Supplementary data text C

In this section, we will provide some additional comments about terrace mapping of certain areas. Information is also contained within the GIS layers of the terrace maps, provided within the data repository (e.g., Fig. C.1).

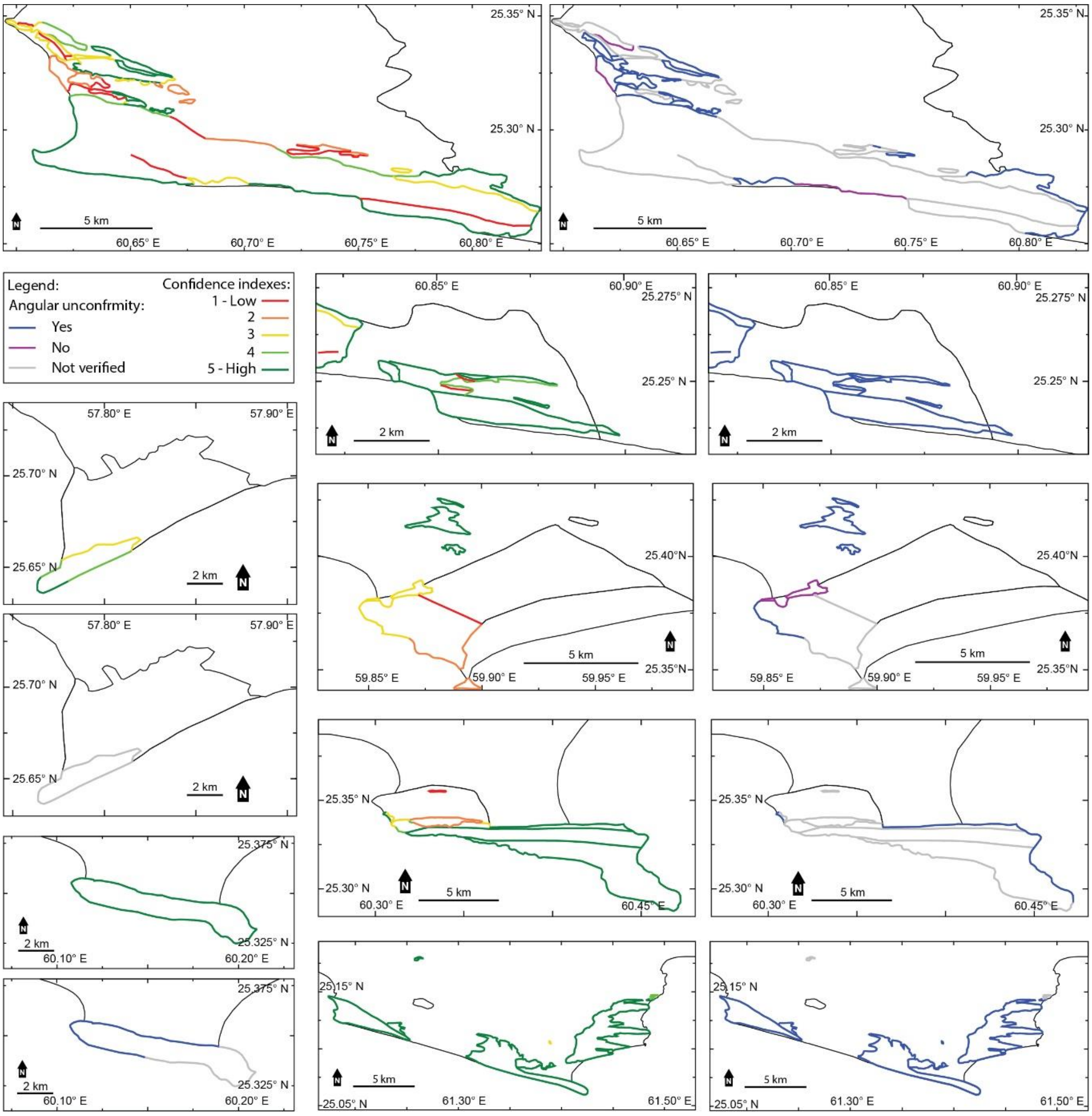

Figure C.1. Example of metadata found within the GIS layer of Makran terrace maps. Here, confidence indexes on terrace borders and angular unconformity between the Tertiary bedrock and the terrace deposits.

1 Jask

We briefly visited Jask terrace and sampled its south-westernmost corner, where the best outcrops of terrace deposit are located. The terrace is situated very close to the current sea-level, therefore the wave-cut surface of the terrace and the bedrock below was not visible. Although it is difficult to precisely map the terrace boundary because of urbanization of the area, our interpreted terrace boundaries are well visible on the DEM. We interpret the Jask peninsula as a tombolo, similar to Konarak or Gurdim, with the terrace deposits acting as the resistive tip.

2 Tang

At Tang, T3 is an obvious terrace, standing as an isolated flat-topped platform surrounded by the low-lying coastal plain. There is an isolated portion of terrace to the south that we interpreted as being part of T3, because the topographic profile through both terraces seem to match (Fig. 4d). The two lower surfaces (T1 and T2) mapped in Fig. 4a are interpreted as terraces. However, bedrock bedding is nearly horizontal in this region, meaning that they could potentially be structural terraces. We did not have any dated samples from this region, but we assigned them to MIS 5a, 5c and 5e, in line with other dated terraces in Makran. This fits a constant uplift scenario of ~0.5 mm/y. We indicate the possible presence of normal faults bordering the sandstone bedrock outcrops, similar to what was observed in Chabahar and Lipar (see below).

3 Konarak

Konarak peninsula is interesting in terms of marine terraces; it presents three to four main terrace levels very well delimited in the east (Fig. 5g). Because it is a restricted area, most of this region could not be visited in the field. However, previous terrace mapping works on Konarak peninsula are available (Little, 1972; Page et al., 1979; Snead, 1993). We used these maps, satellite imagery and DEM to complete our map. Due to Human extraction of sandstone blocks (used to build breakwaters for harbors along the coast), the western part of the terrace area is damaged and difficult to map (Fig. 5g). The reader is referred to the early work of Page et al., 1979 for more details in this area. Little, 1972 and Snead, 1993 interpreted the lower terraces to be a unique surface down-faulted along several east-west striking normal faults. Since south dipping normal faults are common along the Makran coast, we investigated this idea by boating along the easternmost cliff of the peninsula, were we did not observe any faults cutting through the shale bedrock. Therefore, we favor the idea of Page et al., 1979 who interpreted several terrace levels. Konarak T3 (MIS 5e) has a slightly lower uplift rate (Fig. 5i) but this value is a minimum since the shoreline angle is eroded. Overall, the terrace altitudes fit very well in a scenario of increasing uplift rates towards the east, from 0.25 to 0.75 mm/y as well as continuous uplift during terrace development, attested by the increasing tilt as terraces get older.

4 Chabahar and Ramin

The Chabahar and Ramin terraces are built on tertiary sandstone bedrock. The bedding of the bedrock is sometimes subhorizontal, making it difficult to differentiate marine terraces from structural terraces. Although it is not on the terrace map, we visited the northern part of Chabahar headland and we believe that it does not host any marine terraces, but rather some structural terraces. We also observed that the headland is bordered by large faults (Fig. C.2). Field evidences point towards normal fault movement, which implies that the currently topographically prominent headland is actually a down-faulted block (Fig. C.2 inset). We explain this by differential erosion between the easily erodible footwall (shale lithology) and the resistive hanging wall (sandstone lithology). The headland itself is cut by numerous normal faults.

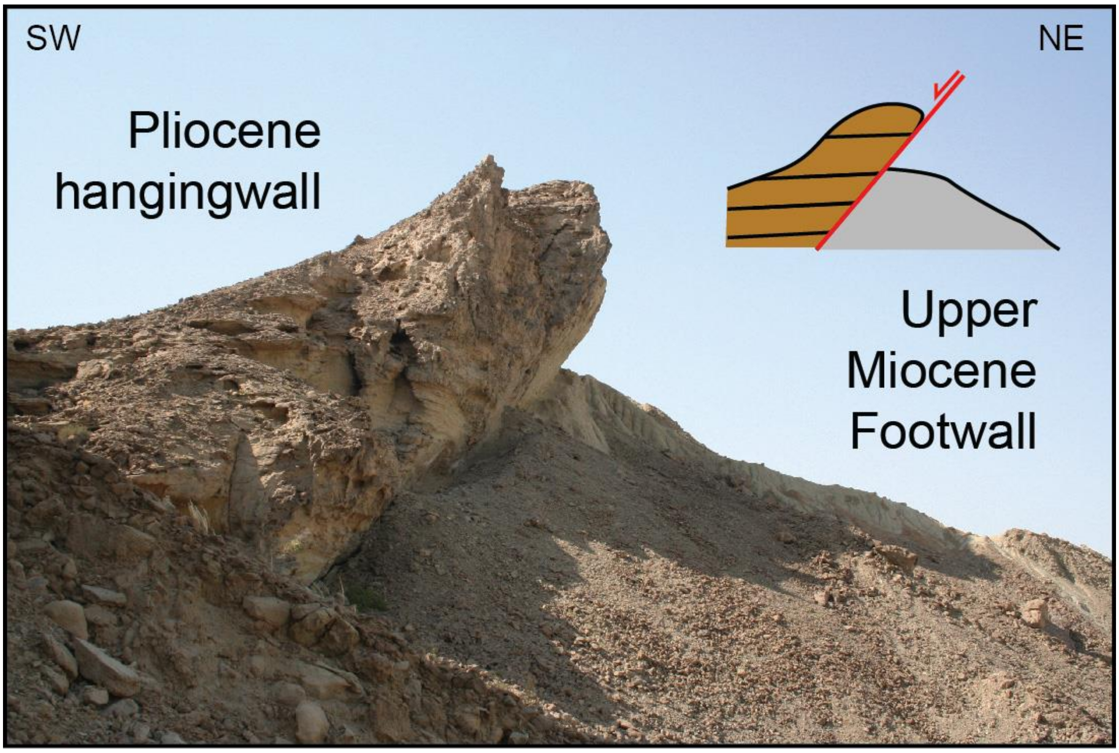

Figure C.2. Major normal fault bordering Chabahar headland. Notice how the footwall, made of erodible shale, is topographically lower than the resistive hangingwall (25.387341° N, 60.718375° E). Ages of the formation from the 1:100'000 geological map of Chabahar (Samadian et al., 1996).

Terrace mapping in Chabahar and Ramin was additionally complicated by anthropogenic disturbances. The region is highly populated and urbanized, moreover the westernmost tip of the headland is a restricted area. Exploitation of rock quarries also has degraded several terraces, notably the eastern part of Chabahar T5 and all Ramin upper terraces (T2-T3-T4-T5).

The Ramin terraces are built on a major south dipping normal fault system (Fig. C.2). The region north of the Ramin (terraces T3-T4-T5) is very complex due to the presence of numerous normal faults, a nearly horizontal bedrock bedding, but mostly to the highly degraded state of the terraces due to anthropogenic rock extraction. We mapped what we believe are terrace limits based on DEM, old satellite imagery (shot before rock extraction) (a 2005 image of Google earth and from Little, 1972) and field evidences such as boulder deposits and angular unconformities. However, the mapping of T3, T4 and T5 and their MIS assignment remains highly speculative. In the eastern portion of the map, numerous south dipping normal faults offset the terrace deposits (offset of up to 50 m for Ramin T2) (Fig. 6d). We have mapped Ramin T1 and T2 as two separate terraces, based on our dating. However, it is still not clear whether the morphological step between them is a shoreline angle or a normal fault (Fig. C.3). It is not always straightforward to differentiate between a paleocliff and a normal fault, especially considering that it can be both at the same time.

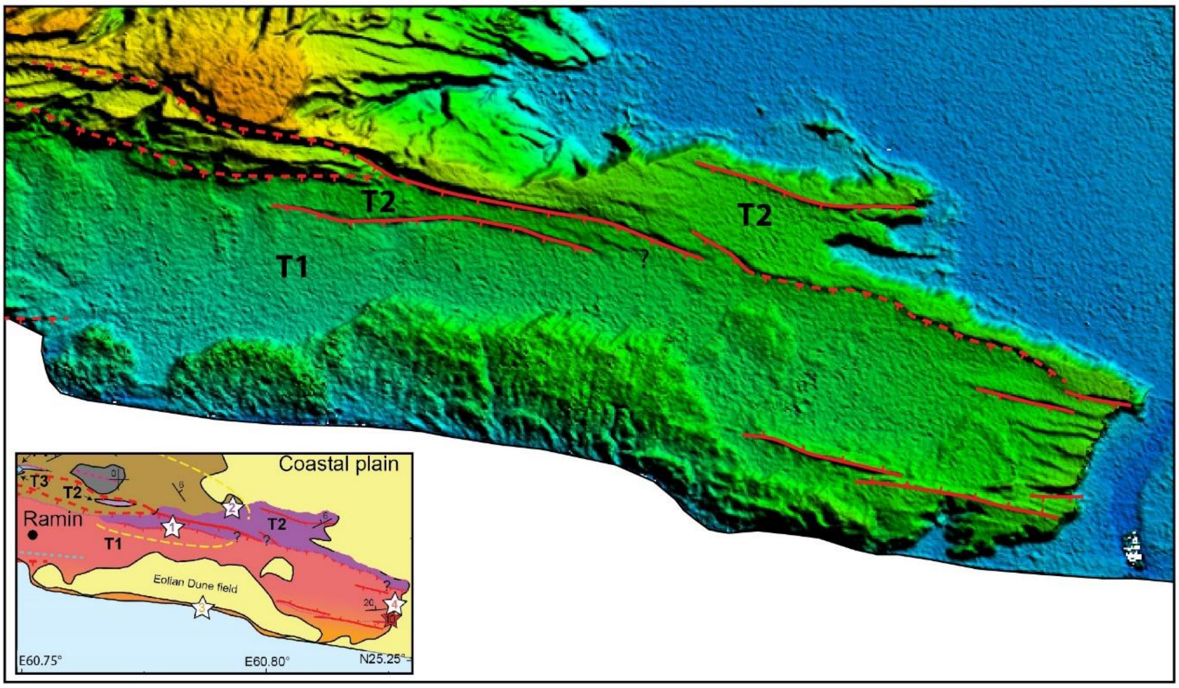

Figure C.3. Ramin region DEM with interpretation of faults and terrace limits. Inset, corresponding corner of the Map (Fig. 6a).

5 Lipar

At Lipar, we find 4 terrace levels. The sandstone bedrock bedding is dipping north by ~20°, which emphasize the flat marine terraces in the landscape (Fig. C.4). Lipar T3 altitude profile is offset twice due to normal faults that we observed on the field. Note that these faults have their southernmost tip in the valley that runs between the north and southern part of T3, hence they do not cross cut T1 (Fig. 4f). These faults cause a shift in uplift rate of T3, but the general trend of uplift increase towards the east remains the same as T1 (the uplift slopes of the portions of T3 and that of T1 in Fig. 4h stays the same). T4 has a lower uplift rate, although it is also located on the footwall of the fault affecting T3. However, the shoreline angle is eroded and the altitude we used for uplift calculation probably fairly underestimates the real shoreline angle altitude.

Figure C.4. Lipar terraces, built on a northward dipping bedrock (25.256597°N, 60.862178° E, looking east).

6 Unstudied terrace areas

To complete the uplift profile along the Makran presented in Fig. 10, a further study of Pakistani terraces is needed. Pakistani marine terraces are present at Jiwani (25.05°N, 61.78°E), Pishukan (25.14°N,62.07°E), Gwadar (25.1°N, 62.31°E), Ras Shamal Bandar (25.25°N, 62.89°E), Astola Island (25.12°N, 63.85°E) and Ormara (25.17°N, 64.62°E). In Iran, the uplift profile through the eastern part of the Iranian Makran is relatively continuous, owing to the abundance of marine terraces in this area. However, the western part of the Iranian Makran is rather bare of terraces except for Jask (discussed in this paper, Fig. 5a), Meydani terraces (25.45°N, 59.03° E) and a single terrace at Derangou, 25km northwest of Tang (25.445 °N, 59.65°E).

As seen previously, the eastern and western Makran seems to have different seismic behavior (Byrne et al., 1992). However, both segments host marine terraces (Fig. 1). A study of the Pakistani marine terraces would be interesting to get more insight on the long-term tectonic behavior of the eastern Makran to be able to compare it to the western segment, presented here.

References:

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