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Discussions

Interactive comment on “Location of the River Euphrates in the Late Miocene; dating of terrace gravel at Shireen, Syria” *by* T. Demir et al.

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Reply to interactive comment by J. Vandenberghe on “Location of the River Euphrates in the Late Miocene; dating of terrace gravel at Shireen, Syria”

by

Tuncer Demir, Malcolm Pringle, Sema Yurtmen, Rob Westaway, David Bridgland, Anthony Beck, Keith Challis, and George Rowbotham

Introduction

Professor Vandenberghe was one of the reviewers of our Demir et al. (2006) manuscript. His review (submitted in November 2006) said that the manuscript was

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fine and that more detailed comments would follow. Thus the Vandenberghe (2007) interactive comment is presumably the more detailed critique that was promised in November 2006; the main points raised are accordingly addressed below.

Discussion point 2

Professor Vandenberghe questions the main objectives of the manuscript. To clarify, we report on gravel of the River Euphrates, capped by basalt that is Ar-Ar dated to ˜9 Ma, at Shireen in northern Syria. This gravel, preserved by the overlying erosion-resistant basalt and also given an age constraint by this relationship, allows us for the first time to reconstruct the history of this major river during the Late Miocene.

Discussion point 3

Professor Vandenberghe complains that insufficient documentation has been provided for our Ar-Ar date for the ˜9 Ma basalt at Shireen; he thus infers that this date might not be reliable. On the contrary, we have provided full documentation of the date in our online supplement. In addition, we have summarised key information in the main text and in Fig. 5. For instance, we have discussed the context of the date by noting that the degree of weathering of the Shireen basalt is similar to that of other Late Miocene basalts in the wider region; there is consequently no basis for supposing it to be younger. We can now also cite the synthesis by Bridgland et al. (2007) of the age-control evidence for the Late Miocene volcanism in neighbouring parts of southeastern Turkey.

We have found the online supplement to be frequently inaccessible due to technical problems, so we are uncertain whether Professor Vandenberghe was able to download it before writing his interactive comment. The sequence of preparation steps that we followed (summarised in the caption to Figure 5, which cites references that explain the procedure in much more detail), for the basalt sample, was intended to reduce, if not eliminate, the principal potential source of error in dating using the K-Ar system, the presence of "inherited" radiogenic argon in phenocrysts. As explained previously (e.g., Singer and Pringle, 1996; Harford et al., 2002), the Ar-Ar step-heating method of analysis that has been used permits multiple age-determinations to be made on any sample, thus enabling robust cross-checking of the results. For the present sample (see Fig. 5 of Demir et al., 2006) we thus have:

Total Fusion age: 8936.6 +/- 57.7 ka (+/- 2 sigma; +/- 0.65%);

Weighted Plateau age: 8809.2 +/- 72.6 ka (+/- 2 sigma; +/- 0.82%);

Normal Isochron age: 8838.0 +/- 115.8 ka (+/- 2 sigma; +/- 1.31%);

Inverse Isochron age: 8826.9 +/- 114.1 ka (+/- 2 sigma; +/- 1.29%);

In accordance with previous recommendations (e.g., by Harford et al., 2002), we regard the weighted plateau age-determination as the definitive age of the sample. Nonetheless, it can be seen that all four of these age-determinations are concordent at the +/- 2 sigma level (i.e., at the 95% confidence level); furthermore, their +/- 2 sigma uncertainties are all ˜1% or better. The methods used to calculate these ages are explained in standard texts, such as by McDougall and Harrison (1999), and so require no elaboration. The age calculations have assumed the decay constants from Steiger and Jäger (1977); the assigned age of 28.34 Ma adopted for the Taylor Creek Rhyolite sanidine standard, used to calibrate the neutron flux during sample irradiation, is from Renne et al. (1998).

A further check of the internal consistency of this Ar-Ar dataset can be made by inspection of the normal and inverse isochron graphs (provided in the online supplement). The y-intercepts of these graphs give estimates of the 40Ar/36Ar isotope ratio in the atmosphere at the time of eruption, which can be compared with the present-day value of 295.5. The normal isochron yields a value of 273.7 +/- 59.4 (+/- 2 sigma); the inverse

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isochron yields 283.3 +/- 58.4 (+/- 2 sigma). The iterative statistical procedure used for fitting these isochrons has been explained previously (e.g., Singer and Pringle, 1996; McDougall and Harrison, 1999; Harford et al., 2002). The fact that the estimated atmospheric 40Ar/36Ar isotope ratio at the time of eruption does not differ significantly from the present-day value justifies our use of the present-day value in the Total Fusion and Weighted Plateau age-determinations.

On the basis of all these objective criteria, we consider our Ar-Ar date to be reliable, within the stated error margins.

Discussion point 4

Professor Vandenberghe queries the basis whereby we have inferred that Euphrates terraces QfII and QfIII in the Shireen area date from MIS 12 and 22. As explained in our text, this is based on downstream projection of the river terraces from the Birecik area, based on an existing age model for the terraces in that area and assuming southward tapering of regional uplift. The basis of these assumptions can be ascertained from the references that are cited. We could instead have used the terrace age-model for this region from Sanlaville (2004), which is based on the assumption that there has been no lateral variation in the vertical crustal motion anywhere along the Euphrates within the Arabian Platform. Using this alternative scheme, terrace QfII would be assigned to MIS 8 and terrace QfIII to MIS 12. However, we consider this combination of ages unlikely, because it would imply much faster incision and uplift in the Shireen area between MIS 12 and 8 and between MIS 8 and 6 than since MIS 6.

The assumption that the existing chronology of the Euphrates terrace staircase in the Birecik area is valid has underpinned much recent discussion (e.g., the analysis by Westaway et al., 2006). It should be noted that there is no age control at Birecik from absolute dating, there having been no local Quaternary volcanism. Given the significance of the Birecik succession, work is currently in progress to reappraise it, but is not yet complete. It is conceivable that the outcome of this reappraisal may be that the existing terrace age-model at Birecik is wrong, and Sanlaville (2004) may be correct that there is no significant tapering in uplift between Birecik and Shireen; the view might thus emerge that Euphrates terraces QfII and QfIII date from MIS 12 and 22 at both Birecik and Shireen. It should thus also be noted that Demir et al. (2006) referred to the present age assignments for these terraces as “tentative”. The MIS 6 age assigned to Euphrates terrace QfI, from Kuzucuoglu et al. (2004), is based on the argument that only a single interglacial palaeosol, considered to represent MIS 5e, has developed in the fluvial deposits of this terrace, which were formerly exposed upstream of Birecik but are now flooded by the Birecik hydroelectric reservoir. Terrace QfI can be assumed to be correctly correlated between the Birecik area and the Shireen area, as before the valley was flooded (by the Birecik, Kargamis; and Tishreen reservoirs) extensive spreads of fluvial deposits, assigned to this terrace, were present, more-or-less continuously, between these localities.

Figure 2 of Demir et al. (2006) has been labelled with terrace ages consistent with the Sanlaville (2004) scheme, which we originally adopted for the purposes of illustrating this paper, making it inconsistent with the labelling applied to Figure 3 of Demir et al. (2006). We now realise that the Sanlaville scheme is probably incorrect and so new (and consistent) versions of Figures 2 and 3 will be provided in the final version of this paper. None of this has anything at all to do with our dating of the Shireen basalt and our consequent inference of the location of the River Euphrates in the Late Miocene; the original reason for mentioning the Pleistocene terraces of the Euphrates in the Shireen area was their appearance on our map and cross section, which are intended mainly to show the disposition of the Late Miocene rocks (Figs 2 and 3 of Demir et al., 2006).

Given that we have been asked to clarify our thoughts regarding the Pleistocene terraces of the Euphrates in the Shireen area, so as to fix any inconsistencies in the description by Demir et al. (2006), some additional comment now seems appropriate.

First, the terraces designated as Qf0 and QfI by Sanlaville (2004) are now flooded, throughout this study area, by the Tishreen reservoir. The heights of these terrace deposits, quoted by Demir et al. (2006), have thus been taken from the existing literature; we have no means of verifying them. For the older terraces, we have attempted to reconcile the information published by Besançon and Sanlaville (1981), Oguchi (2001), and Sanlaville (2004), based on investigations carried out before the valley was flooded, with the SRTM dataset now available and with original field information. Such comparison is made difficult because maps published by Besançon and Sanlaville (1981) and Sanlaville (2004) have no co-ordinates and a minimum of location information, and publiished field descriptions lack detail, for instance, as to whether heights quoted for the tops of Euphrates terraces mean the top of fluvial gravel or of overlying sand or loam. Nonetheless, the principal deposit assigned to terrace QfIII by Sanlaville (2004), reported east of the village of Jaada, can now be seen to correspond to the expanse of fluvial deposits depicted near the NW corner of Fig. 2 of Demir et al. (2006). Comparison of outcrop information and SRTM imagery indicates that the base of this deposit is ˜330 m a.s.l., for instance c. [DA 300 558], and its top is ˜370 m a.s.l. over an extensive area, for instance c. [DA 296 582], rising locally to ˜375 m a.s.l., c. [DA 301 575], or ˜70 m above the local low-stage pre-dam river level. This deposit is thus ˜45 m thick; it presumably accumulated at a time when the rate of surface uplift was low, such that the Euphrates was required to aggrade in order to maintain its gradient in response to the downstream channel-lengthening that accompanied the retreat of the sea from the northern Arabian Platform. Our inference that the upper surface of terrace QfIII dates from MIS 22 implies that this span of time was in the Early Pleistocene. Second, Sanlaville (2004) reported an expanse of deposits of Euphrates terrace QfII, extending westward, upstream, from Jaada along the left side of the Euphrates valley for ˜5 km to Qubbah. Near the western end of this expanse, at a point that we estimate to be c. [DA 258 592] (by comparison of map 2 of Besançon and Sanlaville, 1981, with the SRTM imagery in our online supplement) the top of this expanse was reported by Besançon and Sanlaville (1981) as at 354 m a.s.l., thus ˜44 m above the local low-stage pre-dam river level. Near its eastern end, west of Jaada, this deposit is now exposed in a quarry, at [DA 28131 59503], where Euphrates gravel can be seen to be overlain by ˜8-10 m of loam. From the SRTM imagery, the top of the gravel in this area is ˜345 m a.s.l., or ˜39 m above modern river level. The base of this gravel is below the modern reservoir level of ˜325 m a.s.l. It is unclear whether this gravel is the basal part of the QfIII gravel that crops out nearby, or a younger gravel that is banked against it. Finally, the fluvial deposits depicted in Fig. 3 and near the SW corner of Fig. 2 of Demir et al. (2006) were not reported by Besançon and Sanlaville (1981) or Sanlaville (2004). The SRTM imagery indicates that the deposit in the left side of the Euphrates valley, c. [DA 340 400], reaches ˜350 m a.s.l. and that the deposit on the right side of the valley, c. [DA 342 442], reaches ˜355 m a.s.l. and is at least ˜20 m thick. On the basis of height, we regard the surface of these deposits as forming part of terrace QfII; however, whether this terrace facet is cut into the basal part of the QfIII terrace deposits or is formed in younger deposits is yet to be established.

Taking the reference level for estimating incision as 7 m above present low-stage pre-dam river level, with the above set of terrace heights and the inferred set of terrace ages, we estimate 63 m of incision since the deposition of the sediments now forming terrace QfIII (at a time-averaged incision rate since MIS 22 of ˜0.072 mm/a) and 32 m of incision since the Euphrates was at the level of the top of the gravel, assigned to terrace QfII, at Jaada (at a time-averaged incision rate since MIS 12 of ˜0.076 mm/a). These incision rates are close to the estimates since MIS 6 and 2, made by Demir et al. (2006) using the heights of terraces QfI and Qf0. The rough uniformity in incision rates, predicted during the Middle and Late Pleistocene, provides an indication that the suggested terrace chronology is reasonable. In the final version of our paper, the text and all illustrations will be consistent with this terrace scheme.

Professor Vandenberghe also queries our explanation for the lack of net fluvial incision in the Shireen area between the Late Miocene and late Early Pleistocene. Setting aside the incision to the base of the QfIII terrace deposits, followed by the subsequent

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aggradation (noted above), we attribute this minimal net incision to the progressive downthrow on fault F2, which is marked on Fig. 2 of Demir et al. (2006). This fault is presumed (like many others in the northern Arabian Platform; e.g., Chaimov et al., 1990; Brew et al., 1997; Litak et al., 1997; Coskun and Coskun, 2000) to have been active at some stage between the Late Miocene and Middle Pliocene; it can be seen in Fig. 2 to have offset and warped the local Miocene and older stratigraphy. On the upthrown side of the fault the Euphrates has incised into Eocene limestone, whereas on the downthrown side it has only reached the stratigraphically overlying Oligocene limestone. Using the geological map and the additional topographic information in the online supplement, the overall amount of downthrow and structural warping across this fault can be estimated at ˜100 m. Assuming all this deformation has occurred since ˜9 Ma (because the flow of the Shireen basalt was not directed in the down-dip direction that now pertains as a result of this warping), the Shireen basalt and associated gravel would be ˜100 m higher than they now are, or ˜170 m above the Euphrates. Their dispositions would thus not be anomalous in relation to the Pleistocene river terraces.

Of considerable significance, Professor Vandenberghe also appears to be disputing the idea that, for the Euphrates, the observed incision may dramatically underestimate the amount of regional uplift, because of the dramatic downstream channel lengthening that has occurred, as the coastline has regressed from a position near Kahramanmaras; in SE Turkey in the Middle Miocene and in northern Syria in the Late Miocene (illustrated in Fig. 1 of Demir et al., 2006) to its present position at the head of the Persian Gulf, a total distance of ˜1500 km. The ˜9 Ma Shireen gravel is at ˜370 m a.s.l., and would be something like ˜470 m a.s.l. if the subsequent local warping had not occurred (see above). We estimate that Shireen was not far - say ˜100 km - upstream of the contemporaneous coastline. The Euphrates palaeo-gradient between this point and the coastline was probably very low, and so its change in height between these points can be neglected in this approximate calculation. If any subsequent global sea-level fall is also neglected, some ˜470 m of uplift can thus be estimated at Shireen since ˜9 Ma. For comparison, west of Shireen, Early Miocene marine limestone and Middle

Miocene marine clastics are both found at up to ˜500 m a.s.l. (see Fig. 2 of Demir et al., 2006), and would probably be somewhat higher if the localised warping in the Shireen area had not occurred. However, their disposition is in agreement with the calculation using the Shireen gravel; thus, ˜470 m seems a reasonable estimate for the component of regional uplift in the Shireen area since ˜9 Ma.

In contrast, the estimated incision by the Euphrates in this area (after correction for the localised warping) is only ˜170 m; the difference between this value and the ˜470 m uplift estimate equates to the modern river level of ˜300 m a.s.l. (see Fig. 4 of Demir et al., 2006). It should thus be clear that any meaningful calculation of the Late Cenozoic uplift in this area has to take into account the downstream lengthening of the Euphrates channel, which has caused the observed fluvial incision to dramatically underestimate the contemporaneous uplift. If, instead, the coastline had remained in the vicinity of Shireen, the Euphrates would now have to flow locally just above modern sea-level, and would thus have been required (in order to keep pace with the regional uplift) to have incised some ˜300 m deeper. Use of corrections such as this to convert fluvial incision into uplift, where downstream river channels have lengthened (or shortened) over time is a standard technique that has been widely used before (e.g., Maddy et al., 2000; Westaway, 2001; Westaway et al., 2002; Westaway and Bridgland, 2007). The scale of the Late Cenozoic coastal retreat in the northern Arabian Platform has caused the magnitude of the correction to be much greater than is typical elsewhere, although the principle underlying such a correction is unaffected.

Professor Vandenberghe is asking us to do much more detailed calculations than the above, taking into account how the downstream gradient of the Euphrates channel might have varied spatially and over time. Such calculations are currently impossible, given the data at present available, it being clearly evident (for instance) that we have only one point where we know the location and altitude of the Euphrates in the Late Miocene and so have no basis for calculating its gradient at this time. To do this accurately requires detailed evidence of former channel courses, which is rarely preserved for anything earlier than Middle Pleistocene. However, it is feasible to estimate the overall difference between incision and uplift in the Euphrates since ˜9 Ma, as the above calculation shows.

Technical comment

During the review stage, the other reviewer made a number of helpful suggestions regarding improvements to Figure 1 of Demir et al. (2006). These were taken on board, and the Figure was duly improved. We wonder whether Professor Vandenberghe, who is now also requesting improvements to this Figure, has only seen the original Figure 1, as was submitted for review, rather than the current version. The Figure shows the location of the River Euphrates at different times in relation to the study region, together with other relevant information. The information shown includes the modern geometry of major active faults in the region (to demonstrate that these are distant from the study locality and thus do not affect it), and uplands that developed over blind reverse faults that were active beforehand (in the Late Miocene - Early Pliocene) to demonstrate that the Shireen area is one of many parts of the Arabian Platform that was affected by such deformation.

Conclusions

It is our understanding that the aim of this journal is to facilitate rapid publication of short papers. To accommodate Professor Vandenberghe's critique in full would be to turn what is currently a short paper, on a well-defined topic, into a much longer paper covering other topics that are peripheral to the main aim. Many of his points are already covered by the material that has been provided in the online supplement. The inclusion of this supplementary material is thus warranted, but the manuscript would not benefit from moving it into the main text. We are grateful for the interest in our work this comments reveal and hope that, by summarising some of these issues here and noting and resolving the labelling inconsistencies between Figs 2 and 3 of Demir et al. (2006), we have satisfactory answered his queries.

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