interesting system to explore and drill: in this system the main source rocks are represented by  
556 the Devonian and Silurian hot shales (see Aissaoui et al., 2016; Tari and Kiely, (2017) and  
557 Khomsi et al., (2019). The structural transects presented in this work underline that the major  
558 regional seal of the Paleozoic system is represented by the Triassic salt levels (Figs. 19 and 20).  
559 In the Fernana structures (Fig. 20), the Meso-Cenozoic sequences do not exceed 4500 m in  
560 thickness. The Triassic salt level represents a regional seal above the possible Paleozoic traps  
561 seated in the subsurface of the Tell. As emphasized by Kiely and Tari (2017) for the Atlas belt  
562 and by Khomsi et al (2019), the underlying Paleozoic inherited highs and anticlines should be  
563 sourced by the Silurian hot shales (Aissaoui et al., 2016; Khomsi et al., 2019). Unfortunately,  
564 the lack of deep seismic soundings and investigations still prevents characterizing the sub-salt  
565 traps certainly seated in the Paleozoic sequences and subsurface structures. As recently argued  
566 by Khomsi et al., (2019) and Roure et al. (2019) a deep seismic sounding project would be very  
567 important to unlock the Paleozoic system allowing to image the overall crustal architecture and  
568 potential traps in -10 S TWT (Two-way travel time). From this point of view it seems clear that  
569 the existing industrial seismic sections are limited to the shallow Mesozoic cover and of very

570 low to moderate resolution and with a widely spaced grid in the Tell belt. In Fernana structures  
 571 there is no seismic section yet available. Thus, we hope that in the next years an international  
 572 oil/gas project with deep seismic sections records will allow to visualize properly the structures  
 573 underneath the Tellian allochthon and the Triassic seal.



574  
 575 **Fig. 19** Conceptual models for the play types seated in the Paleozoic subsurface system. (a)  
 576 Trap categories in the Paleozoic productive petroleum system of the Sahara Platform. The map  
 577 on the left indicates the position of the cross-section. (From Acheche et al., 1999; and in Kiely  
 578 and Tari, 2017). Notice that the main trap types are represented by wrench faults, horts, and  
 579 deep seated anticlines underneath the Triassic salt level. (b) Two possible structural  
 580 configurations underneath the Triassic salt levels and walls (in Kiely and Tari, 2017). On the

581 left: inversion tectonics affecting the subsurface Paleozoic structures with Alpine rejuvenation  
 582 and reactivation of deep seated Paleozoic faults together with thrust tectonics affecting the  
 583 Meso-Cenozoic Tethyan structures admitting the Triassic salt as decollement level. The  
 584 Triassic salt ensures also the sealing of the potential Paleozoic traps with possible multiple  
 585 gas/oil trap in the rejuvenated anticline. Fault traps can form in such configuration. On the  
 586 right: An inherited salt wall and diapir above inherited normal faults and tilted but not yet  
 587 inverted blocks affecting the Paleozoic structures.



588  
 589 **Fig. 20** Conceptual models for the play types seated in the Paleozoic subsurface system along  
 590 the Rebia-Adissa transect empathizing the occurrence of oil and gas traps in the Paleozoic  
 591 structures. The sealing is ensured by the Triassic salt level. The presented transect allows to  
 592 predict that the Top Paleozoic is around – 3000 m beneath the surface. Structure A: large  
 593 anticlinorium structure controlled by the Alpine rejuvenation of the Paleozoic inherited faults.  
 594 B and C: pop-up anticlines affecting the Paleozoic structures with the occurrence of possible  
 595 multiple oil/gas reservoirs in the axial part of the Paleozoic structures. D: Tilted blocks along  
 596 inherited normal faults affecting the Paleozoic and possible traps related to fault trapping  
 597 mechanisms. Notice: red color: potential gas accumulation, green color: potential oil  
 598 accumulation.

## 599 5. Conclusions

600 The present structural cross-sections throughout some representative structures and domains of  
 601 the Tell of Tunisia allow us to better describe the structural style and tectonic events in the Tell  
 602 of Tunisia. The structural style of the investigated structures corresponds chiefly to thin-skinned

603 tectonic evolution materialized by tectonic duplexing. The infra-Kasseb unit is characterized  
604 by a sole décollement level localized within the Triassic evaporites, resulting in the duplexes  
605 formation. The Kasseb unit is displaced towards the SE above the roof décollement at the top  
606 of the underlying infra-Kasseb duplexes. The most dominant style of the Tell is represented by  
607 active roof-thrust and duplex structures.

608 In some areas as in Fernana, the Numidian Flysch is detached above the infra-Numidian units  
609 reworking an originally downlap contact. In some other areas, no clear detachment is visualized,  
610 and the Numidian rests in an apparent stratigraphic contact with underlying units, or is separated  
611 from the infra-Numidian units by a north-dipping normal fault, defining a neo-autochthon  
612 displaced together with the Kasseb nappe.

613 Important NW-trending faults controlled the sedimentation during the Tethyan rifting,  
614 contributed then to the morpho-structural configuration of the Tell and have been reactivated  
615 as strike slip faults during the recent upper Miocene-Quaternary events.

616 The Fernana structures underline the importance of the Triassic salt in the overall architecture  
617 of the belt and indicate high halokinetic movements in accordance with a Triassic salt-rich  
618 province. The Triassic salt has played a primordial role in the thrusting events forming the main  
619 décollement level. It is also implicated in the recent thrust rejuvenation with a good example  
620 given in Jebel bent Ahmed where the Triassic sole thrusts over overhangs the upper Miocene-  
621 Quaternary Fernana wedge-top basin. This sole thrust is interpreted as the apical part of the  
622 former diapiric structure.

623 An important Aquitanian-Langhian angular unconformity occurs in the foreland domain of the  
624 Tell throughout the northern Atlas, materialized by Neogene proximal deposits onlapping  
625 already folded and partially eroded structures. The tectonic units of the Tellian wedge thrust  
626 above these Aquitanian-Langhian series. After the emplacement of the nappes in post-Langhian

627 times, the area underwent tectonic compression and thrusting, allowing the folding of older  
628 nappes contacts as well as the rejuvenation of ancient inherited faults and thrust folds. The  
629 major tectonic event seems to be upper Miocene to Quaternary to Recent in age because the  
630 post-nappes upper Miocene continental series of the are folded and tectonically displaced along  
631 some thrusts. ~~The upper Miocene-Quaternary deposits were affected by thrusting and folding  
632 and incorporated mechanically in the footwall of some thrust.~~ The base of the post-nappes upper  
633 Miocene-Quaternary syntectonic deposits are lying with an angular and erosional unconformity  
634 above former duplex structures as in the Fernana wedge-top basin.

635 Along the Tunisian external Tell as shown for Fernana structures, inherited Paleozoic highs and  
636 anticlines, which are sealed by Triassic salt and sourced by the Silurian hot shales characterize  
637 an interesting pre-salt trap system.

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