Bunch et al. (2021) "*A Tunguska sized airburst destroyed Tall el-Hammam a Middle Bronze Age city in the Jordan Valley near the Dead Sea.*"[1]

https://www.nature.com/articles/s41598-021-97778-3

EXPLANATION OF CHANGES IN CORRECTED PAPER

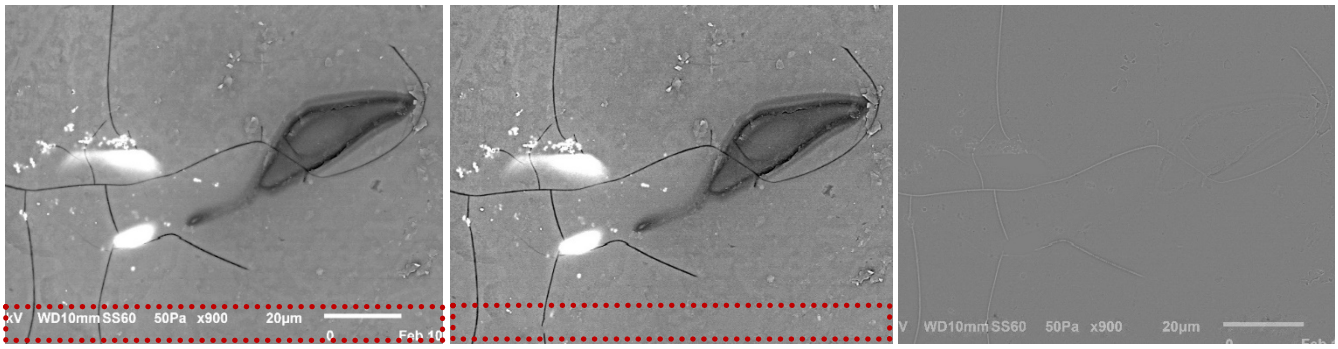
ACCEPTABLE CHANGES: We cropped the borders of many images, often including the bottom legends, and we replaced the cropped scale bar with a new one. No essential data were concealed. All figures were adjusted for brightness, contrast, tone balance, and sharpness, all of which were applied globally across individual images. In addition, cathodoluminescence images were merged from separate red, green, and blue images (RGB channels). As is common practice, each RGB channel was separately adjusted for brightness, contrast, tone balance, and sharpness, all applied globally across individual images. *Scientific Reports* and all other journals accept these types of alterations.

In some cases, we reused a cropped and/or rotated but otherwise unaltered portion of one image elsewhere in the paper. This was done without the use of cloning. All of this falls within the guidelines of acceptable practices by *Scientific Reports*. Cropping is acceptable in all journals as long as only insignificant details are cropped. Examples include Figs. 11a and 43a; 22a and 31a; and 38g and 51e.

UNACCEPTABLE CHANGES: The authors misinterpreted the Instructions to Authors, in which *Scientific Reports* writes that "*a certain degree of image processing is acceptable,*" including cropping, as long as the final image "*correctly represents the original data.*" However, they also add that the use of a cloning tool is not permitted. Thus, some image alterations in Bunch et al.[1] were inappropriate. After an extensive investigation, the journal concluded that the alterations were for cosmetic purposes, did not alter crucial data, and thus, did not change the conclusions of the paper. We replaced them with the originals, and *Scientific Reports* published a new version of the paper with corrected images.

Example #1. For Fig. 31a and about 80% of the improperly altered images in the paper, we used a cloning tool to cosmetically remove the bottom legends of images. We did this so that the image would fit the available space in multi-panel figures and would be as large as possible for readers. For the corrected figures, we fit the entire image with bottom legends into the panel space.

Fig. 31a, original | Altered to remove legend | Inverted overlay



Example #2. At the time of publication, an original unannotated version of the Fig. 3 photo could not be located by the staff of the Tall el-Hammam Excavation Project, who were not co-authors. So, we used a cloning tool to cosmetically remove annotations placed on the photo for a conference presentation. This photo and similar photos below follow the same pattern from left to right: (1) the original, (2) the altered version, and (3) an inverted overlay to highlight the changes. The overlay was created by inverting the altered version in Photoshop and overlaying it over the original at half transparency. Identical areas cancel and turn gray, allowing areas of difference to stand out. Later, the site excavators found the original and it is published in the corrected version of the paper.

Fig. 3, cropped original Altered to remove notations Inverted overlay

Example #3. The annotated Figure 44c of the skeleton (left panel below) was provided by official photographers of the Tall el-Hammam Excavation Project (TeHEP). It is listed below as the "uncropped original," because an unannotated original is not available. We used a cloning tool to remove the label (right panel below). There were no directional arrows on the original photographs, and so, project archaeologists represented to the authors that the view in the photo is to the north and based on that, we removed the caption and added the N arrow (middle panel below).

A commenter on PubPeer questioned the direction based on the shadows, and so, we again questioned the TSU archaeologist, who realized that he had been mistaken and that the actual direction was approximately south. We checked the metadata of the attached original photo and confirmed that the southerly direction is roughly correct based on the shadow direction and timestamp. We did not add any arrows to the corrected photograph because the southerly direction is only approximately known.

Fig. 44c, original Altered to remove label Inverted overlay

Example #4. For several photos (4c and 4d) taken by co-authors, we used a cloning tool to cosmetically remove the tape measures because they are illegible. Depths are described in detail in the manuscript.

Fig. 4c, original | Altered to remove tape measure | Inverted overlay

Photo 4d was altered the same as 4c.

Fig. 4d, original | Altered to remove tape measure | Inverted overlay

Example #5. Several photos (7c and 7d) were provided by the staff of the Tall el-Hammam Excavation Project, who were not co-authors. For cosmetic reasons, we used a cloning tool to remove the red N arrows and we replaced them with NE arrows, indicating the direction of debris flow.

Fig. 7c, original | Altered to remove red N arrow | Inverted overlay

Fig. 7d, original | Altered to remove red N arrow | Inverted overlay

Example #6. Figures 10a-10d were provided by a co-author. For cosmetic reasons, we used a cloning tool to remove the fingers and labels on the pieces of pottery.

Fig. 10a & 10c. Original | Altered image to remove fingers | Inverted overlay

Example #7. In Figures 14a, 14b, and 28a, the background had visible flaws, and so, for cosmetic reasons, we used the cloning tool to remove the flaws (yellow arrows below) and part of the blue background. For the corrections process, we replaced the published photos with new ones.

Fig. 14b. Original | Altered image to remove flaws | Inverted overlay

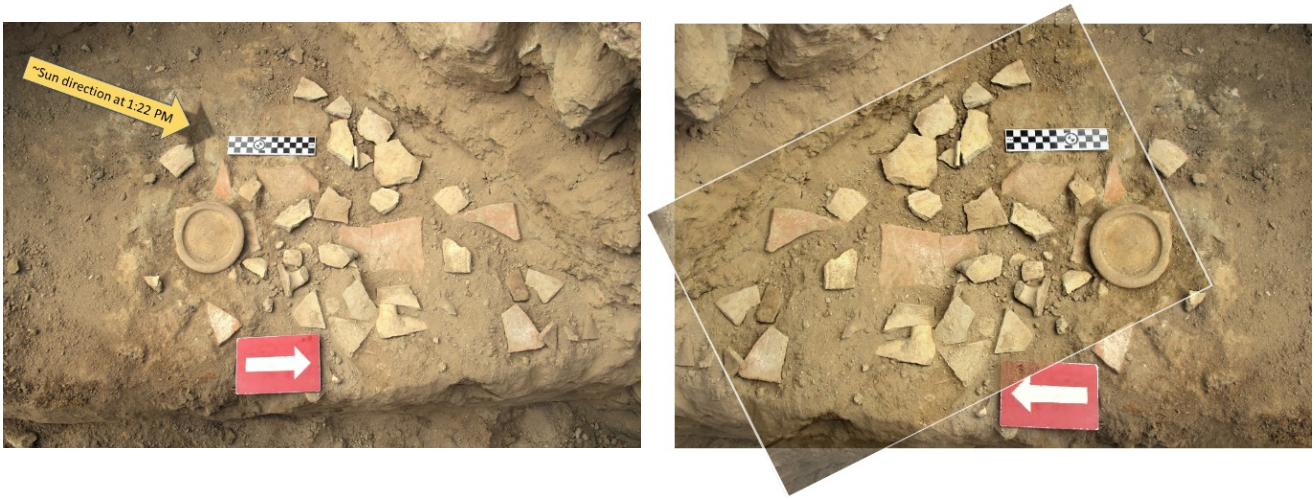
Example #8. For cosmetic reasons in Fig. 15b, we used a cloning tool to remove the partially visible N arrow and replaced it with a NE arrow. We also rotated the image to make the potsherds as large as possible for better visibility. At Tall el-Hammam, the average directionality of debris from SW-NE was determined by the archaeologists from Trinity Southwest University using 15 years of photos, observations, and field notes, which are not part of this study. The compass directions of lines of debris (e.g., trails of potsherds and charred grains) were used to determine an average direction. Their conclusions were provided for this study and confirmed through on-site inspections of selected excavations by four co-authors.

The energy of the proposed blast wave appears to have been redirected by substantial obstructions, including the 4-story palace, ramparts, foundations, and cross-walls. Even though the average direction of the blast wave was SW-NE, intra-city obstructions caused the blast wave to follow the path of least resistance through open areas between walls and down city streets. Blast directions trended typically SW-NE but often varied by approximately ±30°, such as when the blast wave encountered cross-walls.

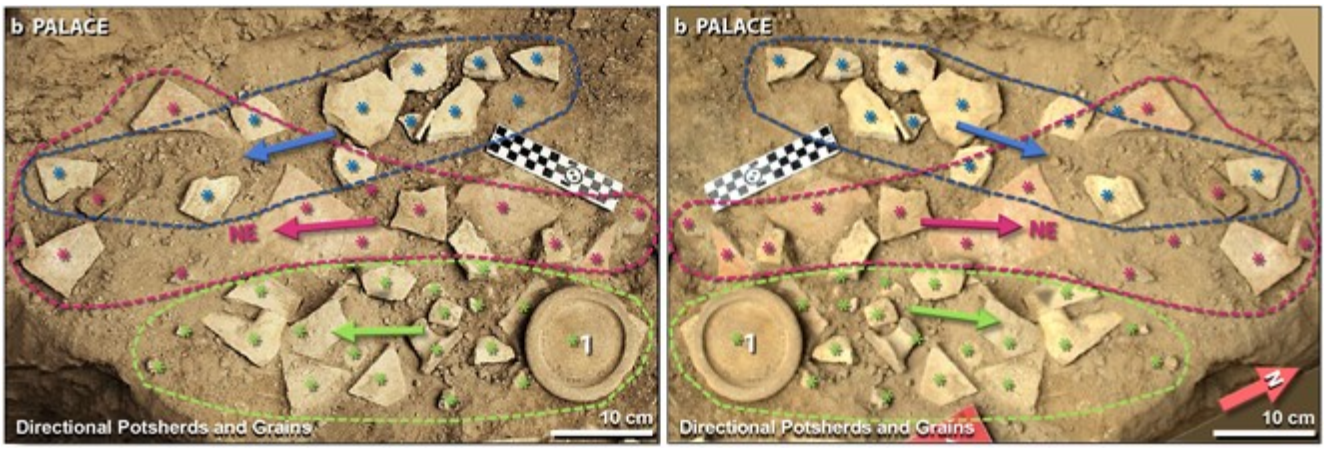
Fig. 15b. cropped, rotated original | Altered image | Inverted overlay

In addition, Fig. 15b was flipped horizontally for cosmetic reasons (two images below). We recognize that this was inappropriate, but doing so did not change any crucial data. For the original photo (left below), the timestamp indicates that the image was taken at 1:22 PM with a corresponding sun direction shown by the yellow arrow. This confirms the N arrow and NW direction as being correct.

Fig. 15b. Original with sun direction shown Cropped and flipped photo horizontally

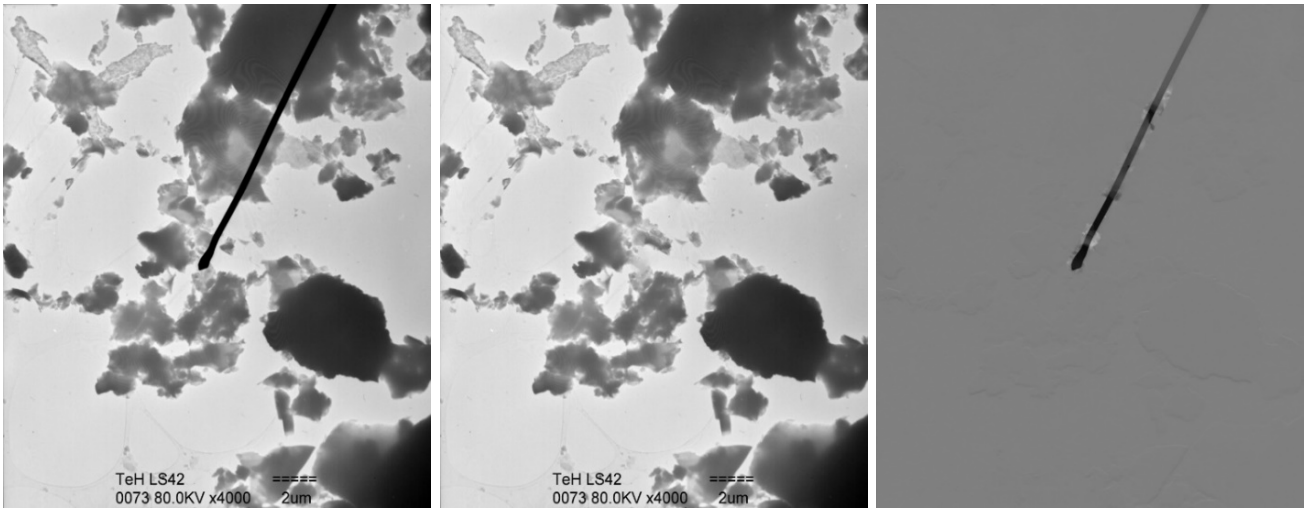


Below is the published version of Fig. 15b with a red arrow showing the NE direction. We flipped the original photograph horizontally for cosmetic reasons. The right panel below shows the flipped photograph with the red arrow pointing NE. Flipping the photograph did not alter any scientific data, debris direction, or the conclusion of the paper that a proposed cosmic impact event destroyed the city of Tall el-Hammam.



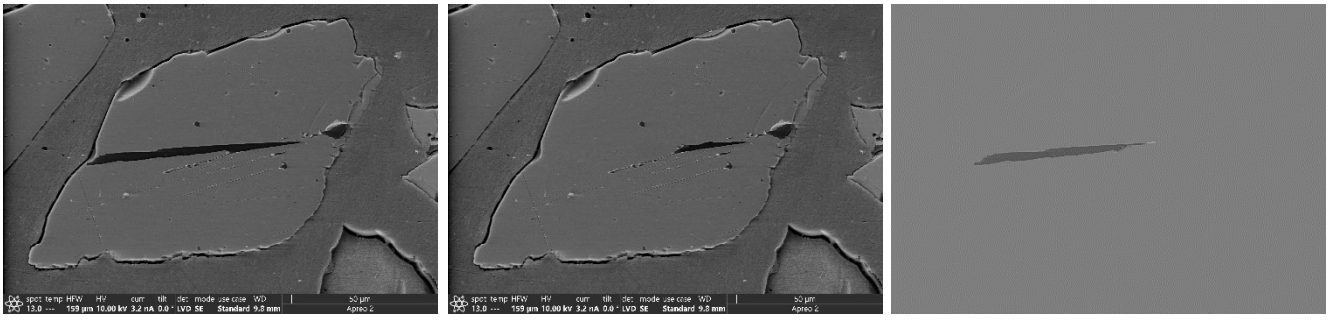
Example #9. In Figure 8a, we used a cloning tool to cosmetically remove the TEM beam blocker.

Fig. 8a. Original Altered image without blocker Inverted overlay



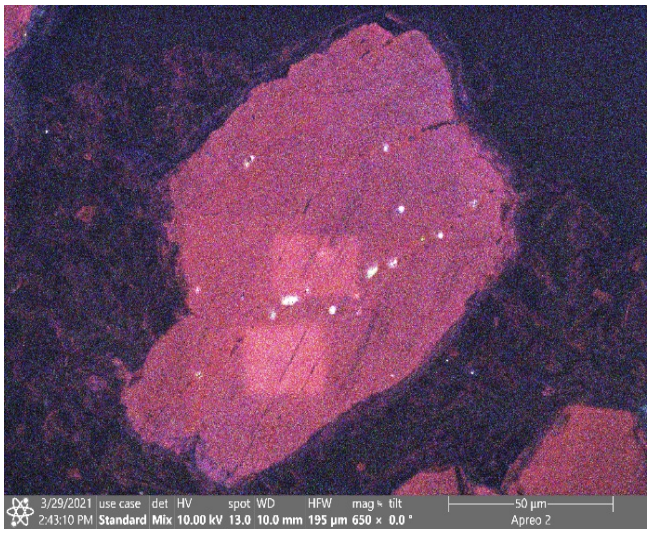
Example #10. For Figure 21a, we used a cloning tool to cosmetically heal an area of gold coating that had peeled off. Although inappropriate, doing so did not change the analysis of shock lamellae.

Fig. 21a. Original Altered image to remove flaw Inverted overlay

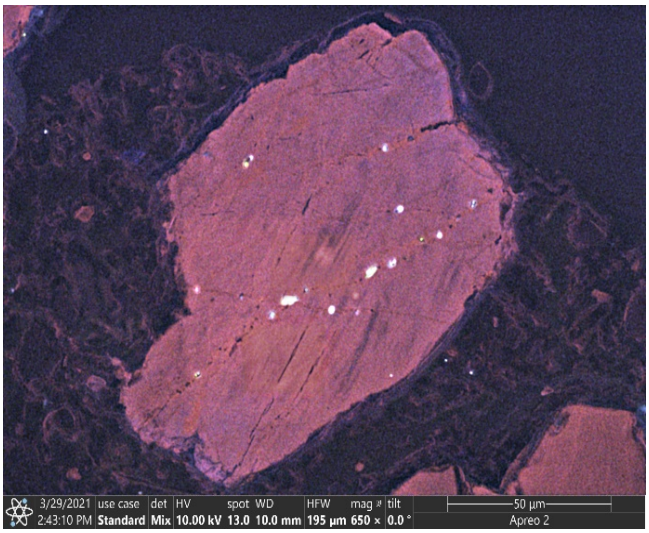


Example #11. In Figure 18d, we selectively adjusted contrast, brightness, and tone to remove rectangles of beam damage on a shocked quartz grain. We also cropped the legend from the published image, which is acceptable to *Scientific Reports*. For this RGB-channel image and others in the paper, we globally adjusted contrast, brightness, and tone, which also is permitted.

Fig. 18d. Original



Altered image with contrast/brightness adjusted



Claim: The wrong OxCal radiocarbon routine was used

A commenter on PubPeer made the following claims:

(1) "*You have 20 ^{14}C dates obtained from a mammoth skeleton. You KNOW that all of the dates MUST reflect the age at which the mammoth died. But, because ^{14}C dating produces date ranges, you want to know what the consensus age is for ALL the dates. You would use 'Combine.'*"

(2) Also: *"The date(s) reported reflect the a priori assumption that all of the ^{14}C dates MUST represent a single event, and not (as presented) a test of whether the dates DO represent a single event.)*

(3) Also: *"The onus is on the researcher to have good reason to believe that a set of dates represents a single event."*

The commenter has confused the two types of OxCal routines, '**Combine**' and '**R_Combine**'. This is from the OxCal's Online Manual by Christopher Bronk Ramsey, the creator of the OxCal program, explaining the use of the Combine function. The first 'Combine' function is a statistical function within OxCal, a Bayesian computer program that uses "*tools for manipulating likelihood probability distributions*"[2], including the Combine function.

Ramsey[3] writes, "*In the following example you can see how results from several different timbers can be used together to provide a more precise date for the ceiling structure of the Jerusalem Chamber undercroft at Westminster Abbey…. In this case, the combined date is for building the structure* [which spanned several years] *rather than for the felling of the trees…. [U]se of the Combine() function to combine the results for the different samples.*"

Ramsey stated that the Combine function is not restricted to a single radiocarbon source, such as a mammoth skeleton, as mistakenly claimed by the PubPeer commenter, but rather is acceptable for use with multiple sources, such as beams, just as we did at Tall el-Hammam.

Sapwood estimates

```
Options()
{
 Resolution=1;
};
Plot()
{
 Sapwood_Model("Mainland Britain", 2.77292, 0.100001, -0.275445, 0.314286377);
 Combine()
 {
  Sapwood("wa21", 1329, 243, 0, 1.06);
  Sapwood("wa22", 1354, 58, 6, 2.74);
  Sapwood("wa23", 1342, 55, 0, 2.55);
  Sapwood("wa26", 1328, 62, 0, 1.71);
  Sapwood("wa28a", 1353, 86, 0, 1.48);
  Sapwood("wa24a", 1337, 76, 0, 1.61);
 };
};
```

Above is a screenshot of the OxCal code from Ramsey.[3] This was for a specific event, i.e., building part of Westminster Abby, a multi-year event with multiple radiocarbon samples that span 26 mean radiocarbon years.

Combine

```
Combine()
{
 R_Date("A",2023,20);
 Gap(70);
 R_Date("B",1961,20);
 Gap(60);
 R_Date("C",1999,20);
 Gap(50);
 R_Date("D",1966,20);
 Gap(40);
 R_Date("E",1954,20);
 Gap(30);
 R_Date("F",1936,20);
 Gap(20);
 R_Date("G",1948,20);
 Gap(10);
 R_Date("H",1925,20);
};
```

The above figure is a screenshot of a Combine example from Ramsey[2]. The samples in that example span 98 radiocarbon mean years. Note: This corresponds to the strong evidence of a single-year fire at Tall el-Hammam with charred beams of various ages, along with single-year seeds that collectively span 90 mean radiocarbon years.

Here is an explanation of the differences in usage between the **Combine** function and the **R_Combine** function. It is from OxCal User's Google Group[4]:

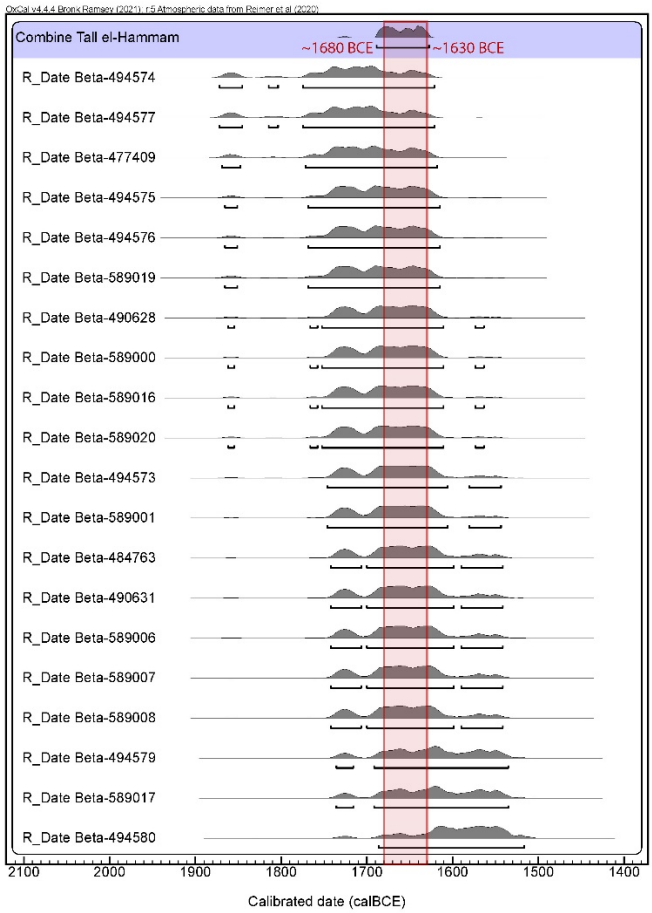
"*R_Combine is used to combine two (or more) radiocarbon determinations that are from the same source so that the merged material is from the same radiocarbon reservoir, for instance, two bones from the same body* [underline added]." This is the one the PubPeer commenter mistakenly claimed that Bunch et al. used. Instead, we used the '**Combine**' function of OxCal, not '**R_Combine**'.

The OxCal Group[4] continues, "*On the other hand, if you believe that the determinations are co-eval, but not from the same radiocarbon source, 'Combine' is a group function that combines any number of PDFs* [posterior distribution functions]…." This is the routine used in Bunch et al., because there were different radiocarbon sources, e.g., charred palace beams and charred seeds. The presence of tens of thousands of charred objects, melted mudbricks, melted pottery, and melted spherules randomly mixed throughout a single monolithic, unstratified, unconsolidated stratum strongly supports the hypothesis that this is a single event representing a city-wide episode of biomass burning. Thus, the Combine function is appropriate to use.

The PubPeer commenter also claims that using the Combine function is "*not (as presented) a test of whether the dates DO represent a single event*." On the contrary, the OxCal Users Group[4] says, "*A Chi Sq test is carried out, however, the test parameter to examine is Acomb which gives a warning if the dates should not be combined."* For Tall el-Hammam, the 'Acomb' value, the test of whether the radiocarbon dates should be combined, equals 143.6% (it can be >100% if the test is highly supportive), as shown in Supporting Information Table S1. This high value indicates strong statistical support for a single age of the fire evidence in the destruction layer.

In summary, the commenter's claim is erroneous but also inconsequential. To demonstrate that, we first ran the 'Combine' routine, which yielded an age of 1661 ± 21 BCE (1 sigma = 1686-1632 BCE). Second, we ran the 'R_Combine' one using the same 20 dates, which yielded an age of 1669 ± 30 BCE (1 sigma = 1687-1631). Thus, the two ages are statistically identical.

Third, we calibrated the radiocarbon ages using IntCal20 and plotted them for comparison without using any statistical routine (figure below). The 20 dates have a common overlap of ~1680-1630 BCE. This range is statistically identical to the ranges found in 'Combine' and 'R_Combine', thus demonstrating that the PubPeer commenter's claim is incorrect.



The above figure shows 20 Tall el-Hammam radiocarbon dates simply calibrated and plotted using OxCal. Without using Bayesian analysis, the 20 calibrated ages have a common overlap of ~1680 to 1630 BCE, nearly statistically identical to the range calculated using the Bayesian 'Combine' function.

Even though the PubPeer commenter was mistaken, if one person misunderstands, others undoubtedly will also do so. Thus, we added the following clarification to the paper under Methods:

"There are two functions in OxCal that are used for combining dates from a single inferred event. The 'R_Combine' function is used to combine two or more radiocarbon dates from the same source, e.g., a single skeleton[2,3]. The 'Combine' function is used to combine two or more radiocarbon dates from different sources that are believed to be coeval, e.g., the date that beams were used to build a cathedral[2,3]. The 'Combine' routine is the one used in Bunch et al., because there were different radiocarbon sources, e.g., charred palace beams and charred seeds. The presence of tens of thousands of pieces of charcoal, wood, melted mudbricks, melted pottery, and melted spherules randomly mixed throughout a single unstratified, unconsolidated stratum strongly supports the hypothesis that they represent a single city-wide episode of biomass burning. Thus, the 'Combine' function is the appropriate OxCal routine to use.

References

1 Bunch, T. E. *et al.* A Tunguska sized airburst destroyed Tall el-Hammam a Middle Bronze Age city in the Jordan Valley near the Dead Sea. *Scientific reports* **11**, 1-64 (2021).

2 Ramsey, C. B. *Analysis Operations and Models*, <http://c14.arch.ox.ac.uk/oxcalhelp/hlp_analysis_oper.html> (2013).
3 Ramsey, C. B. *Analysis Examples*, <https://c14.arch.ox.ac.uk/oxcalhelp/hlp_analysis_eg.html> (2013).
4 OxCal_Users_Group. *Combine radiocarbon dates from the same archaeological level*, <https://groups.google.com/g/oxcal/c/5LG68KUrq-E?pli=1> (2016).