The Marseille and Grand-Rhône Canyons off the Gulf of Lions – Western Mediterranean Sea: an example of sediment transport systems conditioned by salt-related structures.

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Abstract

The Marseille and Grand-Rhône sedimentary ridges, located offshore the Gulf of Lions – Western Mediterranean Sea, are generated by sediment spillover funnelled by, respectively, the Marseille and Grand-Rhône canyons. We observed that the Marseille and Grand-Rhône canyon directions are tectonically conditioned by Plio-Quaternary salt-induced sea-floor reliefs. Overburden extension in the area created an assemblage of listric faults running parallel to the strike of the continental margin. This salt-induced topography resulted in accentuated fault scarps impacting the sea-floor morphology, forcing submarine valleys to deflect to the east. Gravity-induced extension equally influenced the morphological pattern of the valleys overbanking deposits. Sediment spillover occurred on the canyons both flanks, but since active faulting generated space accommodation for overflow deposits, it inhibited the development of typical levee morphology along the canyons left flank.

Introduction

The Marseille and Grand-Rhône canyons exhibit a general E-W trending, approximately parallel to the South Provençal margin, Gulf of Lion – Western Mediterranean sea (Figs. 1, 2 and 3). The Marseille and Grand-Rhône Sedimentary Ridges are directly related to sediment funnelling by, respectively, the Marseille and Grand-Rhône canyons (Figs. 1 and 2). These deposits, built by turbidity currents spillover, spread over the valleys flanks. Thus, their orientation follow the canyon-valley system itself. According to Bellaiche and Mart (1995), these ridges represent a clear example of deep-water deposition systems, constructed during sea level lowerings. Both sedimentary ridges have been reported to as asymmetrical, as a result of preferential deposition on the canyon right flanks. The most developed ridge is the one flanking the Marseille canyon. Coutellier (1985) and Bellaiche and Mart (1995), based on high resolution seismics, evoked the general canyon orientation to be tectonically controled by deep-seated Oligo-Aquitanian lineaments. Ridges asymmetry, in turn, was attributed to the sole effect of the Coriolis forces. However, in this study, high resolution seismic profiling and exploration wells (Autan, GLP2 and GLP1) allowed the identification of salt-structural processes in the Gulf of Lions that were poorly understood until now. Accordingly, we propose that the Marseille and Grand-Rhône canyon directions, as well as their ridges disposal, are tectonically conditioned by salt-induced sea-floor reliefs

Salt tectonic framework of the Gulf of Lions

The Plio-Quaternary salt-structural evolution of the Gulf of Lions was primarily controlled by gravitational gliding over a Messinian detachment salt level. Gravity gliding produced three main tectono-stratigraphic provinces (Gaullier, 1993; Reis, 2001), as classically identified on passive margin basins: an uppermost Listric Faults Province, an intermediate Rigid Gliding Province and a lowermost Salt Domes Province. The Listric Faults Province is largely dominated by basinward-dipping faults and expanded stratigraphic wedges. Faults strike is dominantly parallel to subparallel with respect to the shelf break direction. Downslope, the Rigid Gliding Province is characterized by a rather tabular salt layer, and the overlying sediments remain parallel to the top of the salt. In the Salt Domes Province, salt diapirs increasingly break through the overlying sediments, forming local sediment thickenings. Our study area is located within the extensional zone.

Salt-structural conditioning of the Marseille and the Grand-Rhône Submarine Canyons

As elsewhere gulf-wide, overburden extension within the South Provençal domain created a characteristic assemblage of listric faults running parallel to subparallel to the strike of the continental margin. Fault planes are highly curvilinear and form anastomosing relays. Updip, block compartments are narrow (1-2 km) while listric faults are many kilometers long, approximately between 20-50 km (Fig. 3). These proximal fault arrays remained active all along the Plio-Quaternary deposition. Active faulting resulted in accentuated fault scarps up to tens of meters high, impacting the sea-floor morphology (Fig. 4) (Reis, 2001; Reis *et al.,* 2002-submitted).

An important point about submarine valleys that cross the South Provençal subsystem is their E-W orientation, consistent with the listric faults general strike. Both the

Marseille and Grand-Rhône valleys underwent an abrupt deflection to the east, dictated by the near-floor effect of salt deformation (Fig. 3). Proximally, valleys were captured either by faulted-blocks movement or graben structures, while distally they were systematically confined along fault scarps (Fig. 3). Because growth faults are spatially configured in successive relays, confined paleo-thalwegs jumped from a structural compartment to the next, forming a broad zig-zag pattern, with a resultant E-W trend (Figs. 3 and 4). According to Coutellier (1985), Oligo-Aquitanian embasement faults would be accounted for the canyons E-W trending, and implicitly for their ridges orientation itself. The same author argued that the southern ridge extension was partially blocked out by linear diapiric salt barriers. This scenario seems, though, rather unlikely as our data set evidences that deep-seated faults did not affect the Plio-Quaternary sedimentary cover, nor do salt domes exist in this area (Fig. 3).

In fact, gravity-induced extension is directly responsible not only for the orientation of submarine valleys, but also for the E-W configuration of the sedimentary ridges depocenters. Moreover, the salt-structural framework equally influenced the morphological pattern of overbanking deposits. In morphological profiles, both the Marseille and Grand-Rhône Ridges seem asymmetric, leading authors to assume that overflow deposition was biased to the canyons right bank due to the Coriolis force (Coutellier, 1985; Bellaiche and Mart, 1995). But, in reality, from a detailed correlation of acoustic units and reflectors of the sedimentary Upper Series (Upper Quaternary), we observed that overflow deposits did occur on both sides of the Marseille and Grand-Rhône valleys. Along the Marseille valley, ridge development is indeed only observed on the canyon right flank. However, this asymmetry is not hydrodynamically dependent but salt-tectonically imposed. The Marseille valley left flank is bordered by closely spaced active growth faults, where associated block rotation contributed to create space accommodation for overbanking deposits (fig. 4). Under these conditions, leftside overflow sediments were structurally organized as expanded stratigraphic wedges, recognized by landward diverging reflectors in seismic sections in fig. 4. In consequence, a typical external levee morphology could not develop (Figs. 4b-g). On the other hand, overbanking deposition is neatly organized as a sedimentary ridge along the Marseille valley right flank, favoured by larger and more stable block compartments. As for the Grand-Rhône Ridge, morphological asymmetry is not omnipresent. Proximally, the left levee construction was inhibited by a local topographic high provided by the prominent Marseille Sedimentary Ridge, up to about 600m high. Accretion then occurred preferentially on the valley right flank (Figs. 4a and b). Eastwards, as the Marseille Ridge topography progressively degrades, overflow sediments are able to deposit on both flanks of the Grand-Rhône valley. Overflow deposition on the valley right flank built up the so-called Grand-Rhône Ridge. At the same time, left flank levee deposition gradually onlaps the Marseille Ridge and both sedimentary units merged as one single morphological feature (Figs. 4 b-g).

Conclusions

The near-floor effect of salt-related deformation impacted sea-floor morphology of the Provençal continental rise by creating bathymetric reliefs. In spite of the local character of such a tectonic control, it defined the configuration of the whole sediment transport system and, in consequence, radically changed both the depocenter location and configuration of the Marseille and Grand-Rhône ridges. The structural confinement of these submarine valleys is a striking example of how block faulting can condition the arrangement of sediment transport systems and their associated depocenters. Both systems are orientated E-W, i.e. paralleling listric faults trendings. As well as that, active faulting generates space accommodation for overflow deposits, what prevented the development of typical levee morphology, notably along the Marseille left flank. Consequently, in this work, we do not invoke the Coriolis force as a fundamental mechanism for the ultimate ridges asymmetry. We think that our interpretation is more realistic and consistent with the active regional salt-structural framework.

Acknowledgements

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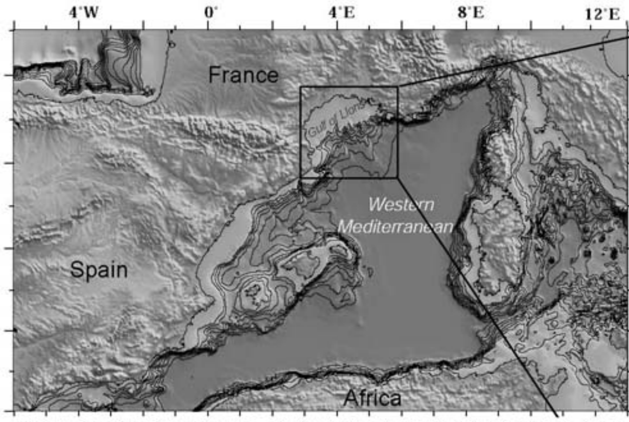


Figure 1: Regional map of the Western Mediterranean Sea (after GTOPO30, Smith and Sandwell, 1997).

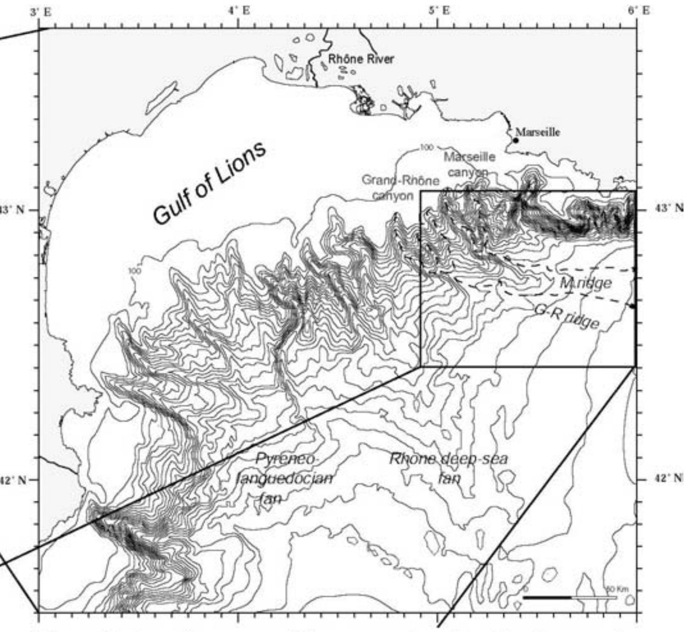


Figure 2: Location map of the area, showing the deep-water depositional systems offshore the Gulf of Lions.

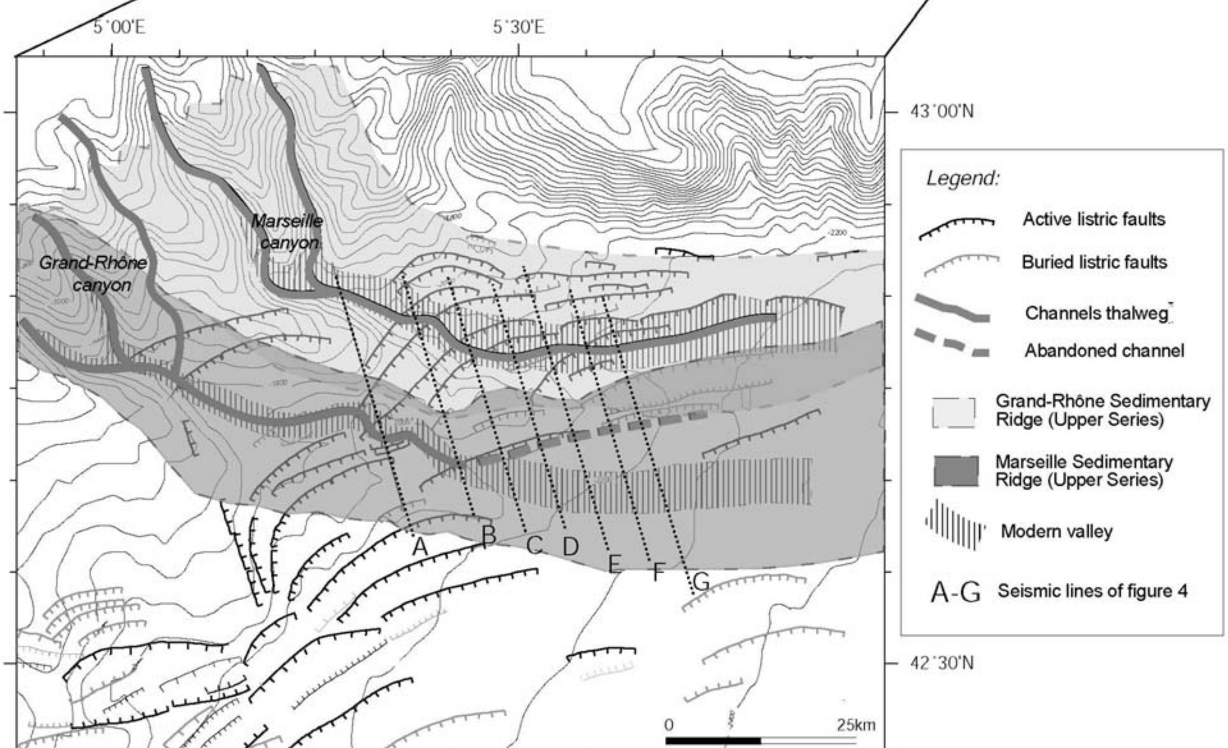
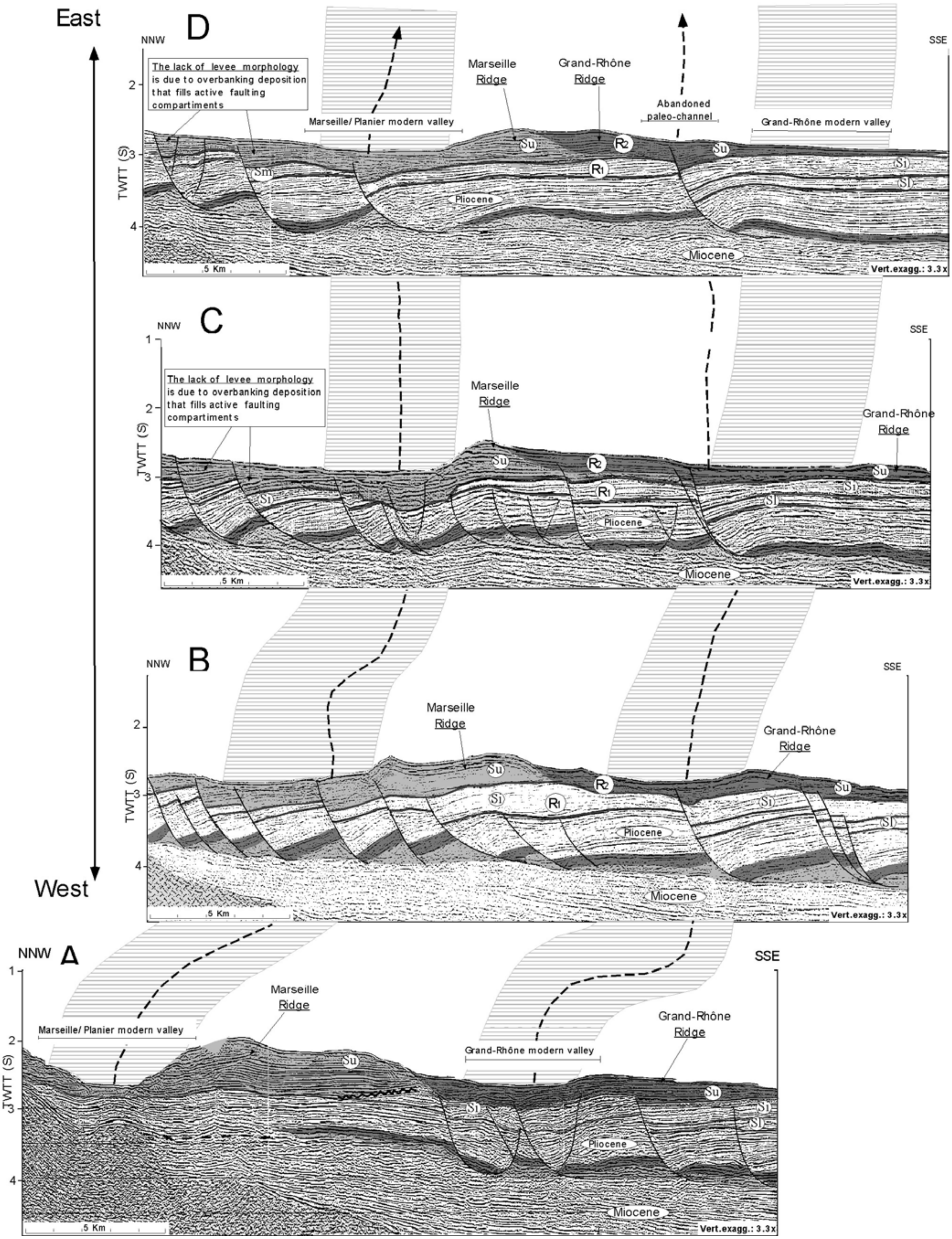


Figure 3: Summary sedimentary and salt-structural map of the South Provençal margin - Gulf of Lions, WesterMediterranean Sea. In the area, sedimentation and salt tectonics are intimately related processes responsible for the configuration of the Marseille and Grand-Rhône Quaternary deep depositional systems. The Marseille and Grand-Rhône canyons/valleys are deflected to the East under the effect of salt-induced bathymetric reliefs (listric fault scarps). The respective depocenters (the Marseille and Grand-Rhône sedimentary ridges) are equally E-W disposed.


East
West
D
NNW
SSE
The lack of levee morphology is due to overbanking deposition that fills active faulting compartiments
Marseille/ Planier modern valley
Marseille Ridge
Grand-Rhône Ridge
Abandoned paleo-channel
Grand-Rhône modern valley
Pliocene
Miocene
TWTT (S)
5 Km
Vert.exagg.: 3.3x
C
B
A
Grand-Rhône modern valley

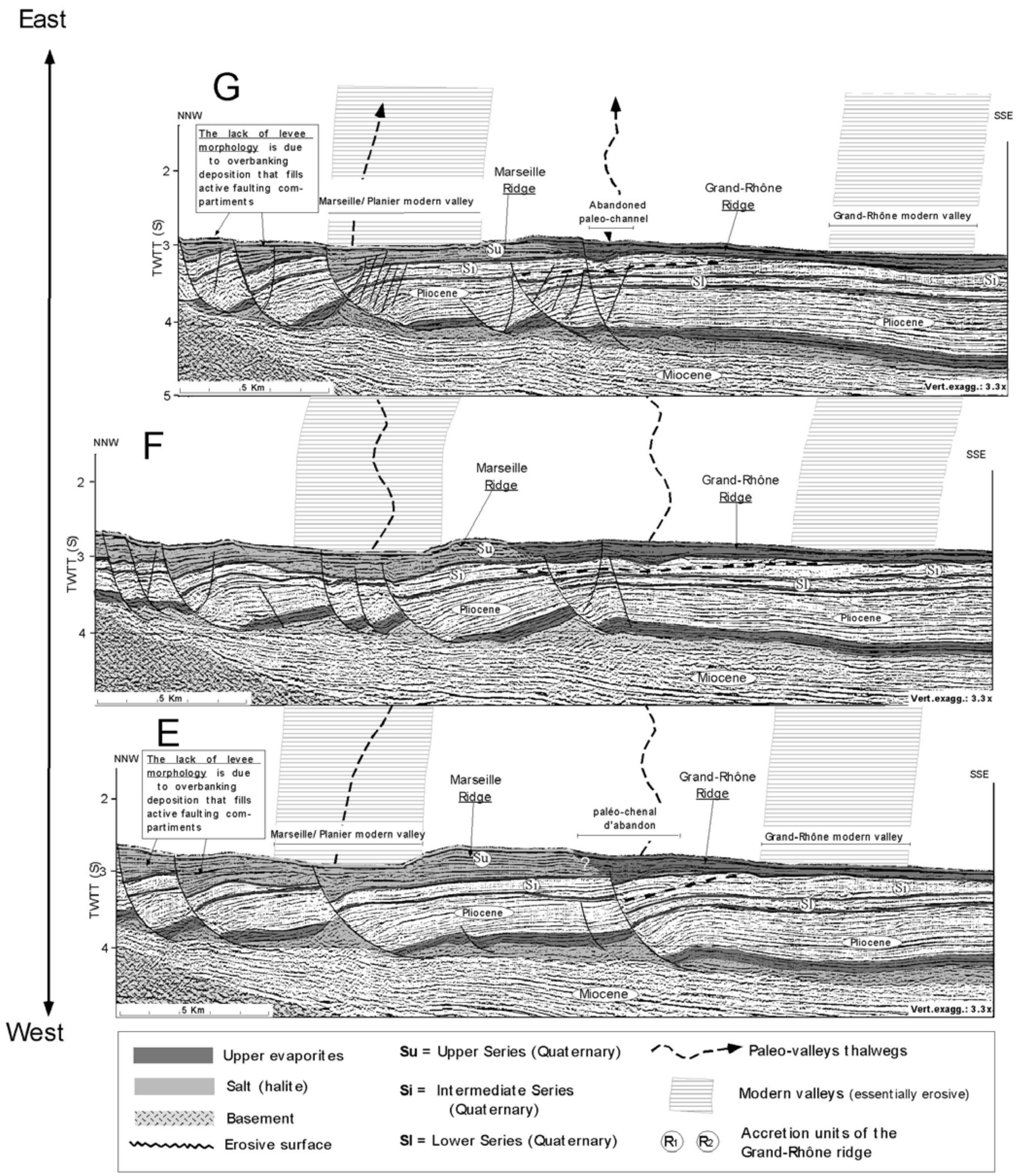


Figure 4: Set of interpreted seismic dip profiles (CEPM multichannel seismics) across the Marseille and the Grand-Rhône sedimentary ridges, offshore the South Provençal margin. Sections show salt-structural conditioning of both the Marseille and Grand-Rhône canyons, that are confined along successively relayed Plio-Quaternary listric faults. See Figure 3 for seismic sections location.