

Comments and Responses
Reviewer 2

GENERAL COMMENTS

1.

Rev. 2: I understand the difficulty of resuming the regional geology, but there are several imprecisions that may have a strong impact on the definition of the mapped surfaces. For example, where it is incorrectly written that the carbonate substratum is Triassic to middle Eocene, you are neglecting the early phase of Alpine Orogeny (Aptian-Maastrichtian), which in turn provides one of the most evident stratigraphic and seismic horizons in the Po Plain subsurface (top of Maiolica Fm). Actually, apart few isolated carbonate platforms in the distal foreland (e.g., Bagnolo platform), since the Aptian the Po Plain Alpine foredeep sedimentation is mostly characterized by marls (e.g., Di Giulio et al., 2001; Tremolada et al., 2008; Sciunnach et al., 2023). What you mean as Carbonate succession top is actually the top of Scaglia Fm, (Scaglia is marl to claystone sediment) and it marks the onset of full Alpine collision (e.g., a tectono-stratigraphic sequence boundary).

Authors: We thank the reviewer for the comment. As explained within the manuscript, we have used public data to build our dataset and the 3D geological model. We generally agree with the reviewer but, in the literature, data (maps and geological cross sections) report generally the top of the Cretaceous (very rarely the Top of the Maiolica Fm.) or the top of the Scaglia Fm. as the end of the carbonate succession. Hence, we were forced to use these data in order to get a good coverage of this important horizon. Indeed, the Scaglia Fm. is characterized by a certain amount of clay, mainly in its Cenozoic phase, but in our work, we were interested in defining those surfaces representing important boundaries with respect to the mechanical properties of the geological succession (indeed the Scaglia Fm. shows this properties). The new Figure S.2 shows well the variation of the sonic log (and hence the mechanical properties) along the horizons selected for our database. In conclusion, our top of the carbonate succession horizon represents a mechanical boundary dividing a mainly carbonate succession (below) and a mainly siliciclastic succession (above) even not always defined by the Scaglia Fm. (in some well data, older carbonate formation where directly covered by siliciclastic units). We have now better explained this procedure following the reviewer's suggestion (e.g., see lines 315-317, 372-377, 402-403 596).

2.

Rev. 2: It is understandable, as correctly written in the text, the need of focussing on the main previous studies, selected for extension and detail, however I've missed the pioneering studies on

the Po Plain shallow aquifers (ENI-RER, 1998; ENI-RL, 2002; Irace et al., 2010), which had a great importance in the definition of the most recent surfaces, whose one is possibly your base of the coarse-grained alluvial deposits. Various papers have also been published about this surface (R-surface, e.g., Muttoni et al., 2003; Garzanti et al., 2011; Scardia et al., 2012; Ghielmi et al., 2013).

Authors: We thank the reviewer for pointing out these literature works that are valuable for our model. The new base of the recent continental deposits was implemented and integrated with the isobath map by Scardia et al. (2012) which integrates data from the Emilia Romagna (Regione Emilia Romagna & ENI-AGIP, 1998) and Lombardy Regions (Regione Lombardia & ENI-AGIP, 2002). We have chosen this map over other recent works as it broadly covers the study area, it is highly concordant with well data, and it represents the base of the recent continental deposits. Please see line 424 and elsewhere within the text and in the figures.

3.

Rev. 2: About the surfaces you chose to focus on, I've found the stratigraphic approach not accurate: you define them as geological or lithostratigraphic surfaces, the former term being imprecise and the latter incorrect or not clear. Are they operational surfaces adequate for practical applications or have they been chosen because are more easily recognizable in well and geophysical data? I believe in the second hypothesis, but on the whole the stratigraphic meaning of these surfaces should be addressed more clearly and your choice (lithostratigraphic vs other kind) should be discussed according to the expected application of your dataset.

Authors: We thank the reviewer for the comment. We have properly modified the text following the reviewer's suggestion. Please see lines 118-122, 315-317, 5372-376, 595-596, 400, and comment 1 to reviewer 2.

4.

Rev. 2: Specifically, the recognized surfaces can be considered as sequence boundaries with chronostratigraphic value. In this sense, the reference to Ricci Lucchi (1986) is misleading and obsolete, because it is based on lithostratigraphic units established for ENI operational purposes, and in my opinion not very useful in defining stratigraphic surfaces with chronostratigraphic value or regional extension. It would be more useful to rely on the more recent syntheses of Fantoni and Ghielmi, which frame the old ENI lithostratigraphic units into the modern sequence stratigraphy. For example, the top of the carbonates, even if associated to the top of Maiolica Fm (see my previous comment) or to the top of the Scaglia, can be considered a tectono-stratigraphic sequence

boundary produced by the onset of an Alpine tectonic phase (eoAlpine or neoAlpine, respectively) and the associated pulses of terrigenous input into the basin. Also the base of Pliocene is a tectono-stratigraphic surface (e.g., Ghielmi et al., 2013), which documents the effect of Apennine tectonics on the Po Plain, modifying the geometry of the previous basin.

The most recent surface, which deserves a more detailed discussion, is a climate sequence boundary (R-surface), well defined in the works of the Po Plain aquifers and in the already mentioned following scientific articles.

Authors: We thank the reviewer for the comment. We have better explained the meaning of our subdivision and properly modified the text following the reviewer's suggestion. Please see comments 1-3 to Reviewer 2.

SPECIFIC POINTS

5.

Rev. 2: The magnetic basement is called Variscan (line 307) or Hercinian (lines 148, 152; Fig. 2): the former is preferable and should be used consistently in the text.

Authors: We thank the reviewer for the comment. We have properly modified the text following the reviewer's suggestion. Please see lines 165, 170, and 337.

6.

Rev. 2: For the alluvial deposits you mention as youngest surface the correct term would be "coarse-grained" (not just coarse) and, if we use a sequence stratigraphy approach (R-surface of Muttoni et al., 2003), at east of Ferrara they pass to shallow-water fine-grained marine sediments (Scardia et al., 2012; Ghielmi et al., 2013;) and at Venice they are prodelta turbidites (Muttoni et al., 2018). Lithostratigraphically they would be different units but apparently you are putting them altogether into a same sequence. This is another example about the importance of defining and justifying the stratigraphic approach you want to use and applying it correctly.

Authors: We thank the reviewer for the comment. In our work, we have reconstructed the base of the recent continental deposits. The new surface has been limited in a restricted area, where the base of recent continental deposits was intercepted by wells and/or other public data (Scardia et al., 2012; Regione Emilia Romagna & ENI-AGIP, 1998; Regione Lombardia & ENI-AGIP, 2002. Please see lines 578-581, 600-603, and new Figure 14a

7.

Rev. 2: Line 104: “geological maps”. Perhaps you mean stratigraphic maps or isobath maps, or better use just maps.

Authors: We properly modified the text. Please see line 109.

8.

Rev. 2: Line 146: carbonate substratum. See my comments about Maiolica and Scaglia.

Authors: Please see author’s answer to comment 1 of Reviewer 2. We properly modified the text according to the reviewer’s comment (line 164).

9.

Rev. 2: Line 196: what do you mean with the reference to ENI S.P.A.? It is not in the reference list and it is not clear. Anyway, I agree with your discussion about the formal base of the Quaternary period, but the point here is how ENI defined the base of Quaternary in its wells. As far as I know, ENI’s base of Quaternary was defined by the FO of Hyaline balthica in the Mediterranean Sea following the recommendations of the 18th International Geological Congress (London, 1948; see for example discussion in Gradstein et al., 2012, p. 980). By the way, the FO of H. Balthica in the Po basin has been recently dated at ca. 1.9 Ma (Monesi et al., 2018) in the Arda River series. On the whole, you should discuss what you use actually as base of Quaternary also according to the stratigraphic data you’re including in your dataset.

Authors: We thank the reviewer for the comment. We modified the text according to the reviewer’s comment using the term Calabrian Base instead of Pleistocene Base (similarly to what has been presented in Toscani et al., 2016). Please see lines 217-219 and elsewhere within the text and in the figures.

10.

Rev. 2: Line 213: geologic maps, see my previous comment

Authors: We properly modified the text. Please see line 232.

11.

Rev. 2: Line 547: the typical Carbonate succession top in the Po basin is the top of Maiolica Fm (e.g., Fantoni and Franciosi (2010). The one you are using is the top of Scaglia Rossa. Actually, the Gallare Marls are also known as Scaglia Cinerea/Variegata on correlated exposures in the Alps and Apennines.

Authors: Please see author's answer to comment 1 of Reviewer 2. We properly modified the text according to the reviewer's comment (please see lines 315-317, 372-377, 402-403 596).