# Comments to M. Rodriguez, Referee #1, rodriguez@geologie.ens.fr

#Review of the manuscript: 'Crustal density model of the Sea of Marmara: geophysical data integration and 3D Gravity Modelling' By Ershad Gholamrezaie et al. For Solid Earth. This is a beautiful and thorough study about the crustal structure of the Marmara Sea with strong implications for the understanding of the geology of the area and the segmentation of the fault system. The study is clear, well written, with nice figures. The link with seismic and tomography studies makes your 3D crustal model very convincing. I therefore recommend the publication in Solid Earth. However, I have a few minor comments, questions and suggestions.

We thank the reviewer for the encouraging review.

## Scientific comments:

#The definition of the pre-kinematic and syn-kinematic sediments is a bit unclear and somehow difficult to relate to the complex geology of the area. What I do not understand is if this terminology refers to the timing of localization/propagation of the North Anatolian Fault, the opening of the Marmara Sea, or the onset of the Main Marmara Fault. . .or maybe all this stages together? I understand that the prekinematic sediments refers to the deposits older than Late Cretaceous, but there are also some tertiary sediments (Eocene) that were unrelated to the history of the North Anatolian Fault. Do you link these sediments with the pre or syn-kinematic history? You should dedicate a full paragraph where you explain clearly this terminology, and make a clear link with the geological episodes in this area. This terminology is sometimes confusing.

We thank the reviewer for pointing this out. We have clarified the formulation to make clear what we mean with syn-kinematic/pre-kinematic sediments (see page 6 lines 8-29 and page 7 lines 15-22 to in revised MS).

With syn-/pre-kinematic we mean with respect to the opening of the Marmara Sea. How far this is related to activity of the NAFZ needs to be discussed. The thickness variation of the youngest sediment unit indicates a clear spatial relationship with respect to two points: (1) with the present-day sub-basins of the Marmara Sea as imaged by bathymetry and (2) with respect to the trace of the MMF in that the latter partly coincides with the margin of the sub-basins. On the other hand, the thickness of the pre-kinematic sedimentary unit displays pronounced minima in the domain of the present-day Marmara Sea, which indicates that this unit has been disrupted during the formation of the Marmara Sea.

#I have found the link with seismic profiles and tomography very convincing (especially the link with Becel et al. and Laigle et al.): Maybe you should add a figure summarizing what we have learned from these studies (i.e. a few cross sections). Some readers may not be familiar with these studies and find all the related sections difficult to follow.

We agree with the reviewer and have added an example for a seismically derived structural cross-section (new Fig. 4), that we also compare to cross-sections in the same position through the three presented end-member models (new Fig. 10).

#One of the strongest result is the identification and mapping of the high density body, with a density ~3. However I feel that the discussion about its origin is incomplete. You link these bodies to deep magmatic activity coeval with the activity of the North Anatolian Fault but the mechanism at the origin of these high density bodies is unclear. Shear heating of the lower crust or the top of the lithospheric mantle? How can you be sure that the formation of these high density bodies is related to the activity of the North Anatolian Fault? What are the arguments? An alternative may be to consider these high density bodies reflects the intra-pontides suture zone. Parts of this suture zone has been mapped onland (see a synthesis in LePichon et al 2014), but the offshore mapping remains unclear. I wonder if what you identify may actually be some ophiolites or metamorphic rocks trapped along this suture zone. In terms of density, ophiolites are >3, some metamorphic rocks can reach the same density. For some insights about the intra-pontides suture zone, I suggest the following papers: Okay and Tüysüz, 1999; Robertson and Ustaömer, 2004. If the ophiolites/suture zone hypothesis is correct, then it means that structural inheritance strongly controls the SED segmentation of the North Anatolian Fault in this area. It would also strongly emphasize some previous suggestions of Celal Sengör, who proposed that the localization of the North Anatolian Fault is strongly influenced by the intra-Pontides suture zone.

Indeed, the discussion was rather brief in the first version of the MS and we agree that there are more concepts to include in the discussion on the origin and nature of these bodies. We thank the reviewer for pointing us to the respective literature, that we have studied. We now provide a more extended discussion on this point, also considering hypotheses put forward in previous work (see page 13, Sec 5. Interpretation and discussion of the best-fit models). We, however, prefer to stay careful in this discussion, as our results are not suited to discriminate between several possible interpretations. We therefore discuss the implications of the different possible interpretations concerning the origin of the high-density bodies but refrain from favouring one. Regarding the intra-pontides suture zone and its relation to the high-density bodies we added the following paragraphs:

Page 15 line 16: "As we do not have further evidence for a magmatic origin of the high density bodies, other possible interpretations of these domains may be considered. For example, these high density bodies could represent inherited structures of former deformation phases such as ophiolites along the intra-Pontide suture that has been mapped on land, but have not yet been explored offshore (Okay and Tüysüz, 1999; Robertson and Ustaömer, 2004; Le Pichon et al., 2014; Akbauram et al., 2016). The two different emplacement mechanisms would have opposing consequences for the propagation of the North Anatolian Fault. The magmatic origin would be consistent with crustal weakening in these domains, whereas the ophiolite origin would imply the opposite. In both cases, however, a local strength anomaly in these domains would be the consequence that could be related to the bending of the fault. Whatever the origin of these bodies, their mafic composition would imply that they represent domains of higher strength in the present-day setting."

Page 15 line 26: "In Model-III as the alternative best-fit model for the Improved–TOPEX gravity dataset, the sixth unit has been calculated identical to the geometry of Model-I (Fig. 9a) but with the average density of 2890 $kg.m^{-3}$ as similar to average density of the lower crust. This density value is consistent with the average density value of intermediate to mafic metamorphic rocks such as granulite (Christensen and Mooney, 1995). In this case, these two dome-shaped bodies may be interpreted as trapped metamorphic rocks along the Intra-Pontide suture zone that spatially correlates with the MMF propagation (Şengör et al., 2005; 30 Le Pichon et al., 2014; Akbauram et al., 2016)."

## Detailed comments:

#the title reads a bit long: I suggest something like '3D crustal density model of the Marmara Sea'

We agree and have changed the title accordingly.

#Geological setting: lateral escape of Anatolia is not only the result of Arabia indentation, there is also a link with the retreat of the Hellenic trench, see Faccenna et al 2006 EPSL for an elegant synthesis

Thanks for pointing this out, we have complemented in the text accordingly:

page 2 line 25: "In the large-scale plate-tectonic framework of Asia Minor, the NAFZ accommodates the westward escape of the Anatolian plate in response to the northward motion and indentation of the Arabian plate into Eurasia and westward enlarging of the deep slab detachment beneath the Bitlis–Hellenic subduction zone (Fig. 1a: McKenzie, 1972; Şengör et al., 2005; Faccenna et al., 2006; Jolivet et al., 2013)…"

#Geological setting: page3 Line 25. LePichon et al 2003 provide some observations suggesting the present-day context is pure strike slip, not transtensional (no oblique extensive stresses), except in the area of Cinarcik where the bend of the fault favors extension:

Scanning the debate on this issue we found that there is contradictory interpretation of the few true stress observations. Hergert and Heidbach (2011) provide plausible arguments for lateral variations in stress regime. We therefore would like to report the full spectrum of the discussion and decided to keep this statement, though complemented by the respective reference. As suggested by the reviewer, the following paragraph was added the revised manuscript:

Page 3 line 24: “In contrast, based on GPS velocity data and surface geological observations, there are also arguments that the kinematics of the MMF correspond to a pure right-lateral strike-slip with the exception of the Çınarcık Basin area that the bend of the Princes Islands segment causes a transtensional setting (e.g. Le Pichon et al., 2003; 2015).’’

#In the discussion, please compare better the improvements of your study with previous ones (Kende. . .etc...)

This has extensively been done, see also answers to reviewers2 and 3.

## Comments related to the figures:

#In the captions, please refer to the meaning of the abbreviations, it is sometimes boring to jump from one figure to another to find the significance.

Done.

#In figure 8: you should number the layers to ease the link with the text (for instance, when you refer to the third layer, the reader has to guess which one is it on the figure...)

Done as new Fig. 10.

#As mentioned earlier, maybe adding some cross sections from previous works (Laigle et al 2008 especially) may help the understanding of your study for a broader audience

Done, new Fig 4.

#I hope you will find these comments helpful and constructive Best regards, Dr. Mathieu

Rodriguez Ecole normale supérieure de Paris

Indeed, we found these comments helpful, thanks again.

#Suggested References:

Faccenna, C., Bellier, O., Martinod, J., Piromallo, C., Regard, V., 2006. Slab detachment beneath eastern Anatolia: a possible cause for the formation of the North Anatolian Fault. Earth and Planetary Science Letters 242, 85-97.

Okay, A.I., Tüysüz, O., 1999. Tethyan sutures of northern Turkey. Geological Society of London, Special publications, 156, 475-515. Robertson, A.H.F., Ustaömer, T., 2004. Tectonic evolution of the intra Pontide suture zone in the Armutlu Peninsula, NW Turkey. Tectonophysics 381, 175-209.

Integrated.