The Barrême Basin and the Gévaudan diapir - an example of the interplay between compressional tectonics and salt diapirism

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1) Abstract, Regional setting

Our understanding of the role of salt diapirism in determining the finite geometry of fold and thrust belts has grown apace in the last few years, but the interplay between the two remains a significant problem for structural interpretation. The Gevaudan diapir in the fold and thrust belt of the sub-Alpine chains of Haute Provence is well known and has been documented by numerous eminent alpine structural geologists. Graciansky, Dardot, Mascle, Gidon and Lickorish and Ford have all described and illustrated the geometry and evolution of the structure, and Lickorish and Ford's interpretation is figured as an example of diapirism in a compressional setting by Jackson and Hudec in their text on salt tectonics. We review these various interpretations and present another.

The differences between the various interpretations say much about the complex interplay of salt diapirism and thin-skinned thrusting and have profound implications for the way we interpret the tectonic and sedimentary evolution of the Barreme basin which lies adjacent to the diapir.

The Barreme basin is a thrust-top fragment of the Provencal foreland basin and has been described in detail from both sedimentological (e.g. Evans and Elliott, 1999) and structural (e.g. Antoni and Meckel, 1998) points of view. Here we make the case that it is also a salt related minibasin - a secondary minibasin developed on a now welded allochthonous Middle Cretaceous salt canopy. We believe that within the basin it is possible to interpret successive depocentres which may record progressive salt withdrawal. We argue that though thrust loading must be the fundamental driving mechanism responsible for salt movement late in the tectonic history of the region, thrusting has not done much more than modify existing salt related geometry.

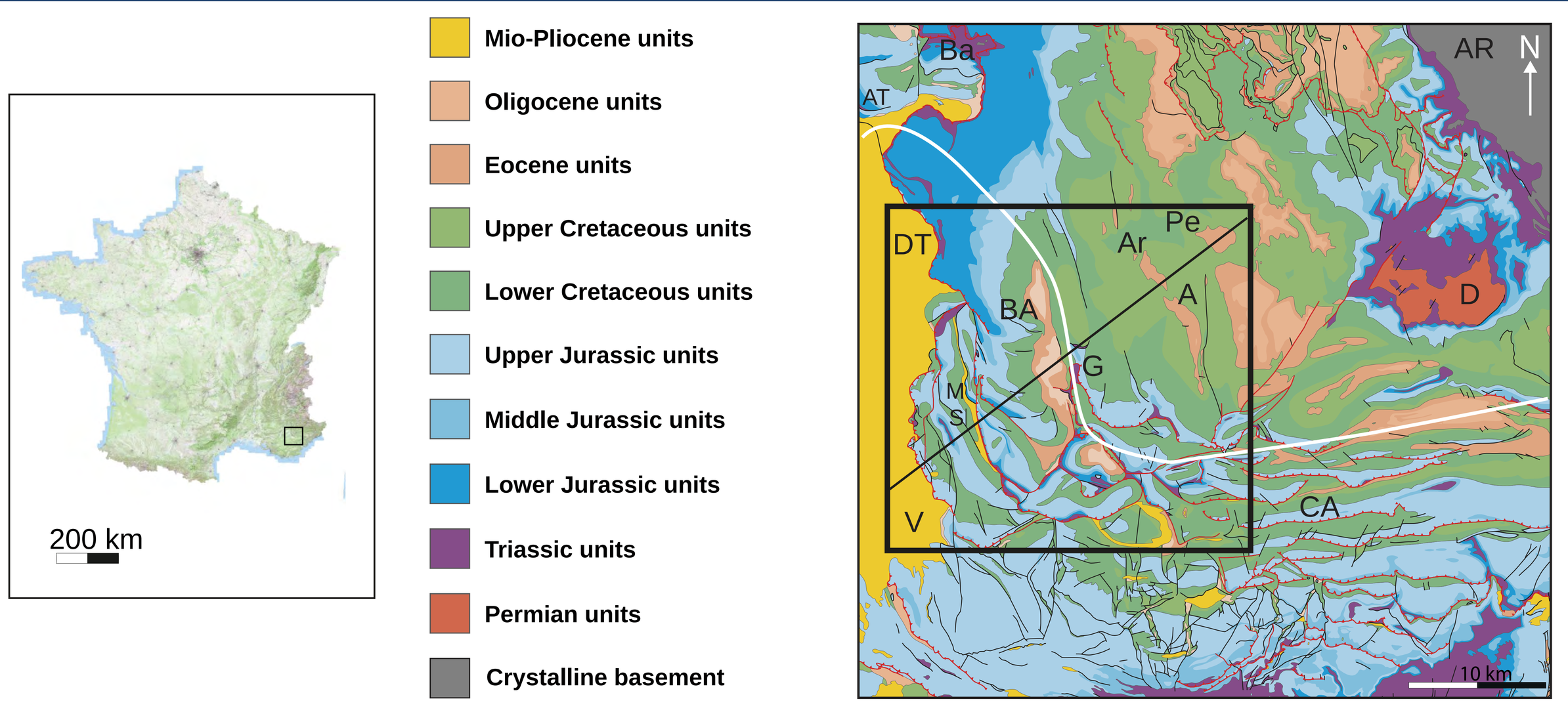


Figure 1. The fold and thrust belt of the Southern Subalpine Chains comprises the Digne and Authon thrust sheets. The thrust system has polyphase deformational history (Graham et al. 2012.) Thrusting started before the Eocene. During the Eocene and Oligocene a series of thrust-sheet-top basins evolved one of which is the Barréme basin. During the Miocene and Pliocene the mountain front reached the Valensole basin.
The study area is indicated by the black rectangle. The location of the regional cross-section (Fig. 3,4) is indicated by the black line. The white line indicates the edge of the Provencal platform during the Early and Middle Jurassic.
AR: Argentera; D: Dôme de Barrôt; A: Annot basin; Ar: Argens syncline: Pe: Peyresq syncline; CA: Castellane Arc; DT: Digne thrust sheet; AT: Authon thrust sheet; G: Gevaudan diapir BA: Barrême basin; Ba: Barles; M: Majestres syncline; S: St Jurs imbricates; V: Valensole basin

2) Stratigraphy

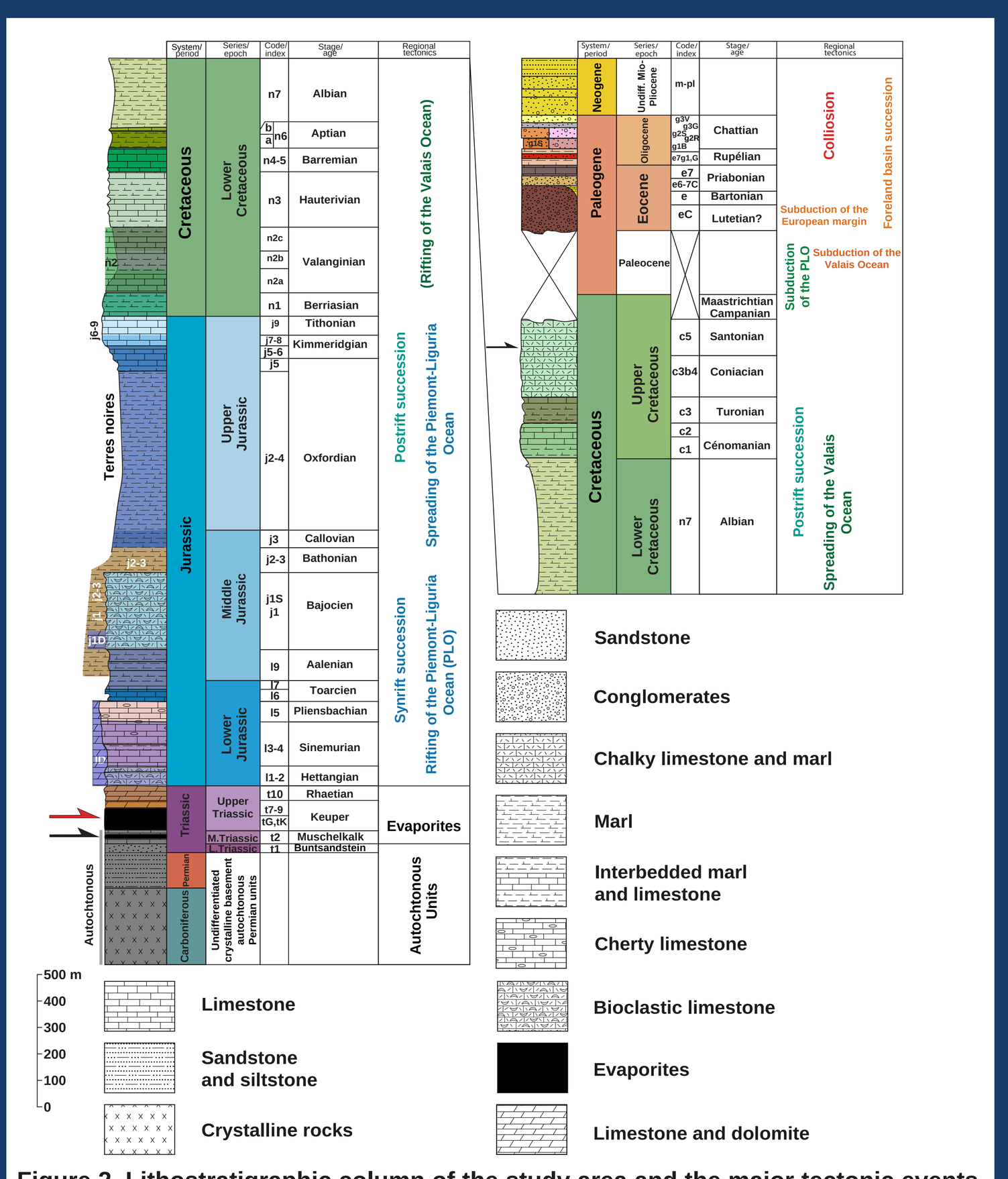


Figure 2. Lithostratigraphic column of the study area and the major tectonic events in the Western Alps. We refer the lithostratigraphic units as they are shown in this lithostratigraphic column.

3) Various interpretations of the Gévaudan diapir and the surrounding basins

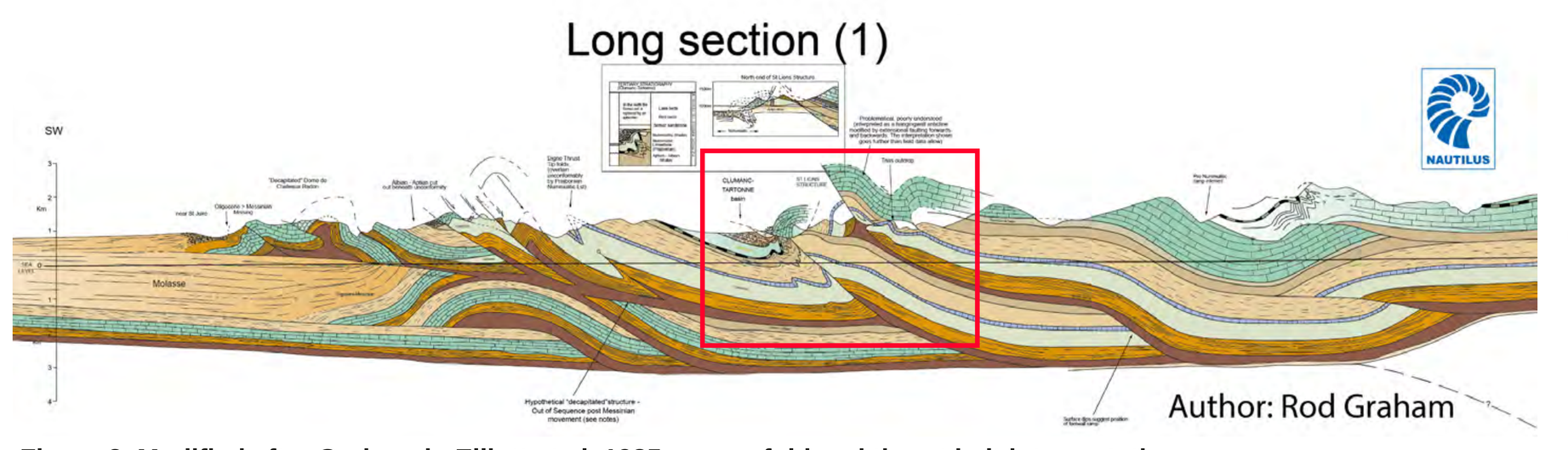


Figure 3. Modified after Graham in Elliott et al. 1985, a pure fold and thrust belt interpretation

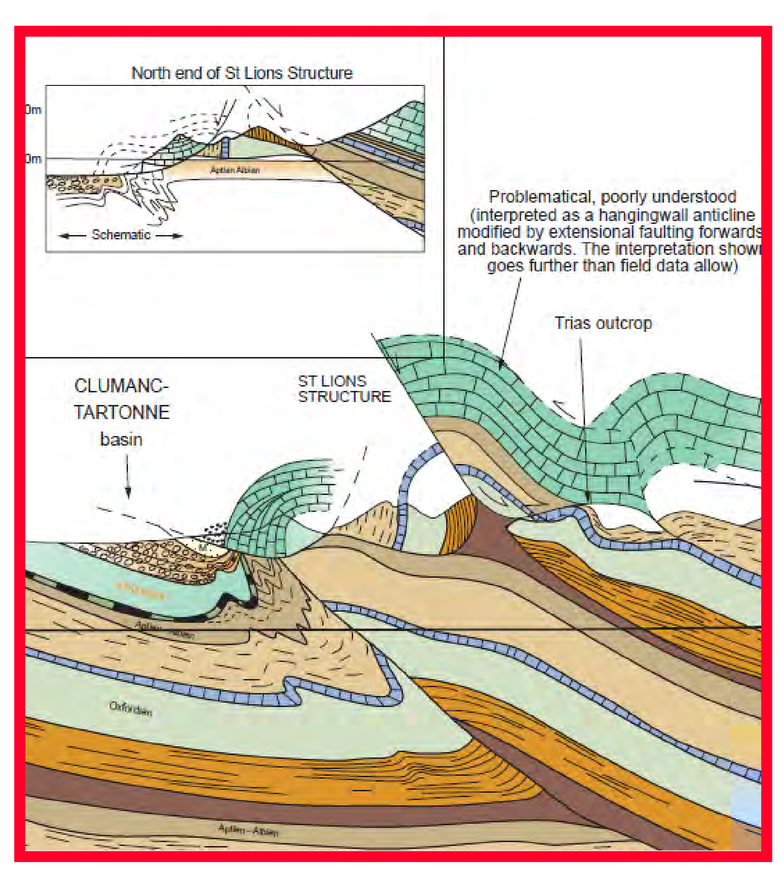


Figure 5. A "non-salt attempt" interpretation of R. Graham around Gévaudan

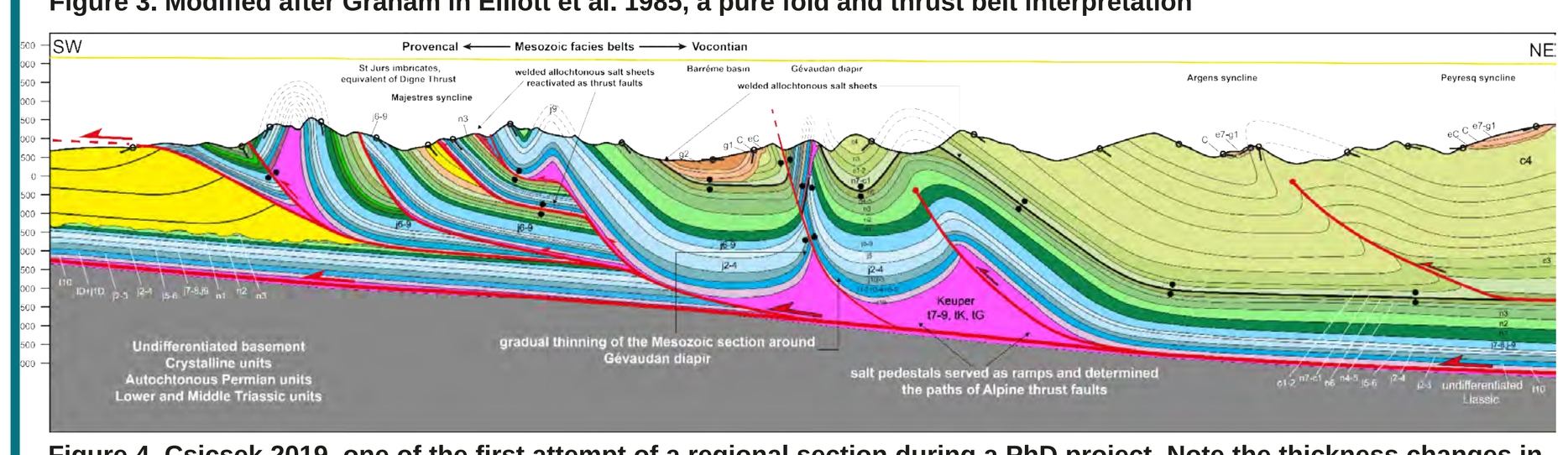


Figure 4. Csicsek 2019, one of the first attempt of a regional section during a PhD project. Note the thickness changes in the Mesozoic succession and a lot of possible, welded salt related contacts.

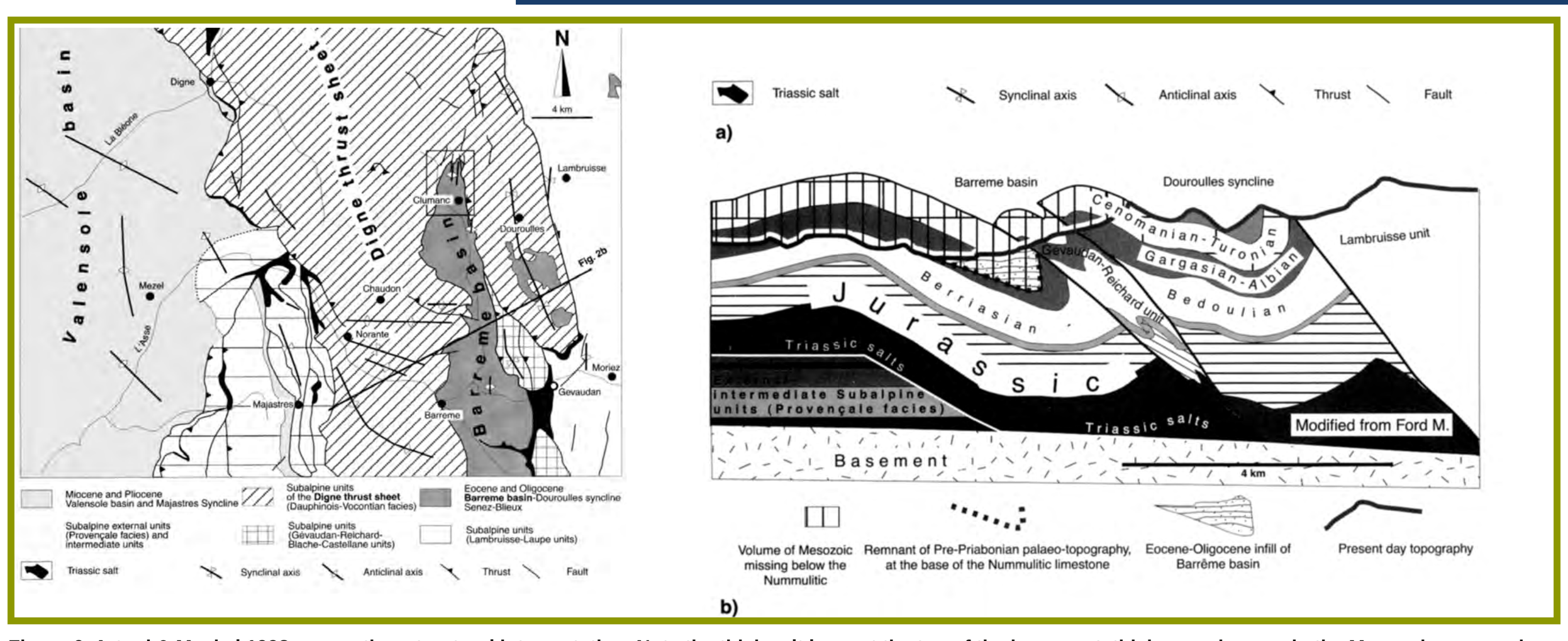


Figure 6. Artoni & Meckel 1998, an another structural interpretation. Note the thick salt layer at the top of the basement, thickness changes in the Mesozoic succession , the steep thrust faults bounding the different units and a possible young-on-older contact between the Gévaudan-Reichard unit and the Douroulles syncline.

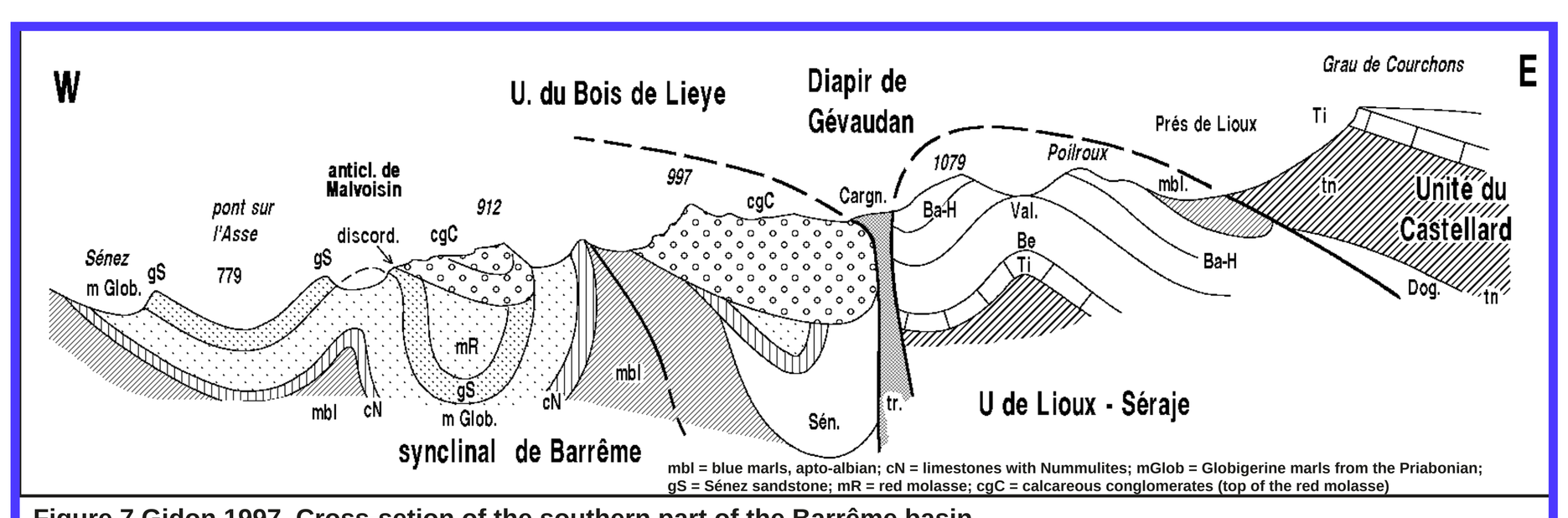


Figure 7.Gidon 1997. Cross-section of the southern part of the Barrême basin.

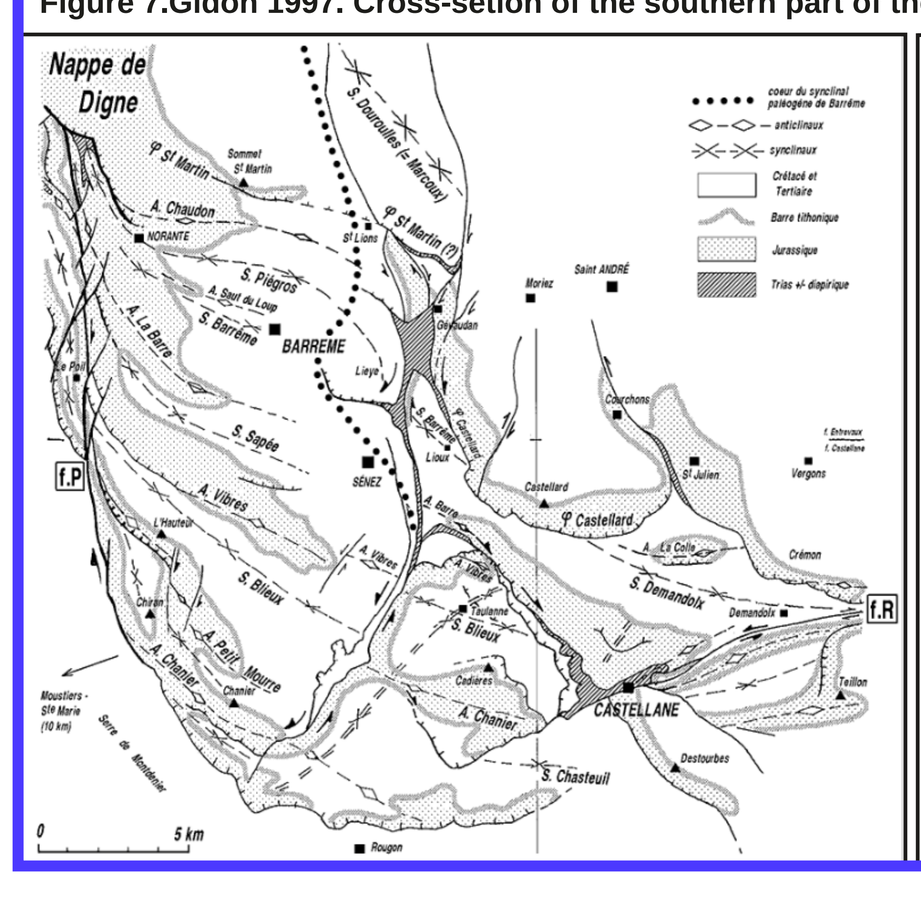


Figure 8. Schematic map of the structures of the Southern Subalpine Chains, Gidon 1997. Note the strike-slip faults around the Gévaudan area.

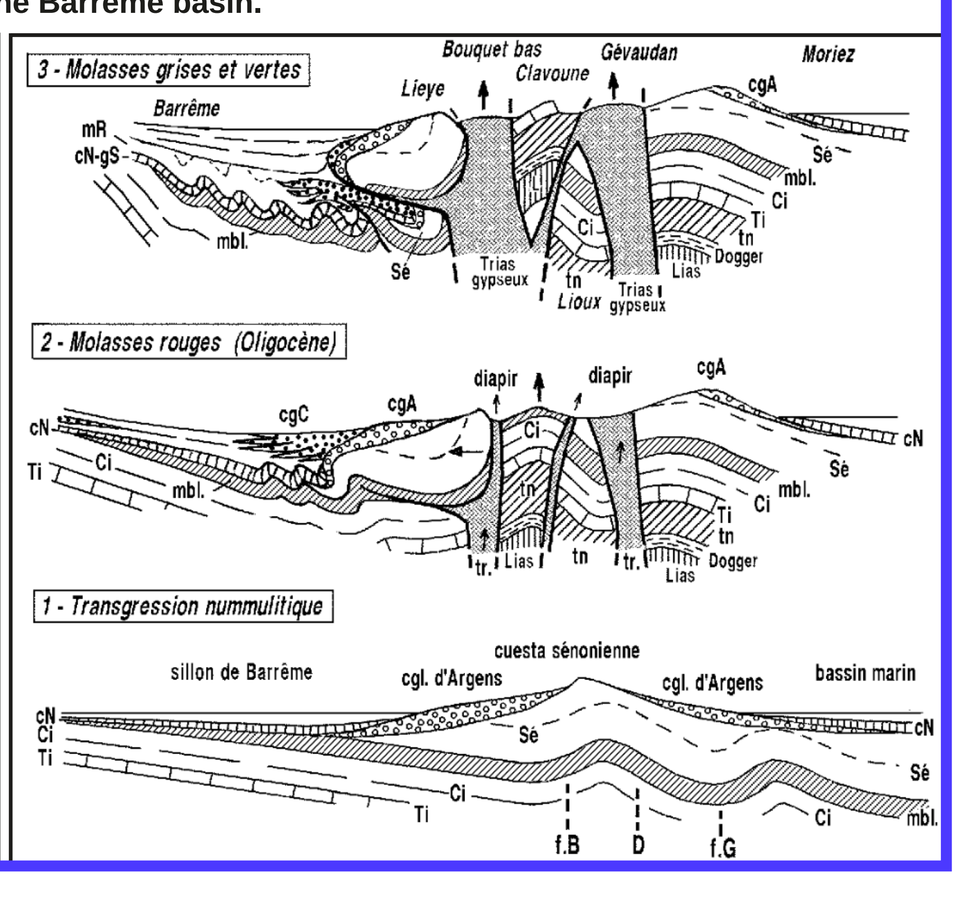


Figure 9. Cartoons shoving the evolution of the Gévaudan diapir and the sourroundign basins.
Note the relatively short period of structural evolution. Gidon 2000.

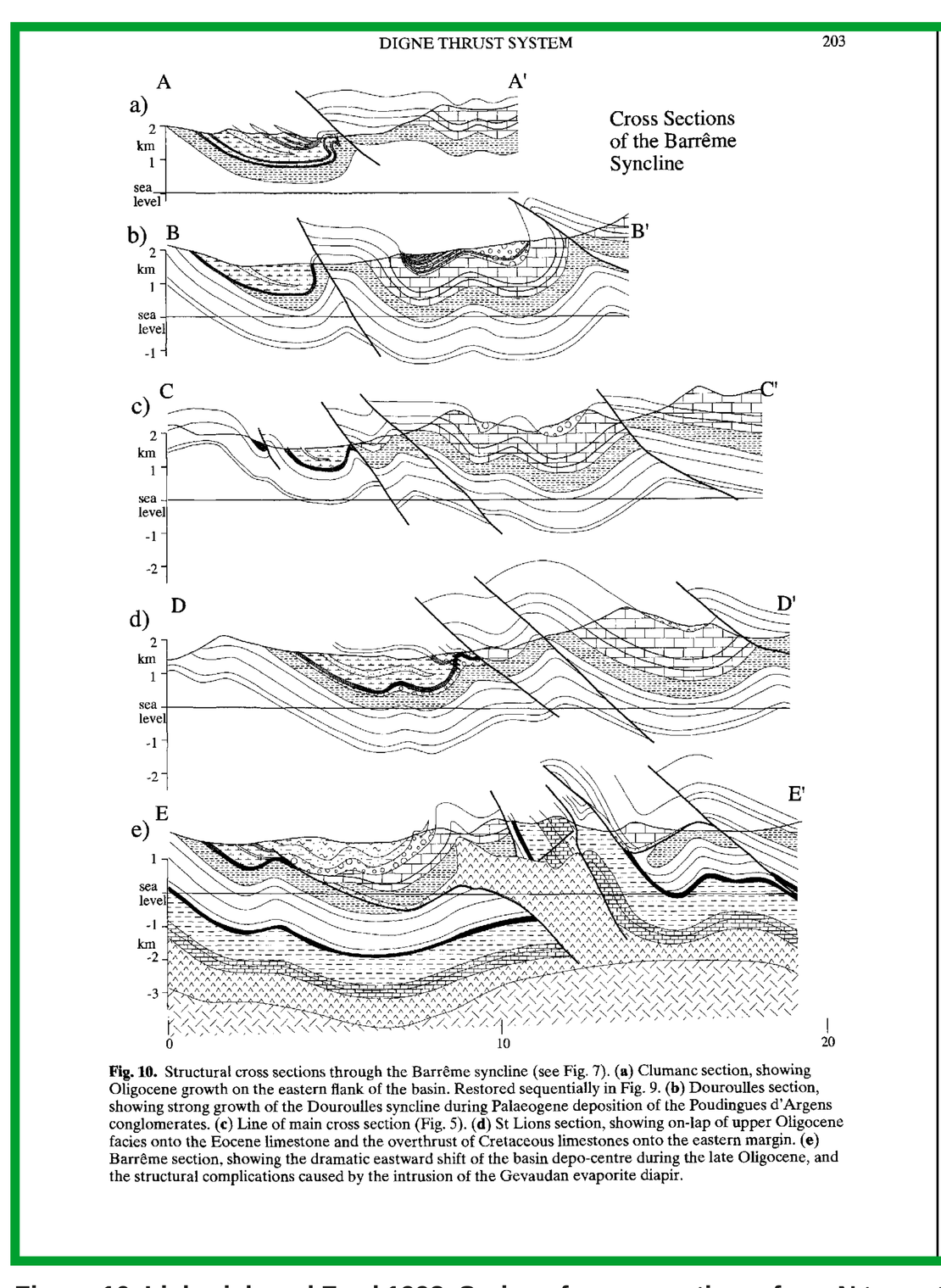


Figure 10. Lickroish and Ford 1998. Series of cross sections, form N to S. Their interpretation includes the eastward migration of the depocenter in the Barrême basin and the intrusion of the Gévaudan diapir during Late Oligocene.

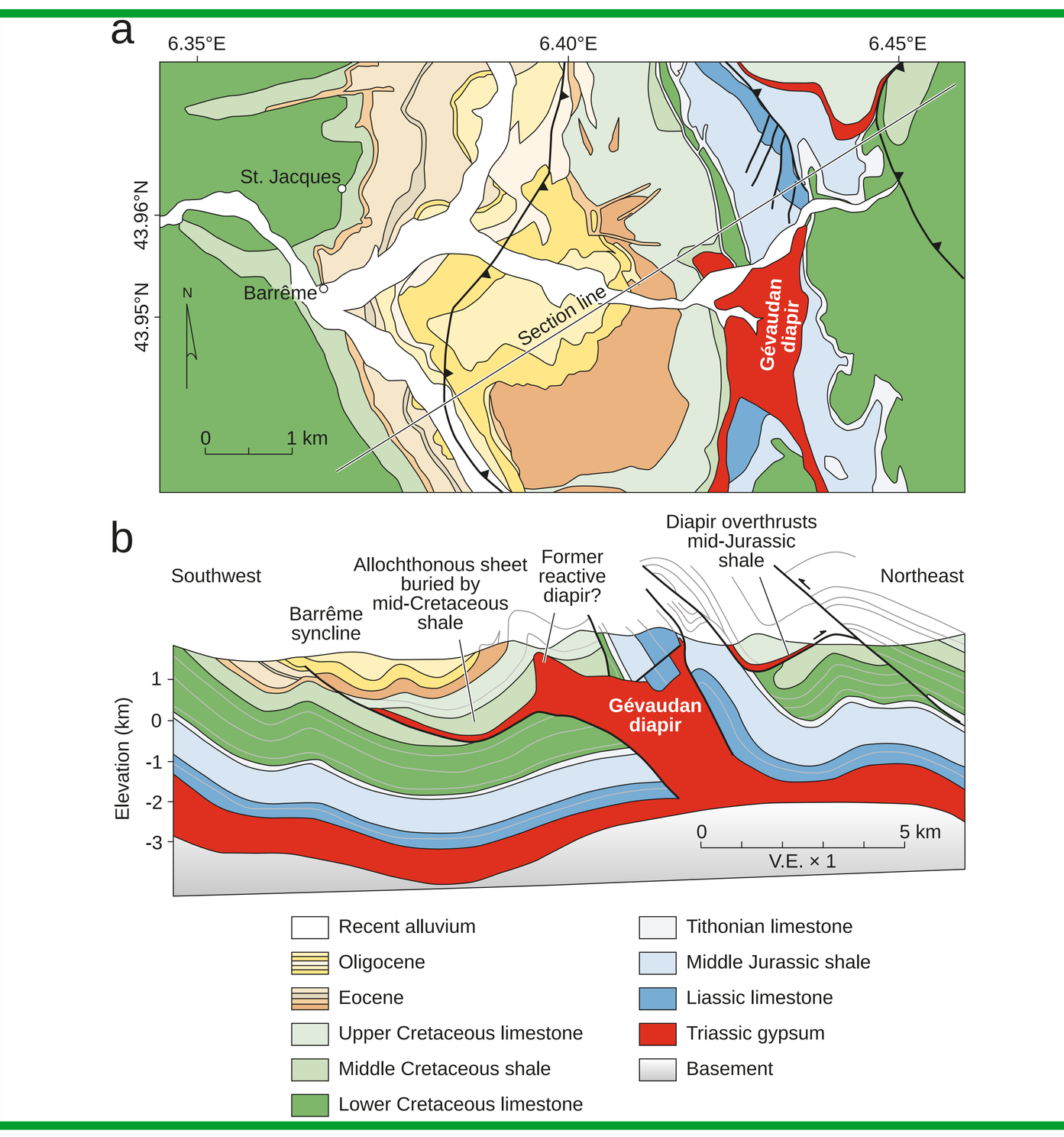


Figure 11. Lickorish & Ford 1998 cross section in Jackson and Hudec 2017. Their interpretation includes an allochthonous salt sheet buried by mid-Cretaceous shale (n7c1). The Eocene and Oligocene units are thickening towards to east.

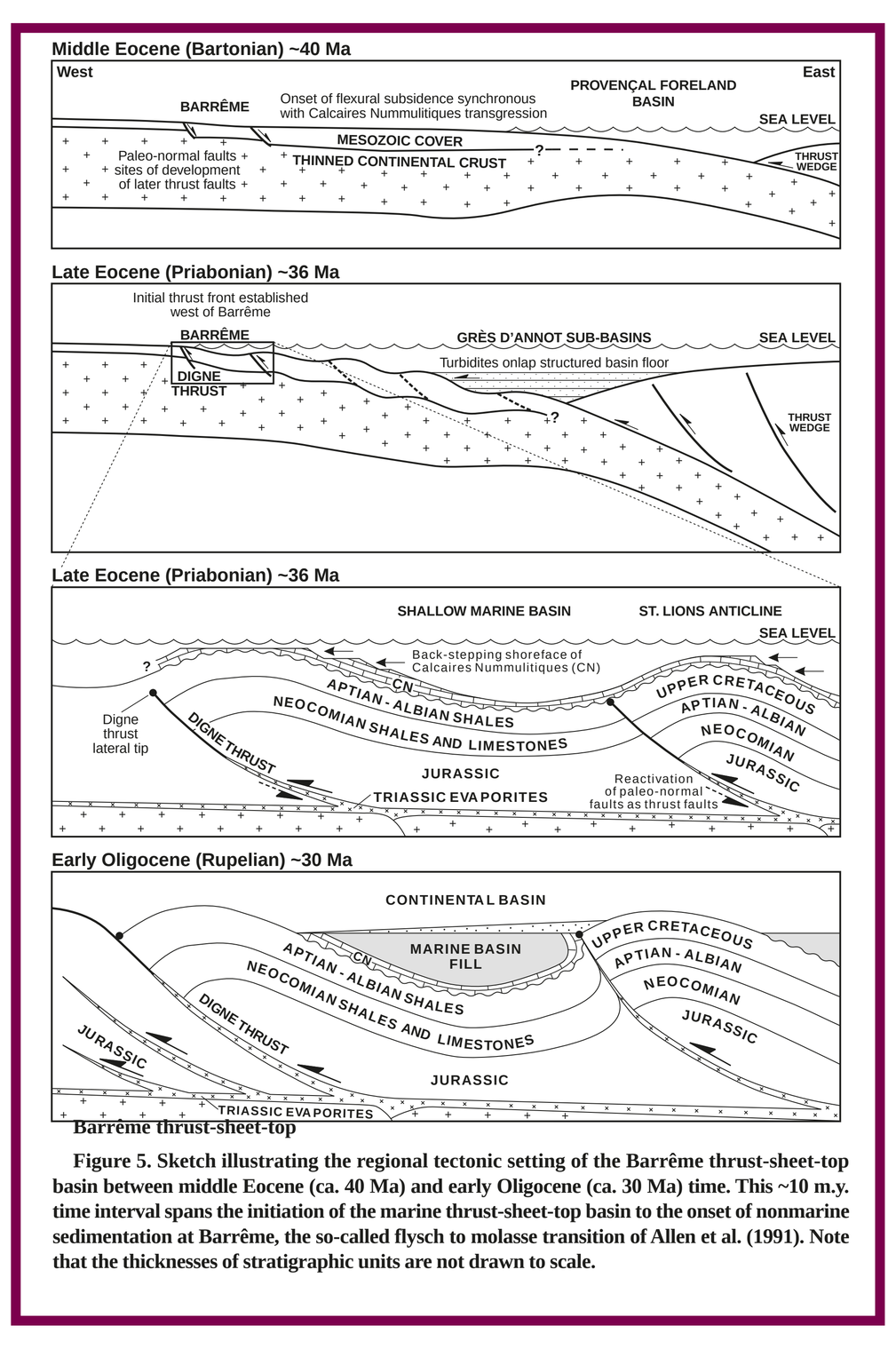


Figure 12. Sketch showing the evolution of the Barrême thrust-sheet-top basin. Note the generally constant thickness of the Mesozoic sccession. Evans and Elliott 1999.

4) Geological and schematic structural map of the study area

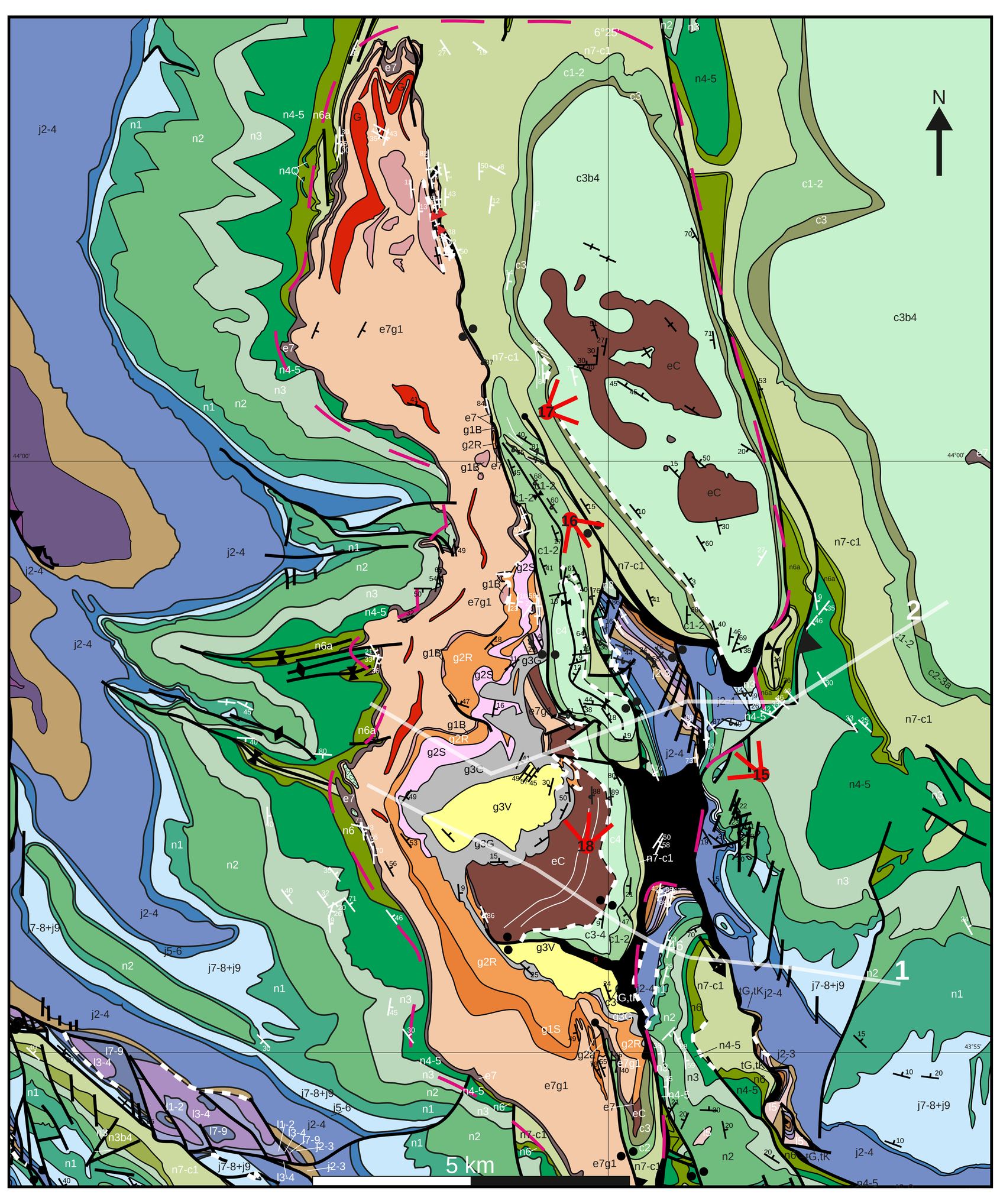


Figure 13. The new geological map of the study area. (Key: Fig.2)

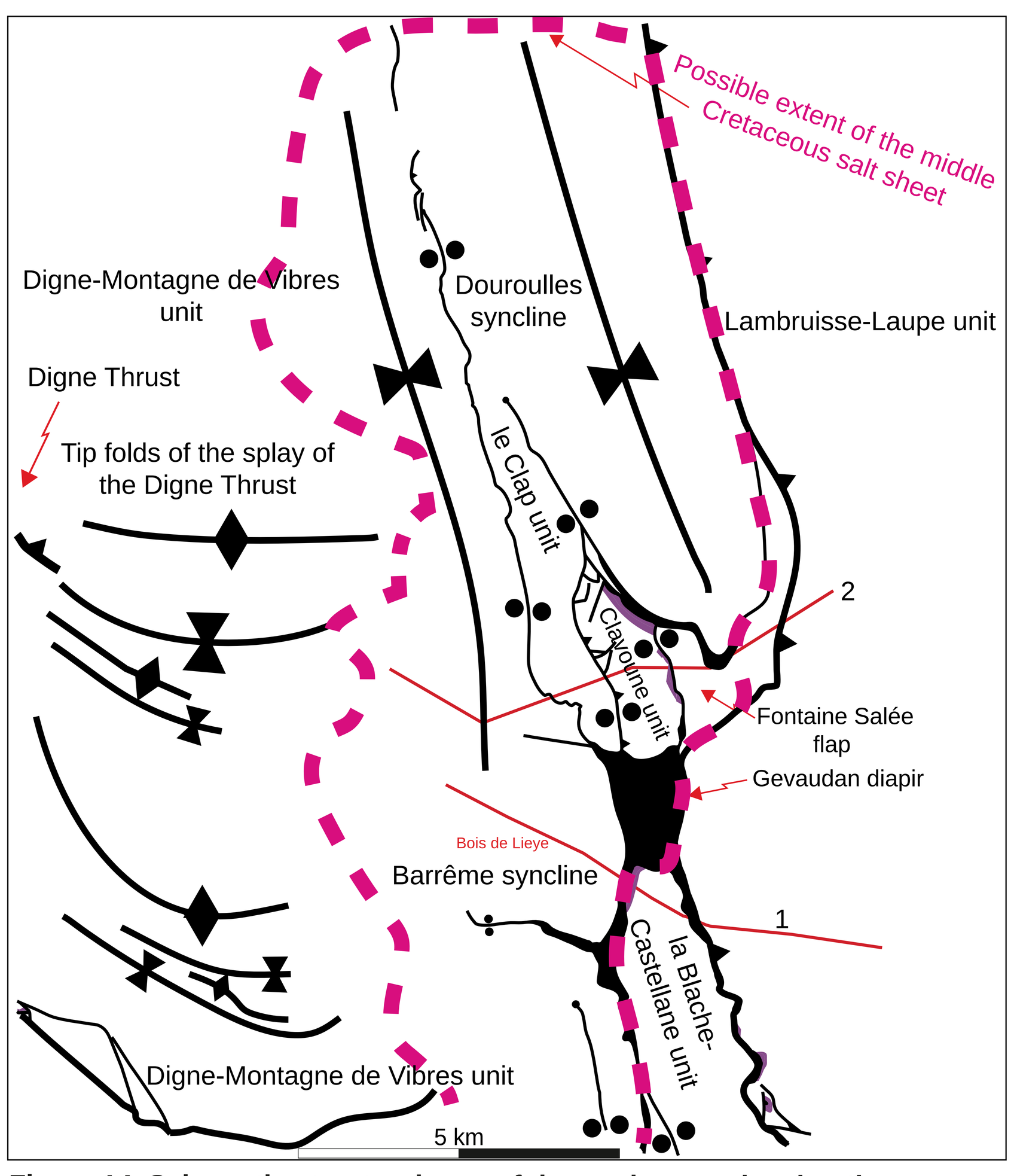


Figure 14. Schematic structural map of the study area showing the occurences of Upper Triassic evaporites (black) and younger Triassic units (purple). The pink dashed line represents the possible extent of the middle Cretaceous salt sheet.

5) Observations, stratal and structural geometries around the Gevaudan diapir

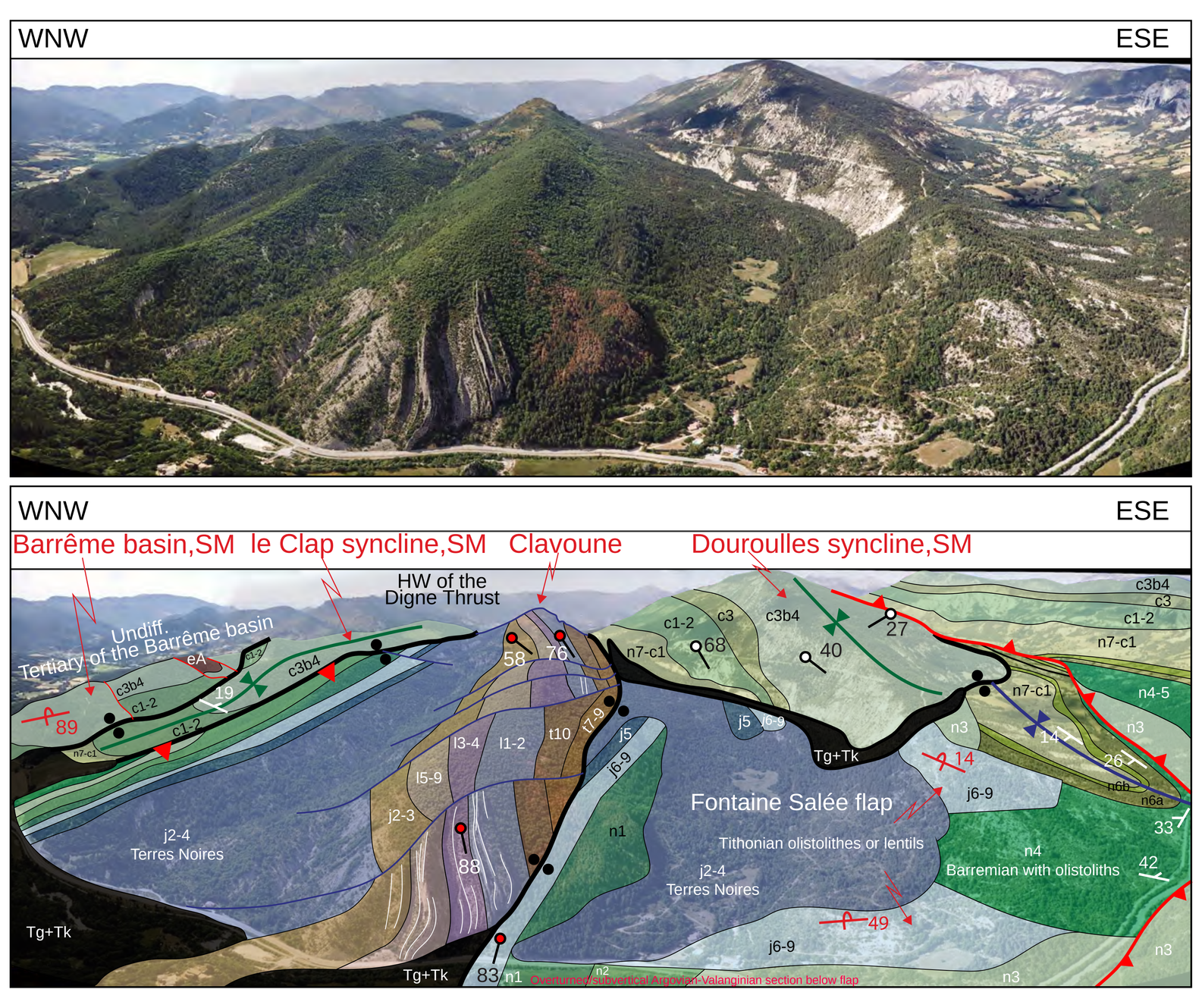


Figure 15. The view of the southern side of the Clavoune section. Springs where salt brine flows to surface are located in the valley E of Clavoune (Morin et al. 2004).

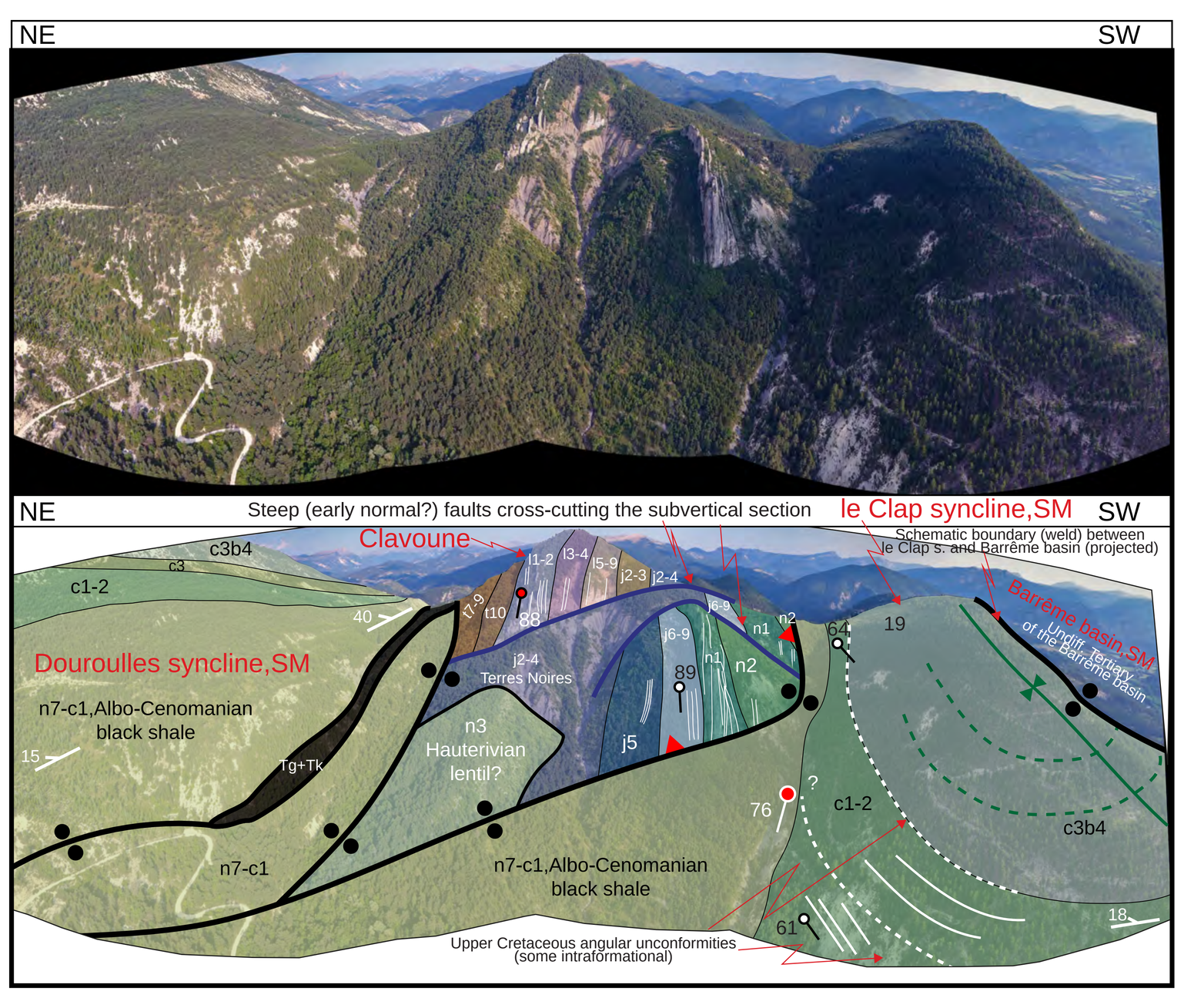


Figure 16. The view of the northern side of the Clavoune section. See Fig. 13 for locaction.

Figure 18. Tilted subvertical Poudingues d'Argens on the eastern flank of the Barrême basin. The underlying Upper Cretaceous succession to the E is also composed of intraformational breccias. The tilting is related to evacuation of the allochthonous salt due to thrust loading. Paleocurrent data measured on tilted channel fill suggest N-S flow direction, parallel with bounding salt wall of the basin. See Fig. 13 for locaction.

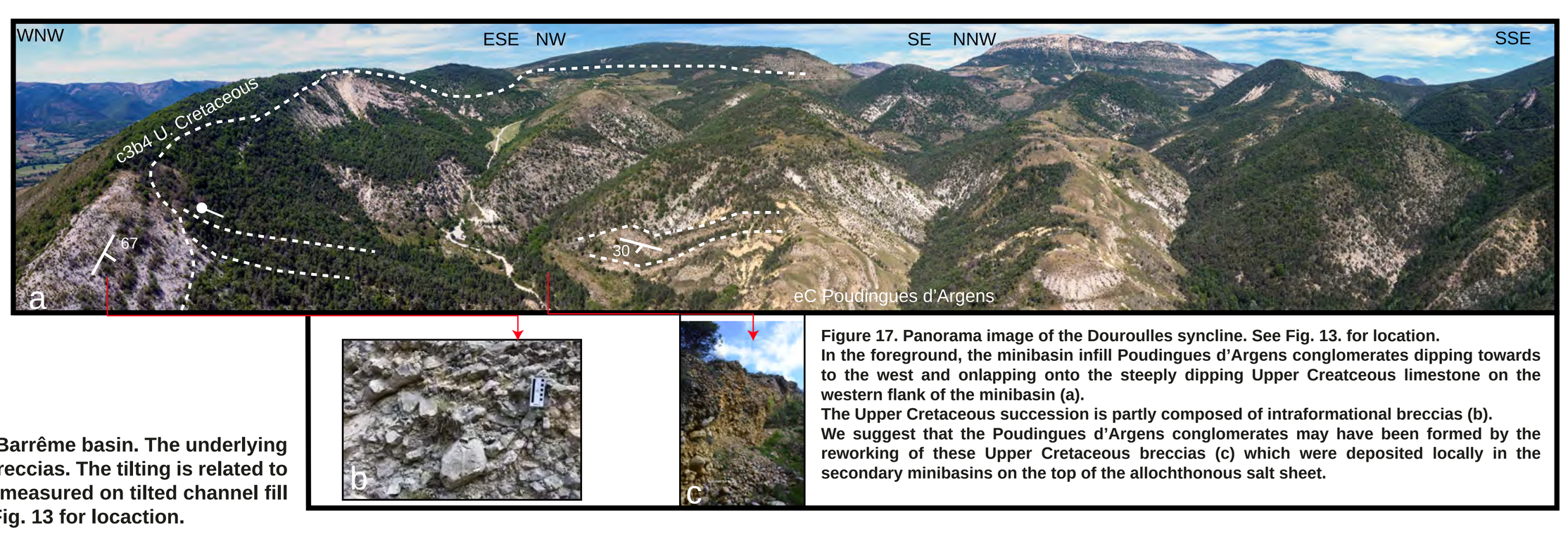
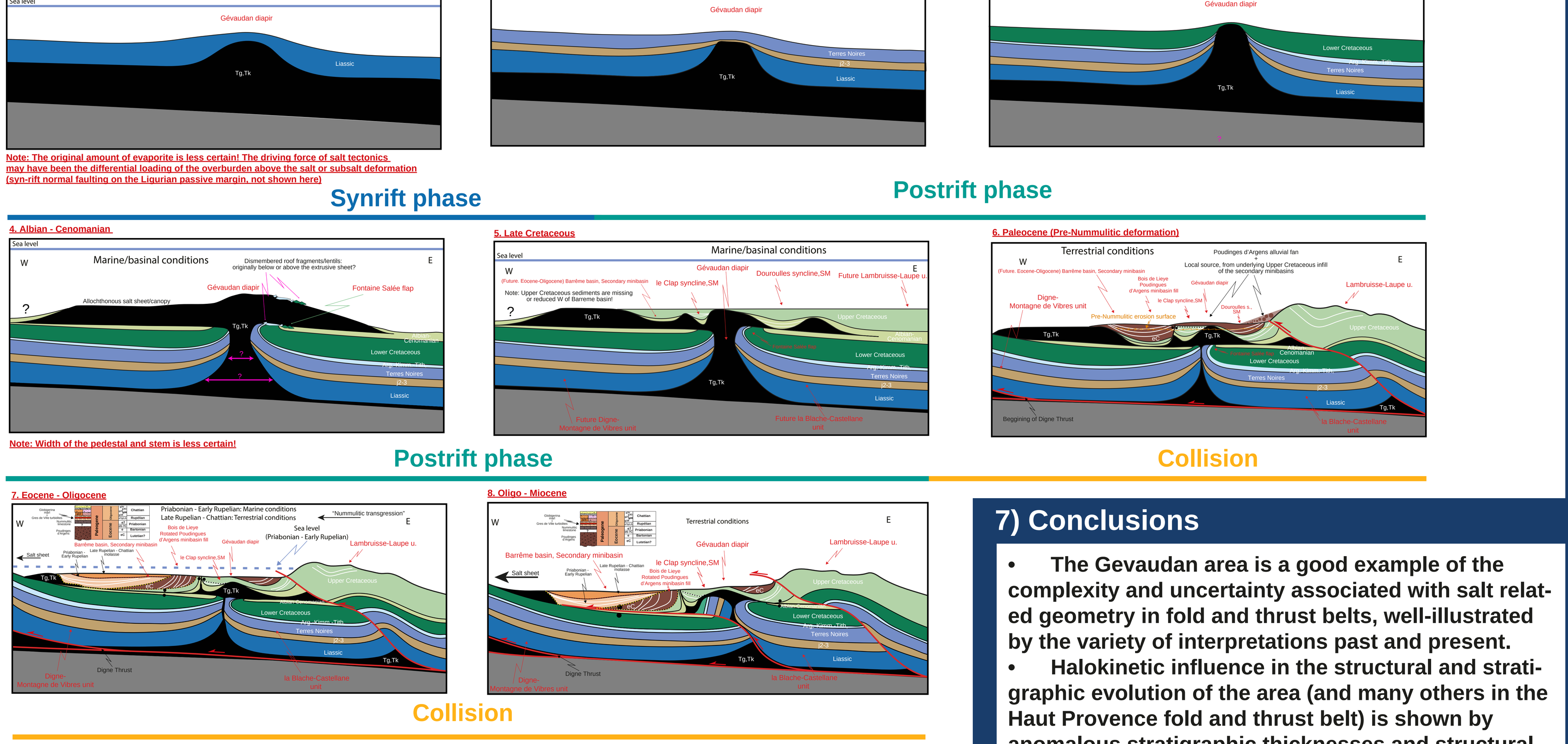


Figure 17. Panorama image of the Douroulles syncline. See Fig. 13. for location.
In the foreground, the minibasin infill Poudingues d'Argens conglomerates dipping towards to the west and onlapping onto the steeply dipping Upper Createceous limestone on the western flank of the minibasin (a).
The Upper Cretaceous succession is partly composed of intraformational breccias (b).
We suggest that the Poudingues d'Argens conglomerates may have been formed by the reworking of these Upper Cretaceous breccias (c) which were deposited locally in the secondary minibasins on the top of the allochthonous salt sheet.

6) Evolutionary diagram

Figure 19. Cartoons shoving possible Early Jurassic - present day evolution of the Gévaudan area, NOT TO SCALE



Present day, SCALED SECTIONS

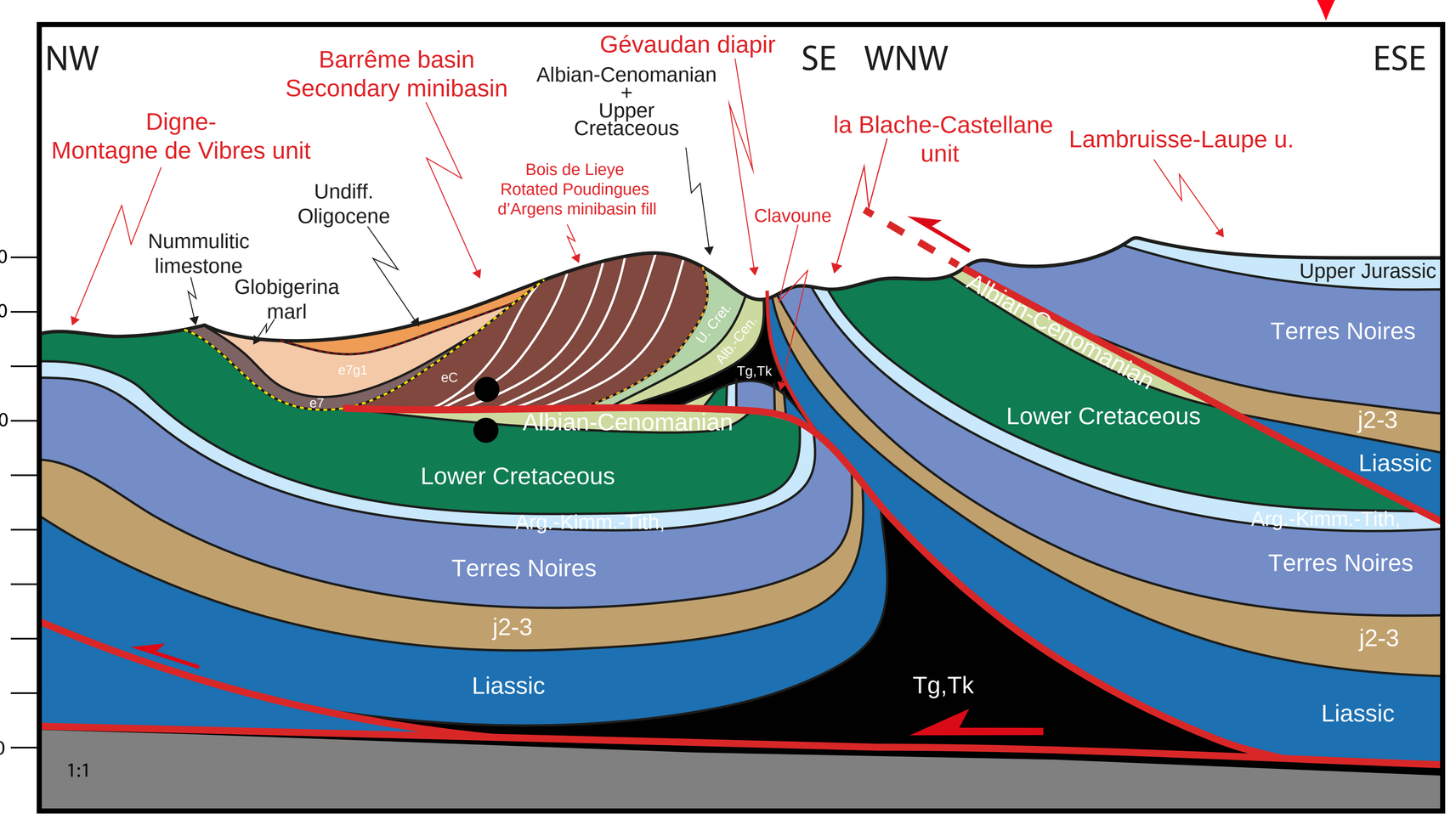


Figure 20. Section line 1. See Fig. 13,14 for location.

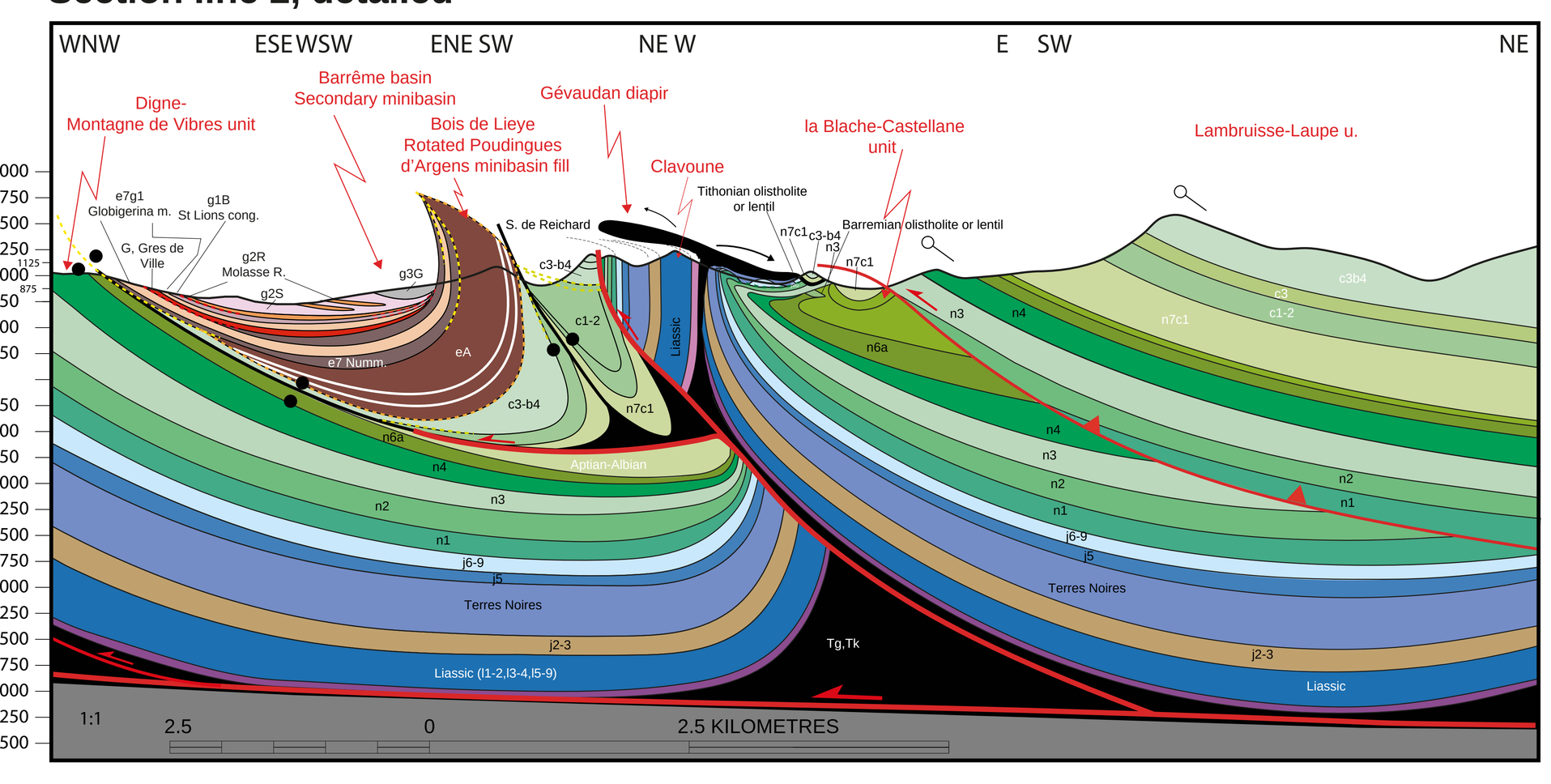


Figure 21. Section line 2. See Fig. 13,14 for location.

7) Conclusions

- The Gevaudan area is a good example of the complexity and uncertainty associated with salt related geometry in fold and thrust belts, well-illustrated by the variety of interpretations past and present.
- Halokinetic influence in the structural and stratigraphic evolution of the area (and many others in the Haut Provence fold and thrust belt) is shown by anomalous stratigraphic thicknesses and structural geometries.
- The well known Barreme Basin, a thrust -top fragment of the Provencal foreland basin, is re-interpreted as a secondary minibasin developed on top of an allochthonous salt sheet which extruded onto the Albo-Cenomanian sea floor at a time of low sedimentation rate. The probable original extent of this canopy is suggested.
- The Barreme Basin had three precursor secondary minibasins which filled with Upper Cretaceous pelagic limestones, then, during the first wave of Alpine thrusting and loading in the latest Cretaceous, by the Palaeocene Poudingues d'Argens - a pebble, cobble and boulder conglomerate formed entirely from Upper Cretaceous debris.
- As the canopy salt evacuated westwards, presumably in response to more internal thrust loading, accommodation space was created for the Eo-Oligocene rocks of the Barreme Basin and the earlier formed Poudingues d'Argens minibasin was strongly rotated to be overlain unconformably by the younger formations. In detail there are several other unconformities in the section.
- Oligocene or Miocene thrusting emplaced part of the near-crest flank of the original diapir as the allochthonous structural 'horse' which now forms the Clavoune hill. The Gevaudan diapir is the remnant of the one-time canopy.
- If these ideas are correct, useful future work might involve a re-investigation of the source to sink of the Tertiary formations in the area.

8) References

ARTONI, A. & MECKEL, L. D. 1998. History and deformation rates of a thrust sheet top basin: the Barrême basin, western Alps, SE France. Geological Society, London, Special Publications, 134, 213-237.
CSICSEK, L. A. 2019. The effects of salt tectonics in the evolution of a fold and thrust belt, Southern Subalpine Chains, France. Conference poster, TSG AGM, Bergen
DARDEAU, G. & DEGRACIANSKY, P. 1990. Halokinesis and Tethyan rifting in the Alpes-Maritimes (France).
BULLETIN DES CENTRES DE RECHERCHES EXPLORATION-PRODUCTION ELF AQUITAINE, 14, 443-464.
EVANS, M. J. & ELLIOTT, T. 1999. Evolution of a thrust-sheet-top basin: The Tertiary Barreme basin, Alpes-de-Haute-Provence, France. Geological Society of America Bulletin, 111, 1617-1643.
GIDON, M. 1997., 2000. Extrait de GEOL-ALP. www.geol-alp.com
GRAHAM, R., JACKSON, M., PILCHER, R. & KILSDONK, B. 2012. Allochthonous salt in the sub-Alpine fold–thrust belt of Haute Provence, France. Geological Society, London, Special Publications, 363, 595-615.
JACKSON, M. P. & HUDEC, M. R. 2017. Salt tectonics: Principles and practice, Cambridge University Press.
LICKORISH, W. H. & FORD, M. 1998. Sequential restoration of the external Alpine Digne thrust system, SE France, constrained by kinematic data and synorogenic sediments. Geological Society, London, Special Publications, 134, 189-211.
MASCLE, G., ARNAUD, H., DARDEAU, G., DEBELMAS, J., DELPECH, P.-Y., DUBOIS, P., GIDON, M., DE GRACIANSKY, P.-C., KERCKHOVE, C. & LEMOINE, M. 1988. Salt tectonics, Tethyan rifting and Alpine folding in the French Alps. Bulletin de la Société géologique de France, 4, 747-758.
MORIN, D., CATHERINE, L., FONTUGNE, M. & GUIOMAR, M. 2004 Aux origines de l'extraction du sel en Europe (VIe millénaire av. JC), La source salée de Moriez-Alpes-de-Haute-Provence. Bulletin de la Société Préhistorique Française, 341-352.

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