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Climate of the Past
Discussions

Interactive comment on "Paleoclimate reconstruction in the Levant region from the petrography and the geochemistry of a MIS 5 stalagmite from the Kanaan Cave, Lebanon" *by* C. Nehme et al.

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First, all the authors would like to thank you for your constructive comments, which helped to improve the quality of the manuscript.

Our answer to each comment given by both reviewers is grouped into one document and presented according to the priority given for each point: answers on major comments (age model, hiatuses…) are followed by answers on minor comments (rephrasing sentences, modifications in figures, references and supplementary file).

Our comments are grouped in the PDF document attached to this comment as well as the modified figures in JPEG and the supplementary file, which contains: 1- the new Age vs depth model of Kanaan Cave 2- the Kanaan cave water analyses 3- the table with the speleothem d18O/d13C values vs the age model

A- ANSWERS FOR MAJOR COMMENTS

1- Comments concerning the age model

Seven new ages were done by Stephen Noble in the NIGL laboratory in October 2015 and added to the previous 10 ages run in November 2014 (see the table 1 summary for Lebanon data.xls). For this reason, the paragraph about U-Th geochronology on p. 3251 was re-written (in quotes). Some explanations given in [...] are only to add more details to the reviewers' comments" "A rectified age model is proposed here based on the new ages recently completed: the stalagmite grew from 127.22 ± 1.3 ka (2σ) to 85.4 ± 0.8 ka (2σ). An extrapolated age of 83.1 ka for the top of the stalagmite was calculated from the age-depth model in Fig. 4 obtained using the P_Sequence function of the OxCal geochronology application, which is based on Bayesian statistics (Bronk Ramsey, 2008). All ages in Table 1 are calculated with two different possible detrital U-Th compositions, as no data from the Kanaan cave is presently available to better constrain the corrections. The first correction is the typical continental detritus composition as used by Verheyden et al., 2008 and the second is that used determined by Kauffman et al. (1998) for the Soreq caves which might better reflect the prevalent detritus composition in a carbonate-dominated terrain."

[In that paper, Soreq Cave samples were analyzed using two-point isochrons to yield initial Th composition data. The attached table illustrates the differences between using normal continental detritus compositions for correction as in the previous work for the Lebanese caves following the Edwards lab approach vs. corrections following Kaufmann et al. 1998 detritus composition estimates following the Caltech-Jerusalem lab approaches for these types of speleothems. The calculated age differences are minor compared to the overall age uncertainties but using average continental detritus composition to reduce the data results in systematically older ages. For each sampled location, the magnitude of the difference between ages calculated using the two contrasting detrital compositions is inversely proportional to (230Th/232Th), which is consistent with the age differences being relatively insignificant because (230Th/232Th) for most samples is more than 100]

"Basically the age uncertainties and 230Th/232Th activity ratios in the dataset are such that both options (i.e. Soreq Cave vs. average continental detritus) result in statistically equivalent dates (e.i. Sample 10: 99.94 ± 0.69 ka calculated with the average continental detritus and 99.40 ± 0.94 ka calculated using Soreq cave detritus). The greater number of disturbed ages in the lower segment of the stalagmite, which has comparatively high initial thorium concentrations (230Th/232Th activity ratios as low as 34) are most likely due to contamination of the U-Th subsamples with organic material, or Fe oxydes from mud layers that are common in this part of the record. The basal age of 223.15 ±4.78 is clearly out of sequence probably due to accidental inclusion of host rock in the analyzed sample. Consequently, the oldest valid U-Th date is 127.2 ± 1.3 ka from a sample located 7 mm above the base of the stalagmite, and extrapolation of the age model places the beginning of growth at ∼128.8 ka. However as no other coeval stalagmites from the Kanaan cave have yet been dated, it is unclear whether the base of our record corresponds to the onset of the LIG optimum. In general, U-Th dates from the upper segment of the stalagmite were more consistent with only one out of seven dates (80.6 ± 0.5 ka) clearly out of sequence. Following the exclusion of obvious outliers, the remaining U-Th dataset showed a number of age reversals. For the purposes of age-depth modelling, where age reversals were resolvable at the 3-sigma level, the younger date was assumed to represent the correct age progression and the older dates were excluded such as the basal age in the previous age model (Verheyden et al., 2015). Age models obtained using linear interpolation, and the OxCal package were statistically equivalent at the 95% confidence level, with the latter chosen as the basis for stable isotope proxy data interpretation, owing to its more robust treatment of

uncertainty propagation."

[The 127.2 ±1.3 ka date was obtained in the Geochemistry Laboratory, Earth Science Department, University of Melbourne, Australia (see table 1). Activity ratios were determined using a NU Plasma MC-ICP-MS following the procedure of Hellstrom, 2006)]

2- Comments concerning the hiatuses

[We consider your remark concerning the significance of a hiatus in speleothems. It can be due to climatic events of regional significance or to local settings such as local changes in the vadose zone involving modification in the seepage water routes above the stalagmite. As new ages were obtained, a new age model was added to the CPD and δ18O and δ13C curves were plotted to the new age model (see figure 3, 4 and 5). The only significant hiatus that still persists is the D2 (∼110.6 to ∼103.6 ka). That is why we suggest deleting sentences in p. 3253 (line 11 to 16 and 22 to 26) relative to the D1 discontinuity. As for the D1 (between ∼126.7 and ∼126.3 ka) as well as others corresponding to the muddy layers in the whole segment 2, their time interval are too small compared to the resolution of the age model. The muddy layers show a deposition of mud on the apex of the stalagmite during brief time intervals due to a ponding process controlled locally by the topography of the site. Consequently, a severe drought is not likely to happen in such conditions. That is why we interpreted these small muddy layers likely associated with brief growth hiatuses from ∼128 ka to ∼120 ka as a consequence of rapid ponding rather than to a severe drought. Taking into account the isotopic composition in this segment, the growth rate and the petrographical aspect, the climatic conditions during the last interglacial (∼128 to ∼120 ka) were more likely to be wet in general. Discontinuity D2: Between (∼110.6 to ∼103.6 ka, sediment evacuation continued beneath the cave floor leading to a consequent subsidence in the Collapse Chamber and thus tilting the speleothem by around 45°. The absence of thin clay particles in the upper segment (segment 1) suggests that no water accumulation occurred in the collapse chamber after ∼103.6 ka, probably due to the continuous clay evacuation with more enlarged fissures underneath the chamber floor, allowing water to drain away rapidly without leading to a ponding process. However a non-growth of the stalagmite between ∼110.6 to ∼103.6 ka could be of local origin (change in the percolation route or the tilting of the stalagmite's axis) or a climatic origin (not enough water available to percolate).]

For this major discontinuity, we agree on the fact that because only one stalagmite was analyzed the local or regional significance of hiatuses cannot be confirmed. That is why we introduced two sentences in p. 3254 that nuances our explanation: "However, with only one speleothem studied for the MIS 5 period, the local origin of a non-growth of the stalagmite (change in the percolation route or the tilting of the stalagmite's axis) between ∼128 to ∼120 and ∼110.6 to ∼103.6 ka cannot be ruled out"

3- Kinetic fractionation during calcite precipitation

As we don't have for the moment a second speleothem of the same age to confirm or not a precipitation process under equilibrium conditions during MIS5, we rely on present calcite precipitation in the whole cave. Additional tests were conducted recently to determine whether present-day calcite precipitation is occurring under equilibrium conditions. These analyses, which we suggest to add in the text (p. 3250 and 3252), could be an additional argument that state a non-severe disequilibrium in present calcite precipitation: "Six samples from recent calcite deposits were measured using a using the Nu-carb carbonate device coupled to a NU Perspective MS at the Vrije Universiteit Brussel with analytical uncertainties (2σ) less than 5%. Recent calcite analyses in the cave (soda straw, recent calcite deposition) display an average δ13C value of -11.6‰ ± 0.4 and δ18O value of -4.9‰ ± 0.7. (see supplementary material). The average δ18O value for the recent calcite is close to the theoretical calcite precipitation value of -4.6‰20°C - present temperature in the cave - using Kim and O'Neil (1997) equilibrium equation"

4- Interpretation of the isotopic curves

- In p. 3257 (line 4, 6.2.1. An "early humid LIG), the sentence in line 7 to 9 is to

be deleted as no significant and long hiatus occurred during the LIG as stated in the previous version. With the new age model, hiatuses associated with the muddy layers are smaller than the resolution and uncertainty of the ages in the lower section.

- In p. 3257 and 3258 (6.2.2. the 125 ka change), several modifications are suggested to rectify and nuance previous interpretations: - In p. 3257 (line 22) and in all the text in this section we suggest changing the 125 ka to the 126 ka change as it occurred at 126.3 ka ± 0.9. - In p. 3258 (line 6 to 10) we suggest to rephrase sentences. With the new age model of the stalagmite, there is no time lag between the K1-2010 stalagmite record and the marine record of core ODP 961 and LC21. Both records are in phase with each other: "The onset of the δ18O enrichment in the K1-2010 isotopic record coincides with the onset of the δ18OG.ruber enrichment in LC21 core (Grant et al., 2012) and in ODP 967 site (Emeis et al., 2003)" - In p. 3258 (line 22) we suggest to add some sentences concerning the amplitude of the δ18O enrichment that totals ∼3.2‰ in K1-2010 stalagmite from 126 to 120 ka. This change cannot be only explained by the modification of the δ18O signal of the Mediterranean Sea which totals an ∼2‰ offset from ∼126 ka to ∼120ka (Grant et al., 2012). " However the amplitude of the δ18O enrichment in the K1-2010 stalagmite from 126 to 120 ka totals ∼3.2‰ and is much higher than the amplitude of the δ18OG.ruber enrichment (∼1.85‰ in the Eastern Mediterranean sea (Grant et al., 2012). This would be explained by Sapropel events in the EMS and their derivative processes during the S5 (Ziegler et al., 2010): the source effect is thus a major driver to the δ18O values change in continental records, but other derivative factors of the S5 event contributed in the δ18O change in K1-2010 record such as the rainfall amount, the temperature or changes in the wind trajectories" - In p. 3258 (line 23 to 26), we suggest re-writing these sentences as both Soreq and Kanaan records show generally a similar timing for the 126 ka change. However the pattern of the change in both records is different: "The K1-2010 δ18O profile indicates that this major change occurred in phase with other continental records in the Levant region. The δ18O and δ13C change in the K1-2010 profiles lasted 6000 years, started gradually, and then continued more rapidly, ending at ∼120 ka (interpolated). The initial pattern of the change could be more gradual than the change in the Soreq cave isotopic records which could reflect the lower resolution of the K1-2010 record due to the occurrence of short hiatuses (mud layers) in that period."

- In p. 3259 (line 3, 6.2.3. glacial inception), minor modifications will be introduced to change the onset of the glacial inception which is now around ~120 ka instead of ~122 ka in the previous version. - In p. 3259 (line 23 to 25), modifications were made in the sentence to clarify the origin of the wet pulse in southern Levant during MIS 5a: “Speleothem growth rates decreased after MIS5c (Vaks et al., 2006) with less rainfall from the Mediterranean Sea reaching Tzavoa cave (Northern Negev). Speleothem records from caves located further south in the Negev desert (Vaks et al., 2010) along with the Mudawara paleolake records in southern Jordan showed a wet pulse during the MIS 5a, related more to rainfall originating from the Indian Monsoon” - In p. 3259 (line 26 to 28) and 3260 (line 1 to 5), we added two new references and rectified two sentences to nuance the intensity and the origin of wet pulses in the DSB during the LIG and the glacial inception period as the debate is still on going on this issue among the scientific community: "Moreover, Lake Samra records in the Dead Sea basin are less in phase with Levantine records further north and show low lake levels during MIS 5c and 5a and minor high levels during MIS 5d and 5b (Waldmann et al., 2009). These wet pulses indicate though wet periods (Neugebauer et al. 2015) but with less amplitude than the wet phase in the northern Levant. The climate picture of the Dead Sea basin during the glacial inception . . . invoke climatic variations driven by the monsoon system (Torfstein et al., 2015) and its boundary shifts (Parton et al., 2015; Bar-Mathews et al., 2014) or by the North Atlantic and Mediterranean climates (Neugebauer et al. 2015)”

-In the conclusion. p. 3261 (line 7 to 9), we added a new sentence based on the new work recently published by Cheng et al., 2013 showing a severe out-of-phase climatic variability during the last 20.000 years between the northern and the southern Levant. However, the K1-2010 records demonstrates an important wet phase during the MIS 5 in the northern Levant that differs in amplitude with the wet phases demonstrated

by Soreq and Peqiin records and by the new work of Neugebauer et al. 2015 (less in amplitude comparing to the northern Levant). As the debate is still on going in the scientific community on the amplitude of the wet phase in the DSB and its origin during the LIG and all the MIS 5 period, we cannot state clearly yet an out of phase climatic variability between the northern and Southern Levant records but a different amplitude of wet phases during the MIS 5 period: “The climatic scheme suggested from K1-2010 isotopic profiles and growth rates is in overall agreement with Yammouneh paleolake records in northern Lebanon, and with Soreq and Peqiin speleothems records. However, the K1-2010 records show different amplitude pattern with continental records located further south but don’t show clearly a severe out of phase in climate variability during the MIS 5 as demonstrated by Jeita speleothem records for the last 20.000 years (Cheng et al., 2015).:

B-ANSWERS FOR MINOR COMMENTS

1-Minor Comments

- In p. 3241, we simplified the title of the MS as suggested by reviewer 2: Reconstruction of MIS-5 climate in central Levant using a stalagmite from Kanaan Cave, Lebanon - We added Diana Sahy as well as John Hellstrom as co-authors along with their affiliations.

- In p. 3245 (line 21) we suggest this reference for stating that the global mean temperature for the LIG period was less than 2°C than present (Otto-Bliesner et al., 2013).

- In p. 3249 (line 13-14), we suggest to rectify these sentences into: “10 U series dating was carried out at the NERC Isotope Geosciences Laboratory (NIGL), British Geological Survey, Keyworth, UK (Verheyden et al., 2015). 7 new ages were recently completed by the NIGL geochemistry laboratory and the geochemistry laboratory, Earth Science Department, University of Melbourne, Australia” proposing then a more complete age model.

- For the definition of the LIG onset and demise, we usually used the "acme" time period (128 to 122 ka) as cited by Cheng et al., 2009 from speleothems in China. Cheng et al., 2009 is already cited in the reference list. At a larger scale, Ice records from EDC records in Antarctica (Jouzet et al., 2007) set the interglacial interval from 130 to 120 ka The LIG optimum differs from one record to another (Govin et al., 2015), and is shorter in continental records compared to previous MIS glacial and interglacial cycles. The time interval for the MIS 5 is still between 75 and 130 ka. However the LIG optimum is equivalent to the MIS 5.5 interval, which is very short over the continent and ranges from 128 to 122 ka from calcite records and from 130 to 120 ka from ice cores. In p. 3254, p 22, we suggest this following sentence: " before the speleothem tilted seems to start at 123 ka, corresponding to the demise of the LIG optimum (Cheng et al., 2009)."
- In p. 3255 (line 2), we added some text to clarify that the δ13C shift to more positive values is not only due to the soil degradation but also to change in vegetation type or density.

2- Modifications in Figures

- We replaced the table 1 with a new table, which includes all the datings made by the NIGL (UK) and the Geochemistry laboratory at the Earth Science Department, Melbourne University (AU). - We modified the figure 2 to locate the cave relative to Beirut city by adding a small map to the Figure 2. - Figure 3 was modified to integrate all the ages in the petrography log - Figure 4 was replaced by a new version showing a better model age using Oxcal program - Figure 5 was modified to plot the isotopic curves to the new age model constructed from Oxcal. - Figure 7 was modified to add the new isotopic curves of Kanaan cave (δ18O and δ13C). Slight modifications of the curve were due to the new ages run lately. Also we added the new δ13C and δ18O curve of Soreq (Grant et al., 2014) given to us by Bar-Mathews, so the regional interpretation will be more correct.

3- Supplementary material

To add additional arguments to the manuscript, three items were added to the manuscript as supplementary material: - The age vs δ18O and δ13C isotopic curves in excel file. - Water and recent calcite in Kanaan cave in PDF with the LMWL equation inserted in the graph. - The age model in PDF with two graphs: the first one is the age model with the linear interpolation method and the second one with the Oxcal Bayesian statistical method.

4- References

Here are the references that will be added to the manuscript:

- Almogi-Labin, A., Bar-Matthew,s M., Shriki D., Kolosovsky, E., Paterne, M., Schilman, B., Ayalon, A., Aiznshtat, Z. and Matthews, A.: Climate variability during the last 90 ka on the southern and northern Levantine basin as evident from marine records and speleothems. Quaternary Science Reviews 28, 2882-2896, 2009.

- Bronk Ramsey, C. Deposition models for chronological records, Quaternary Science Reviews, 27, 42-60, 2008 will be added as reference for the OxCal software used for age-depth modelling.

- Cheng, H., A. Sinha, S. Verheyden, F. H. Nader, X. L. Li, P. Z. Zhang, J. J. Yin, L. Yi, Y. B. Peng, Z. G. Rao, et al. The climate variability in northern Levant over the past 20,000 years, Geophys. Res. Lett., 42, 8641–8650, 2015.

- Hellstrom, J. U–Th dating of speleothems with high initial 230Th using stratigraphical constraint. Quat. Geochron. 1: 289–295, 2006 will be added for the U-Th dating sample in the basal part that was performed previously by John Hellstrom.

- NEEM community members. Eemian interglacial reconstructed from a Greenland folded ice core. Nature 493, 489- 494, 2013.

- Neugebauer I., Schwab M.J., Waldmann N.D., Tjallingii R., Frank U., Hadzhiivanova E., Naumann R., Taha N., Agnon A., Enzel Y., and Brauer A. Hydroclimatic variability in the Levant during the early last glacial (âĹij117–75 ka) derived from micro-facies

analyses of deep Dead Sea sediments. Clim. Past Discuss., 11, 3625–3663, 2015. North Greenland Ice Core Project members. High-resolution climate record of Northern Hemisphere climate extending into the Last Interglacial period. Nature 431, 147-151, 2004.

- Otto-Bliesner, B.L., Rosenbloom, N., Stone, E.J., McKay, N.P., Lunt, D.J., Brady, E.C., Overpeck, J.T.. How warm was the Last Interglacial? New model-data comparisons. Philosophical Trans. R. Soc. A Math. Phys. Eng. Sci. 371, 2013 was added for stating the global mean temperature during the LIG period.

- Rohling E.J., Marino G., & K.M. Grant. "Mediterranean climate and oceanography, and the periodic development of anoxic events (sapropels)." Earth-Science Reviews 143, 62-97, 2015.

- Torfstein A., Goldstein, S.L., Kushnir, Y., Enzel, Y., Haug, G., Stein, M. Dead Sea drawdown and monsoonal impacts in the Levant during the last interglacial. Earth and Planetary Science Letters 412, 235-244, 2015.

-Verheyden S., Nehme C., Nader F.H., Farrant A.R., Cheng H., Noble S.R., Sahy D., Edwards R.L., Swennen R., Claeys Ph., Delannoy JJ. X. The Lebanese speleothems and the Levant palaeoclimate. In: Bar Josef Y. & Enzel Y. Quaternary Environments, Climate Change, and Humans in the Levant. Cambridge University Press, UK, 2015

- Van Geldern R. & Barth Johannes A.C. Optimization of instrument setup and post-run corrections for oxygen and hydrogen stable isotope measurements of water by isotope ratio infrared spectroscopy (IRIS), Limnol. Oceanogr. Methods, 10, 2012 will be added in the text to refer to the CRDS technique used for water analyses.

- Bar-Matthews et al., 2014 will be replaced by Bar-Matthews 2014 in all the text.

- Vaks et al., 2013 will be replaced by Vaks et al, 2010 in the text and in the list of references.

- Saad et al., 2005 will be corrected to Saad et al., 2000 as the year of publication was

in 2000 and not in 2005.

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/11/C2307/2015/cpd-11-C2307-2015-supplement.pdf

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Interactive comment on Clim. Past Discuss., 11, 3241, 2015.

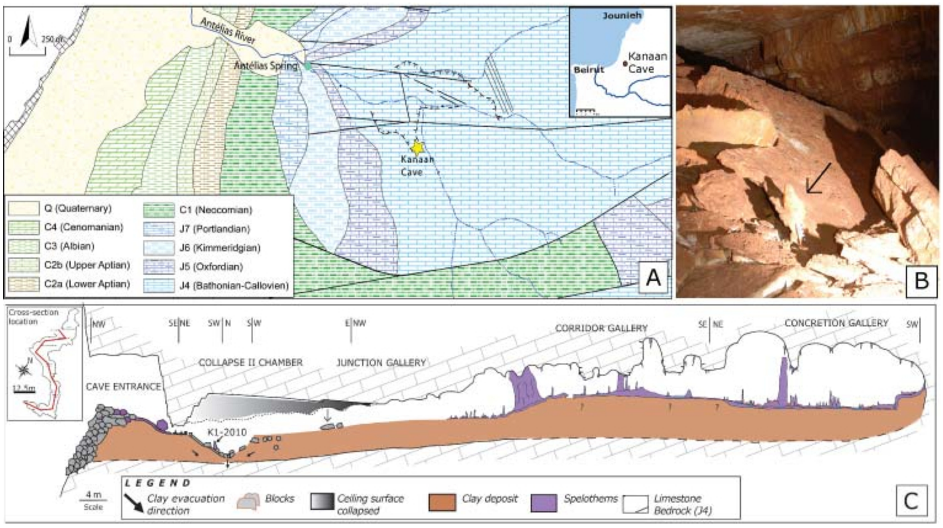
0
250 m
Antélias River
Antélias Spring
Kanaan Cave
Jounieh
Beirut
Kanaan Cave
Q (Quaternary)
C4 (Cenomanian)
C3 (Albian)
C2b (Upper Aptian)
C2a (Lower Aptian)
C1 (Neocomian)
J7 (Portlandian)
J6 (Kimmeridgian)
J5 (Oxfordian)
J4 (Bathonian-Callovien)
A
B
Cross-section location
N
12.5m
NW
SE NE
SW N
S W
E NW
CORRIDOR GALLERY
SE NE
CONCRETION GALLERY
SW
COLLAPSE II CHAMBER
JUNCTION GALLERY
CAVE ENTRANCE
K1-2010
4 m
Scale
LEGEND
Clay evacuation direction
Blocks
Ceiling surface collapsed
Clay deposit
Spelothems
Limestone Bedrock (J4)
C

Fig. 1.

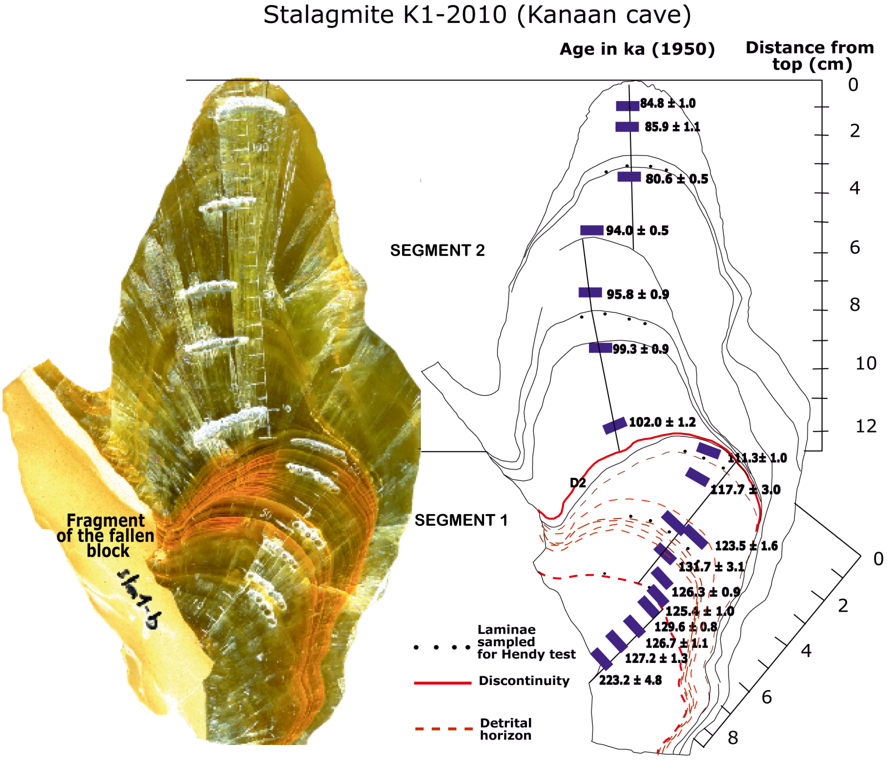
Stalagmite K1-2010 (Kanaan cave)
Age in ka (1950)
Distance from top (cm)
0
2
4
6
8
10
12
84.8 ± 1.0
85.9 ± 1.1
80.6 ± 0.5
94.0 ± 0.5
95.8 ± 0.9
99.3 ± 0.9
102.0 ± 1.2
111.3± 1.0
117.7 ± 3.0
123.5 ± 1.6
131.7 ± 3.1
126.3 ± 0.9
125.4 ± 1.0
129.6 ± 0.8
126.7 ± 1.1
127.2 ± 1.3
223.2 ± 4.8
SEGMENT 2
SEGMENT 1
D2
Fragment of the fallen block
Laminae sampled for Hendy test
Discontinuity
Detrital horizon
0
2
4
6
8

Fig. 2.

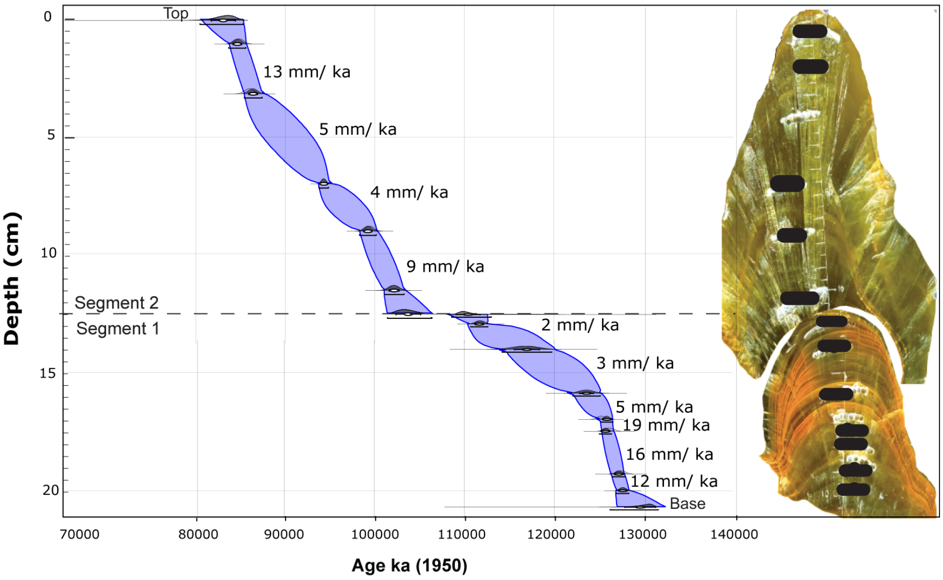
Depth (cm)
0
5
10
15
20
Top
13 mm/ ka
5 mm/ ka
4 mm/ ka
9 mm/ ka
Segment 2
Segment 1
2 mm/ ka
3 mm/ ka
5 mm/ ka
19 mm/ ka
16 mm/ ka
12 mm/ ka
Base
70000
80000
90000
100000
110000
120000
130000
140000
Age ka (1950)

Fig. 3.

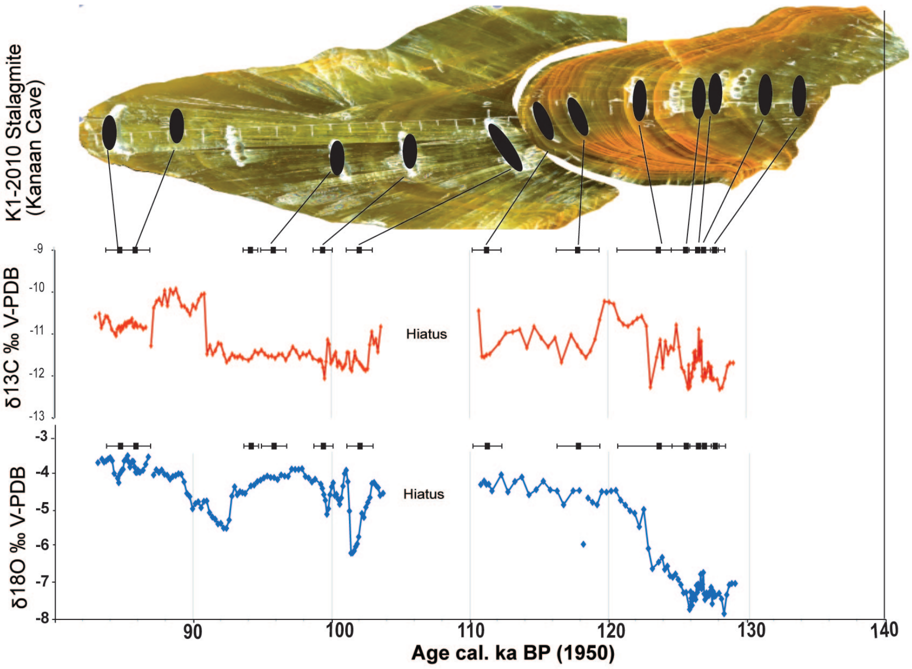
K1-2010 Stalagmite
(Kanaan Cave)
δ13C ‰ V-PDB
-9
-10
-11
-12
-13
Hiatus
δ18O ‰ V-PDB
-3
-4
-5
-6
-7
-8
Hiatus
90
100
110
120
130
140
Age cal. ka BP (1950)

Fig. 4.

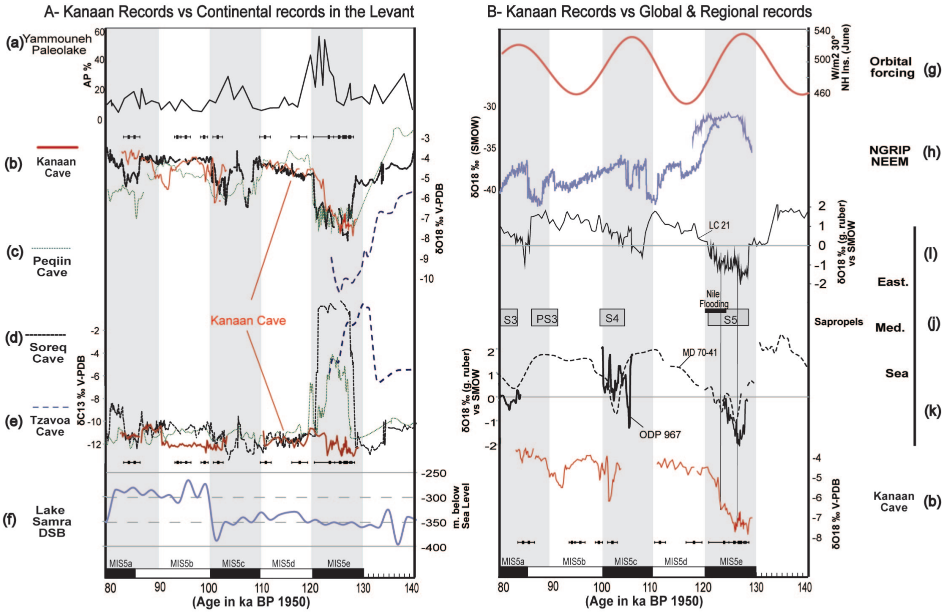
A- Kanaan Records vs Continental records in the Levant
(a) Yammouneh Paleolake
AP %
(b) Kanaan Cave
(c) Peqiin Cave
(d) Soreq Cave
(e) Tzavoa Cave
(f) Lake Samra DSB
δ18O ‰ V-PDB
δC13 ‰ V-PDB
m. below Sea Level
Kanaan Cave
MIS5a
MIS5b
MIS5c
MIS5d
MIS5e
(Age in ka BP 1950)
B- Kanaan Records vs Global & Regional records
Orbital forcing (g)
W/m2 30° NH Ins. (June)
NGRIP NEEM (h)
δO18 ‰ (SMOW)
LC 21
δO18 ‰ (g. ruber) vs SMOW
Nile Flooding
S3
PS3
S4
S5
Sapropels
East. Med. Sea (i) (j) (k)
MD 70-41
ODP 967
Kanaan Cave (b)
δO18 ‰ V-PDB
(Age in ka BP 1950)

Fig. 5.